Appendix 9

Multiple Category Evaluation - Findings and Conclusions

December 2010

METROLINX
An agency of the Government of Ontario

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Context

Metrolinx operates a comprehensive transportation system of light rail transit, bus and commuter rail lines in the Greater Toronto and Hamilton Area (GTHA). The system includes the GO rail network, which is an essential part of Metrolinx's service to the area commuters. GO Transit currently provides commuter rail service on seven corridors in the GTHA, using conventional diesel locomotives and non-powered bi-level coaches in push-pull configuration.

In late 2008, Metrolinx published a Regional Transportation Plan – The Big Move – a multimodal vision for regional transportation to strengthen the economic, social and environmental sustainability of the Greater Toronto and Hamilton Area. The Big Move sets out a fast, frequent and expanded regional rapid transit network as a key element of the plan. The plan includes establishing Express Rail and Regional Rail services at speeds and frequencies that could be enhanced by system electrification.

Electrification Study

Metrolinx has initiated a study of the electrification of the entire GO Transit rail system as a future alternative to the diesel trains now in service. The GO Electrification Study is examining how the future GO rail services will be powered – using electricity, enhanced diesel technology or other means – when these services are implemented in the future. The Study is assessing the benefits and costs of a full range of technology options, including enhanced diesel, electric and alternative technologies. The Study considers a rail system that includes the existing GO Transit network, the proposed network expansions to St. Catharines, Kitchener/Waterloo, Allandale, Bloomington, Bowmanville, as well as the future Pearson Air Rail Link.

The Detailed Assessment – Findings and Conclusions

The *Detailed Assessment* builds on several previous reports prepared as part of the GO Electrification Study:

- *High Level Decision-Making Framework* – outlines the overall decision-making process being used to develop findings and conclusions for the Study.
- *Baseline Report* – describes the base case being used to compare future technology and network options. This base case is referred to as the "reference case" and incorporates existing attributes and approved/planned enhancements of GO's rolling stock, rail infrastructure and service levels.
- *Rolling Stock Technology Assessment* – identifies and assesses a broad range of existing and future rolling stock and electrification system technologies that could be used to provide future GO rail services, and recommends a "short list" of technologies for more detailed assessment and analysis.
- *Network Options Report* – describes the process of identifying and evaluating network options for further consideration. These are options for where on the GO Transit network, on one or more of the existing or planned GO rail corridors, the "short listed" alternative rolling stock technologies could be deployed in the future.

Based on the findings of the high level evaluation, it was concluded that Electric Locomotive trains would be the technology to be taken forward to the detailed evaluation stage of this Electrification Study. In the case of the Airport Rail Link, it is assumed that the initial deployment of Diesel Multiple

Units (DMUs) will be replaced by Electric Multiple Units (EMUs) if the Georgetown line is electrified either in part or in full.

This report presents a detailed analysis on the "short list" of 6 network options (plus the Reference Case) informed by the high level evaluation of sections of the network. These options range from only electrifying one line to electrifying the whole network. The "short list" of options is:

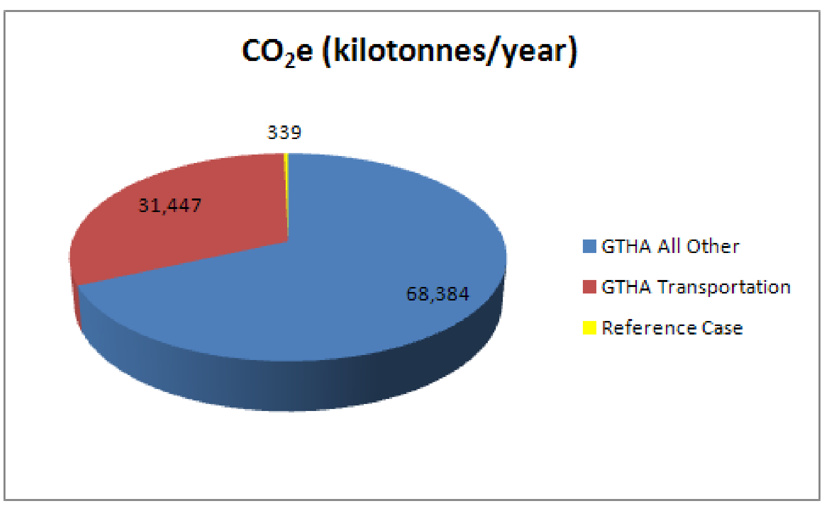
- **Reference Case** – None of the corridors are electrified
- **Option 1** – Electrifying the Georgetown line (including ARL) only
- **Option 2** – Electrifying the Lakeshore line only (East and West, excluding Hamilton TH+B and St Catharines)
- **Option 3** – Electrifying the Georgetown and Lakeshore lines
- **Option 11** – Electrifying the Georgetown, Lakeshore and Milton lines
- **Option 15** – Electrifying the Georgetown, Lakeshore, Milton and Barrie lines
- **Option 18** – Electrifying the entire network (including Hamilton TH+B and St Catharines)

These six network options are evaluated using the Multiple Category Evaluation (MCE) methodology, systematically comparing the impacts on costs, users, environment, economy and community, and illustrating the trade-offs among the often conflicting criteria. A detailed evaluation of each subcategory from the MCE is carried out and the assessment of the options is presented in the MCE Summary Table; see Table 3 at the end of the Executive Summary.

Environment and Health

Trains propelled by electricity emit notably less Greenhouse Gases (GHG) and Critical Air Contaminant (CAC) than the emission standards of the Tier 4 diesel-electric locomotive. As shown in Figure 1, GO Rail's contribution to GHG is very small compared to the overall emissions from transportation in Ontario.

Figure 1 Current Annual GHG Emissions in GTHA



By electrifying larger sections of the GO Rail network, greater GHG reductions can be achieved – electrifying the entire network would deliver a 94% reduction of GO Rail's future contribution to GHG emissions, although this reduction would only be a small fraction (0.32%) of the overall region's emissions. Nevertheless, all options with the exception of Option 1 (the electrification of the

Georgetown line) meet or exceed the RTP's strategic target of reducing GHG emissions per passenger by 25%.

Electric trains do not emit CAC from the locomotives, but rather at the source of electricity generation. The impacts of CAC on the local community and adjacent sensitive receptors were considered, and the more the network is electrified, the more people benefit from improved air quality. However, analysis of the concentrations of air contaminants such as particulate matter ($PM_{2.5}$), NO_x and SO_x with Tier 4 Diesel locomotives shows that the impact in the Reference Case would already be well below the stringent World Health Organization standards. As more corridors are electrified, the local air quality improves, but the health benefit associated with electrification is likely to be relatively small.

The Electrification Study also investigated the potential impact of electromagnetic fields (EMF) from overhead power lines and OCS. There are numerous and inconclusive epidemiological studies on this topic and there is no consistent relationship between electromagnetic fields and health issues.

While operating an electrified system has increase safety risks for trespassers and workers, these can be mitigated by the appropriate signage, protection and education as demonstrated in systems around the world.

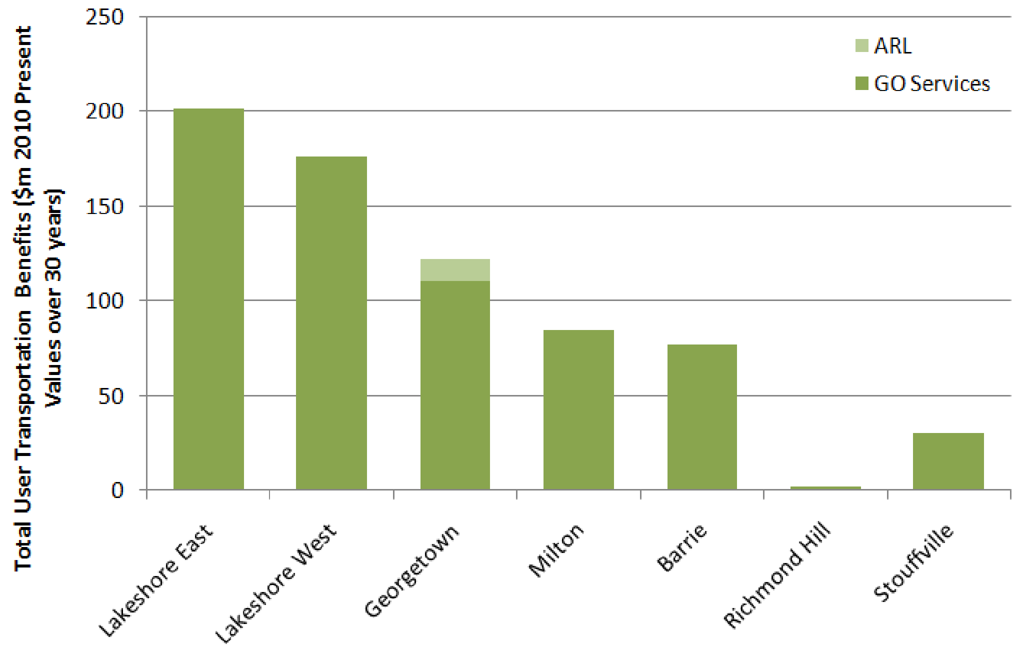
There is a slight reduction in noise and vibration due to electric locomotives being slightly quieter. However, the differences in noise levels between diesel and electric locomotive trains would not generally be perceivable.

User Benefits/Quality of Life

Electric locomotives produce journey time savings because of higher performance characteristics meaning that they accelerate and decelerate more rapidly. For example, the time savings using an electric locomotive train from Hamilton to Union station would save passengers 7 minutes. The more corridors electrified, the greater the time saving benefits, with Option 18 delivering almost $700m in 2010 present values in user benefits over the evaluation period.

Figure 2 breaks down the user journey time savings by corridor.

Figure 2 Total User Journey Time Savings by Corridor ($m 2010 Present Values)



Almost half of the total journey time benefits can be delivered through the electrification of the Lakeshore East and West corridors (Option 2), as it has the highest ridership. The average journey time savings per passengers on electrified corridors are between 2 to 3 minutes, modestly increasing the overall transportation efficiency of the GO Rail network. It should also be noted that time savings offered by electric locomotives do not offer the more significant change in journey time improvements offered by EMUs.

The journey time savings are expected to result in an increase in GO's ridership by around 4%, or more than 10,000 additional GO Rail journeys per day by 2031. The faster electric trains will encourage modal shift from car to GO Rail – a fully electrified network is expected to remove 1.6 million auto trips per annum by 2031, thereby slightly increasing the overall transit mode share of the region. The reduced vehicle kilometres travelled would result in highway decongestion for non-users and a reduction in vehicle operating costs and collision costs.

Initially, the reliability of services is likely to be lower when new electric trains are introduced. As initial technical issues are resolved, electric locomotive trains are typically more reliable than diesel locomotive trains in the longer term, but overall the reliability benefits to passengers are not significant given that failures due to locomotives are relatively infrequent.

As electrification does not include new stations and the service levels / capacity is based on the Reference Case, it does not materially change the access to the transit system or enhance comfort/capacity to passengers.

Social and Community

From the social community perspective, all six options will have residents, and users of community, institutional and recreation features within the zones of influence experiencing some negative social community impacts due to visual impacts of the Overhead Contact System (OCS), substations and autotransformers. These impacts can be particularly adverse in the rural sections of each corridor, although there are ways to partially mitigate these impacts by planting trees for example. In addition, the construction impacts – primarily dust and noise – will also have a negative impact on the social community.

The electrification alone does not materially improve land use integration, and the main adverse impacts are expected to be related to the nuisance from construction works.

The need for grounding within 250m of the nearest rail, as required, for structures, buildings, station platforms, fencing, pipelines, above-ground fuel tanks and other utilities, may negatively interfere with and impact adjacent properties.

Economic

The Reference Case presents a point in time which was established for the purposes of comparison without burdening Electrification with the proposed development and service plans that are planned regardless of the technology. The major factors in the economic analysis include the life cycle (30 year) costs of changing the technology. This includes the incremental difference between the capital costs of the Tier 4 diesel versus the electric locomotive. The life-cycle cost benefit analysis undertaken has suggested that as more corridors are electrified, more transportation benefits can be delivered. The results are presented in Table 1.

Table 1 Detailed 30 Year Life-Cycle Transportation Appraisal of Electric Locomotive Trains (All Figures in $m and Discounted at 5% p.a. to 2010 Present Values)

Electric Locomotives: Transportation Appraisal Impacts (All figures in $m and Discounted at 5% p.a. to 2010 Present Values)	**Option 1**	**Option 2**	**Option 3**	**Option 11**	**Option 15**	**Option 18**
	Georgetown + ARL	**Lakeshore:** Hamilton James to Bowmanville	**Option 1+2**	**Option 3 plus Milton**	**Option 11 plus Barrie**	**Full Network**
Infrastructure Capital Costs	521	764	1,089	1,251	1,584	2,369
Rolling Stock Capital Costs	62	91	139	212	310	543
Operations & Maintenance Costs	-88	-337	-424	-506	-595	-697
Incremental Revenues	-23	-50	-73	-86	-96	-109
TOTAL PRESENT VALUE COSTS	**473**	**467**	**731**	**871**	**1,204**	**2,106**
Journey Time Saving Benefits	145	409	554	657	752	845
Reliability Benefits	1	3	4	5	6	7
Auto Cost Savings	24	105	129	154	181	206
TOTAL PRESENT VALUE BENEFITS	**169**	**518**	**687**	**816**	**939**	**1,058**
Net Present Value (NPV)	**-303**	**50**	**-44**	**-55**	**-265**	**-1,048**
BENEFIT COST RATIO (BCR)	**0.36**	**1.11**	**0.94**	**0.94**	**0.78**	**0.50**

In terms of cost effectiveness, Option 2 (Lakeshore) provides the highest value for money in terms of delivering transportation benefits with a benefit cost ratio (BCR) of 1.1:1, followed by Option 3 (Lakeshore, Georgetown) and Option 11 (Lakeshore, Georgetown, Milton), both at 0.9:1. For every dollar invested, there is approximately a dollar in benefits in return over the life-cycle. These options perform better primarily because they are the most intensively used corridors – more passengers benefit from time savings, while a high level of service also gives significant operating and maintenance cost savings.

The remaining options (1, 15 and 18) offer notably lower value for money in delivering transportation benefits. Option 1 (Georgetown) performs poorly with a BCR of 0.4:1 because electrifying the Georgetown line alone does not have the critical mass in transportation benefits to offset the initial capital expenditure of electrifying large sections of the Union Station Rail Corridor, and to electrify the Airport Rail Link alone would have a lower BCR because it would incur most of the infrastructure costs but have limited journey time savings compared to Option 1 in its entirety. Options 15 and 18 involve electrifying corridors that are not as intensively used; they also require the premature replacement of existing diesel locomotives, meaning that they are not as cost effective.

In terms of delivering GHG reductions, Option 2 is the most cost effective, followed by Option 3 and 11, and the same order holds when the cost per new rider is considered. As there are limited health benefits associated with CAC reductions, a cost effectiveness measure for each CAC chemical has not been employed in the evaluation, although the relative performance of each option is unlikely to be different to the order based on the cost effectiveness of GHG reductions.

Electrifying the GO Rail network is expected to generate employment during construction and in operation which in turn increases the economic output of the region. Option 2 also delivers the most long term economic benefits per capital invested.

Due to faster journey times and slightly improved air quality, noise and vibration, property prices along the electrified rail corridor could benefit from a slight increase in value, although some properties immediately overlooking the OCS may result in a decrease in value, depending on site-specific conditions.

Financial

The incremental capital cost of electrifying the entire GO Rail network is approximately $4.0 billion in 2010 prices (excluding inflation), as shown in Table 2. This includes the infrastructure capital costs (primarily comprising of site enabling works and power system works) and rolling stock costs. These high level costs were estimated in advance of any detailed design work, and as such the infrastructure capital costs include approximately 50% level of contingency across the options. It should be noted that this cost captures only the additional requirements to operate electric trains over and above the Reference Case. It does not include other infrastructure and rolling stock requirements to meet the Reference Case level of service.

This increased capital cost is partially off-set by the operating and maintenance cost savings of the electric locomotive. Electric trains provide additional revenues due to an increased demand from transit time savings, and as a result all options significantly reduce the net annual operating costs (and therefore subsidy). Electrifying the entire network would result in almost $79m savings per annum by 2031 in real 2010 prices, although a significant proportion of these cost savings would only materialize on the assumption that the price of diesel increases at twice the rate of electricity.

Table 2 Total Incremental Capital Costs by Option ($m 2010 prices)

Cost Item	Incremental Costs ($m 2010 prices)					
	1	**2**	**3**	**11**	**15**	**18**
Catenary System	221	369	511	581	711	861
Power Supply System	100	166	230	262	320	388
Maintenance & Layover Facilities	16	27	28	31	37	40
Overhead Structures/Infrastructure Re-work	87	97	117	136	183	666
Sitework & Special Conditions	230	309	489	569	743	980
Professional Services	53	67	100	116	153	275
Infrastructure Capital Costs	**706**	**1,035**	**1,476**	**1,695**	**2,147**	**3,210**
Rolling Stock Capital Costs	**84**	**123**	**188**	**288**	**421**	**736**
Total Capital Costs	**790**	**1,158**	**1,664**	**1,983**	**2,568**	**3,946**

Note: As the project continued to be developed and assumptions were continuously reviewed, cost estimates were refined. Subsequent to this evaluation the overall capital costs increased between 6% and 10% for each option. This did not affect the results of the B/C analysis. Please refer to section 12.4 for more information.

Deliverability

The electrification of an operational railway network will pose notable construction challenges in order to reduce the impact to transit users, other passenger and freight service operators and the local community. It is anticipated that the construction works would not require notable closures to the railways during the day, while freight services running overnight will use diverted routes where possible to minimize disruption. However, some disruption must be expected.

All options involve the electrification of sections of track not currently owned by GO, which means that further investigations on the acceptance of CN and CP should be established before any option is taken forward. The construction techniques themselves are not especially challenging and all options are buildable, although the reconstruction of the tunnel approaching Hamilton TH+B could present engineering and disruption issues for Option 18.

Risk and Uncertainties

The risks associated with electrification were considered extensively and in most cases these have been factored into the costing or other parts of the assessment. The key risks would be that other operators such as CN and CP may set exacting requirements for electrifying corridors owned by them which make it no longer justified. This affects all options to a certain extent, and detailed discussions with CN and CP would be required if the project was to be taken forward to the next stage of design and development.

The transportation BCR takes into account the monetized impacts over the project life cycle, and this depends on a number of key assumptions, including the deliverability of the Reference Case. A wide range of sensitivity and scenario tests concluded that while there is potentially a wide range of BCRs depending on various assumptions, overall, the relative performance of each option still holds. Option 2 (Lakeshore) consistently emerges as the best performing option while Option 3 (Lakeshore and Georgetown) and Option 11 (Lakeshore, Georgetown and Milton) remain very similar in BCR terms relative to one another. Having considered the range of likely uncertainties, Option 1 (Georgetown) and Option 18 (Entire Network) are unlikely to deliver a BCR greater than 1:1, and the justification of pursuing those options in the timeframe of this Study would have to be supported by other non-monetized benefits.

Summary Findings and Conclusions

The detailed evaluation of the six network options considered in the Electrification Study concluded that there are environmental benefits associated with electrification, particularly in reducing GO's greenhouse gas emission footprint. There are also regional and local air quality improvements expected, but as GO has already committed to operating diesel locomotives which are compliant with Tier 4 emission standards in the medium term horizon, the incremental impacts of electrification, in the context of health is relatively modest.

Another benefit associated with electrification is the reduced journey times for passengers as electric trains can accelerate and decelerate more rapidly than diesel trains. These time savings translate to welfare benefits to users and improve the economic competitiveness of the region. However, the transit benefits in scope are relatively modest when compared to the significantly more expensive Electric Multiple Units.

The overhead catenary system, particularly in rural areas, is likely to result in a negative visual impact to the landscape. The construction of an electrified system is also likely to result in some temporary impacts to the environment and community, although GO have pledged to retain passenger services during construction.

Electrification of any option would involve a significant capital investment, and although electric locomotive trains are expected to deliver significant operating and maintenance cost savings over its lifetime, this is dependent on the future outlook on energy prices.

Of the options considered, electrifying the Lakeshore corridor between Bowmanville and Hamilton James (Option 1) is the most cost effective option in delivering environmental, transportation and economic benefits, while the inclusion of the Georgetown (Option 3) and Milton corridors (Option 11) deliver higher levels of benefits without significantly reducing the cost effectiveness of implementing those options.

Table 3 Multiple Category Evaluation Summary Table

Category	Sub-Category	Measure	Option 1 Georgetown	Option 2 Lakeshore (excl.TH+B/St Cat)	Option 3 Lakeshore* + Georgetown	Option 11 Lakeshore*, Georgetown, Milton	Option 15 Lakeshore*, Georgetown, Milton, Barrie	Option 18 All Corridors (incl. TH+B and St Cat)
Environmental and Health	Greenhouse Gas and Climate Change	Regional Greenhouse Gases Reductions - Qualitative assessment based on the overall impact on climate change	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive
		Percentage reduction in GO Rail's total GHG contributions (note: excludes modal shift emission reductions)	15%	40%	55%	64%	78%	94%
	Regional Air Quality	Regional Air Quality - Qualitative assessment based on reduced CACs emitted by GO Rail to the region	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive
	Local Air Quality	Local Air Quality - Qualitative Assessment based on the impact on reduced CAC and the population who benefit from it	Slight Positive	Slight Positive	Moderate Positive	Moderate Positive	Moderate Positive	Moderate Positive
		Value of Health Benefits - Based on reduction of GO Rail's contribution to regional smog ($m per annum 2010 prices)	4	7	11	13	15	18
	Other Health	Physical Fitness - Qualitative assessment based on the number of additional transit users	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive
		Electro-Magnetic Fields (EMF) - Qualitative assessment based on guidelines by the Institute of Electrical & Electronics Engineers	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact
		Qualitative assessment based on the change in safety hazard of the railway network after mitigation measures are in place	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact
	Noise and Vibration	Noise - Qualitative assessment based on the change in noise levels and the population who benefit from it	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Slight Positive	Slight Positive
		Vibration - Qualitative assessment based on the change in vibration levels and the population who benefit from it	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Slight Positive	Slight Positive
	Terrestrial Ecosystem	Qualitative assessment based on the impacts towards the terrestrial ecosystem's natural heritage	Slight Negative	Slight Negative	Slight Negative	Slight Negative	Slight Negative	Slight Negative
	Aquatic Ecosystem	Qualitative assessment based on the impacts towards the aquatic ecosystem's natural heritage	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Slight Negative
	Effect on Parks / Public Open Space	Qualitative assessment based on the likely impacts towards parks and open spaces used by the local community	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact
User Benefits / Quality of Life	Transportation Efficiency	Average Journey Time Saving of Electric Train User (mins per passenger)	2.8	2.6	2.7	2.5	2.5	2.4
		Total Journey Time Saving ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	122	334	456	541	617	692
		Journey time benefits for highway users ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	23	75	98	117	135	153
		Reduction in Auto operating costs ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	41	136	176	209	242	275
		Reduction in vehicle collisions ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	6	20	26	30	35	40
	Reliability	Passenger Reliability Benefits ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	0.8	3.1	3.9	5.0	6.1	7.2
	Transit Network/ System Access	Qualitative assessment based on the improvement of accessibility of transit	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact
	Comfort and Expandability	Qualitative assessment based on the change in crowding levels on the trains and GO's ability to expand capacity accordingly	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact
Social Community	Land Use Integration	Qualitative assessment based on how improved transit can help shape communities and link up key activity centres	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive
	Social and Community	Qualitative assessment based on the perceived impacts towards the local communities	Moderate Negative	Moderate Negative	Moderate Negative	Moderate Negative	Slight Negative	Moderate Negative
Economic	Cost-Effectiveness	Transportation Benefit:Cost Ratio (BCR)	0.4 :1	1.1 :1	0.9 :1	0.9 :1	0.8 :1	0.5 :1
		Cost per New Rider in 2031 ($m Capex/new daily passenger)	0.44	0.26	0.27	0.26	0.30	0.41
		Tonnes of GHG saved (from technology and modal shift) per annum per $10m capital cost	670	1,220	1,170	1,140	1,060	840

		Long Term Economic (GDP+Wages) PV Benefits per $10m capital cost	3.2	7.2	6.5	6.4	5.7	4.2
	Land Use and Property Development	Qualitative assessment based on the influence on land use and potential for development	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive
	Property / Land Take	Qualitative assessment based on the property/land required to implement the option	Slight Negative	Slight Negative	Slight Negative	Slight Negative	Slight Negative	Slight Negative
	Wider Economic Impacts During Construction	Incremental GDP and wages due to construction ($m Real 2010 prices)	270-460	310-500	470-760	570-870	680-1,060	1,210-1,850
		Number of regional jobs created due to construction (Employment-years)	2,100-3,500	2,400-3,800	3,600-5,800	4,500-6,800	5,200-8,200	9,700-14,800
	Wider Economic Impacts During Operations	Incremental GDP and wages in the long term due to improved transit times ($ per annum in 2031)	15	49	64	74	87	97
		Number of regional jobs in the long term due to improved transit times (Employment-years in 2031)	160	500	660	770	890	1,000
	Taxes	Effect/increased provincial and federal taxes in 2031 ($m per annum)	4	14	19	22	25	28
Financial	Capital Cost	Incremental Capital Cost ($m 2010 prices, i.e. excluding inflation)	790	1,160	1,660	1,980	2,570	3,950
		Incremental Capital Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	580	850	1,230	1,460	1,890	2,910
	Total Life Cycle Cost	Life Cycle Present Value Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	470	470	730	870	1,200	2,110
	Operating Cost	Incremental Operating and Maintenance Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	-90	-340	-420	-510	-590	-700
	Total Revenues	Incremental revenues of the transit network ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	23	50	73	86	96	109
	Operating Sustainability	Reduction in Operating Subsidy in 2031 ($m Real 2010 prices per annum)	-15	-49	-64	-76	-88	-103
Deliverability	Constructability	Qualitative assessment of the construction constraints, techniques and impacts to transit users	Slight Negative	Moderate Negative	Moderate Negative	Moderate Negative	Strong Negative	Strong Negative
	Acceptability	Qualitative assessment of public and stakeholder (owner and operator) acceptance of each option	Slight Negative	Moderate Negative	Moderate Negative	Moderate Negative	Strong Negative	Strong Negative

1. INTRODUCTION

1.1. Background

The Greater Toronto and Hamilton Area (GTHA) is in the midst of a transportation transformation as a result of a renewed public commitment to invest and grow regional transit. The Big Move - a compelling integrated, multi-modal vision for regional transportation adopted by Metrolinx in 2008, will strengthen the economic, social and environmental sustainability of the Greater Toronto and Hamilton Area and profoundly change how people and goods are transported within the region. GO, a division of Metrolinx and the GTHA's principal inter-regional transit service, will play a decisive part in this transformation. The means by which GO's rail system grows and develops is therefore essential to realizing the ambitious vision of The Big Move and creating a GTHA that is shaped and supported by a world-leading regional transportation network.

1.2. Study Purpose

Metrolinx initiated a study of the electrification of the entire GO Transit rail system as a future alternative to diesel trains now in service. The purpose of the Study was to examine how the future GO rail services will be powered – using electricity, enhanced diesel technology or other means – when improved services are implemented in the future. The Study assessed the benefits and costs of a full range of technology options, including enhanced diesel, electric and alternative technologies. The Study considered the existing GO Transit network, the proposed network expansions to St. Catharines, Kitchener/Waterloo, Allandale, Bloomington, Bowmanville, as well as the future Pearson Air Rail Link.

1.3. Document Structure

This document sets out the approach and findings of the Detailed Evaluation. The report is structured as follows:

- Section 2 discusses the purpose of the Reference Case and describes the Evaluation Process;
- Section 3 defines the six selected network options for detailed evaluation;
- Section 4 sets out the Evaluation Framework;
- Section 5 documents the Environmental & Health Assessment;
- Section 6 documents the Transportation Assessment;
- Section 7 documents the Social Community Assessment;
- Section 8 documents the Economic Assessment;
- Section 9 documents the Financial Assessment;
- Section 10 documents the Delivery Assessment,
- Section 11 summarizes the findings of Sections 5 to 10 in the Detailed Evaluation Summary; and
- Section 12 considers the analysis of uncertainties affecting the transportation case.

2. EVALUATION PROCESS

Throughout this Study, all options are evaluated in comparison with a Reference Case. This Section details the Reference Case and gives a brief overview of the Evaluation Process.

2.1. Reference case

The Reference Case was developed to provide a consistent basis and assumptions for comparing future technology and network options as part of the Electrification Study. It represents a reasonable scenario for future GO rail services which incorporates existing attributes and approved/planned enhancements of GO's rail network, rolling stock, rail infrastructure and service levels consistent with the GO Transit's strategic plan.

The assumed planned enhancements for GO Transit network include the proposed network expansions to St. Catharines, Kitchener/Waterloo, Allandale, Bloomington, Bowmanville, as well as the future Pearson Air Rail Link as illustrated in Figure 3.

Figure 3 Reference Case GO Transit Network Corridors

The Reference Case was prepared specifically for this Study and includes a high level service concept (not a plan), which is one possible outcome, subject to detailed feasibility, passenger demand and capital/operating funding. This Study has made a number of assumptions about the GO rail network, service level and available infrastructure to enable a consistent and identifiable approach to be taken when comparing alternative technologies.

The key assumptions for the Reference Case are as follows:

- Union station will have the capacity to receive the inbound and outbound services in the reference case
- Each train will have 10 bi-level coaches, each carrying 1,540 seated passengers and this will be the same for each corridor
- Train consists (number of passenger coaches) will not be changed during normal daily operation
- The operations of CN/CP and Via Rail are allowed for and are assumed to have no impact on the proposed schedule
- The whole GO rail network will be considered for electrification
- Tier 4 Diesel MP40 rolling stock will be in operation. This will therefore be the rolling stock against which other technologies are assessed in the Study
- The Air Rail Link (ARL) shuttle service will use the Georgetown corridor and terminate just outside Union station
- An increase in service will occur over the next decade as described in the reference case service concept supplied by GO Transit for Metrolinx, as detailed below

The reference case refers to a future level of service planned by GO and Metrolinx. These service concepts were prepared to provide an effective base, which can be used to assess the benefits of alternate modes of propulsion. Further analysis of the operating plan is required to refine and optimize systemic requirements. Final implementation may vary as feasibility is confirmed, demand warrants, and operating/capital funding is provided in the medium-term horizon.

The details below are taken from the description of the reference case service concept as supplied by GO for Metrolinx. This reference case is only an indication of the increase in service over the next decade assumed for the purpose of this Study. Further details are set out in the Reference Case Workbook in Appendix 3.

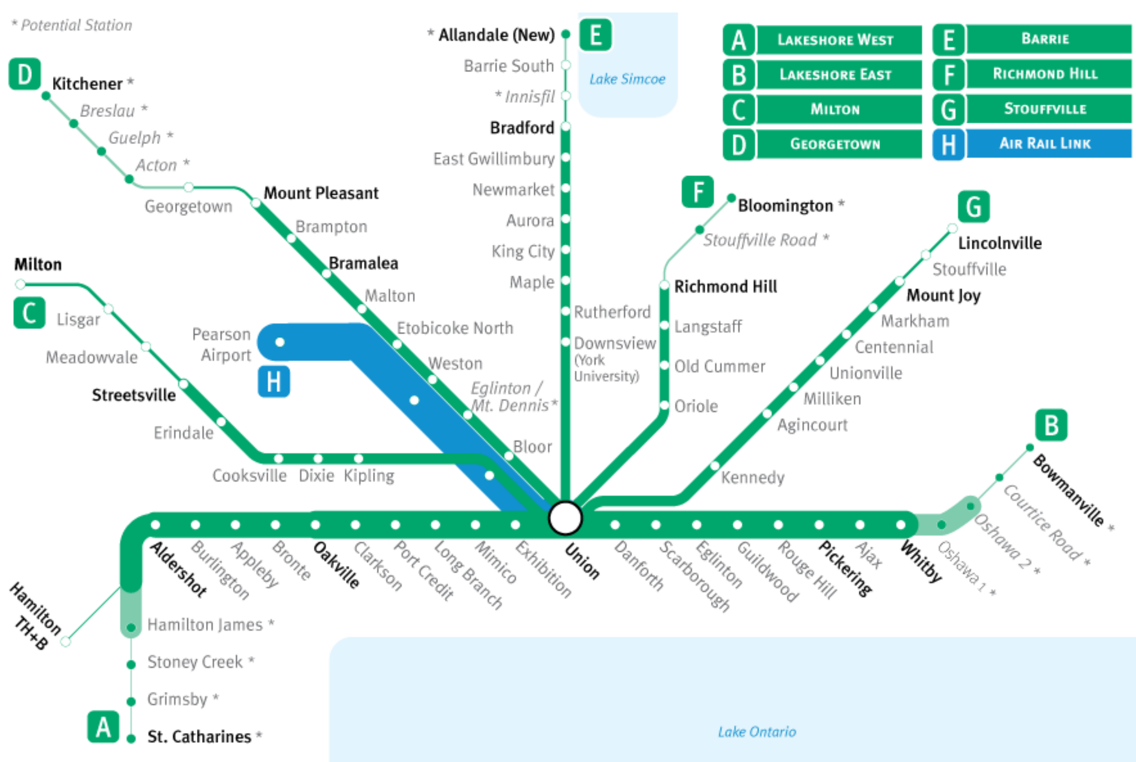
In addition, all lines will experience a significant level of counter-peak and off-peak service, which is not provided today. Lakeshore East and West will generally receive two trains per hour in the off-peak, while other corridors have an hourly service. Some routes, such as between Georgetown and Kitchener, to Hamilton TH+B and St Catharines are expected to operate peak only services. The level of service specified would require the delivery of various infrastructure enhancements and this Study assumes that those can be provided. Full details of the Reference Case service levels and stopping patterns can be found in the Reference Case workbook.

The total number of trains arriving into Union station in the AM peak and over a weekday is set out in Table 4. The relative total number of trains per day across the network is illustrated in Figure 4, where the thickness of the line is proportionate to the levels of service operated across each section.

Table 4 Reference Case: Increase in Service Assumptions

Corridor	Number of trains arriving at Union Station in the 3-hour AM peak		Number of trains arriving at Union Station every weekday	
	Current	Reference Case	Current	Reference Case
Lakeshore West	13	20	63	104
Lakeshore East	12	17	63	98
Milton	7	14	14	62
Georgetown	6	14	13	61
Air Rail Link (ARL)	0	12	0	140
Barrie	4	10	8	53
Richmond Hill	4	9	9	52
Stouffville	5	12	10	59
Total	**51**	**108**	**180**	**629**

Figure 4 Reference Case: Schematic Illustrating Service Assumptions



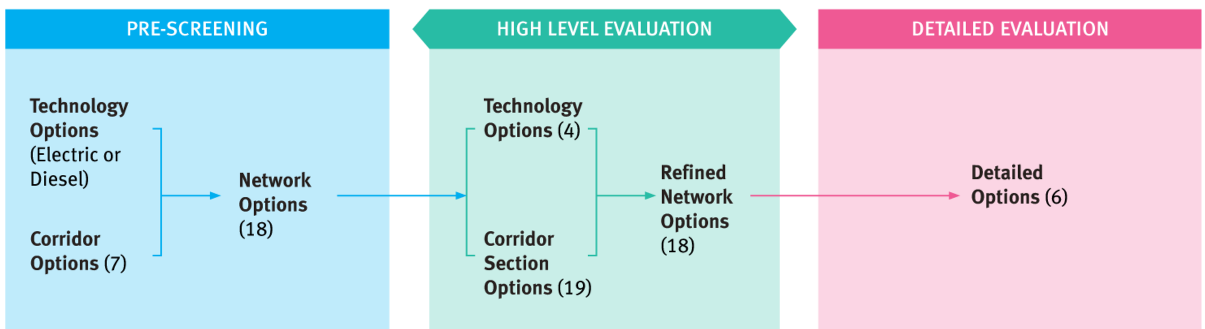
2.2. Evaluation Process

The evaluation was undertaken in three stages with increasing detail as the Study progressed. Further details on the evaluation process are set out in the High Level Decision Making Framework document. The three stages included are:

- **Pre-screening** of potential network options to derive 18 network options which only consider the various corridors for electrification using a generic electric train technology;
- **High Level Evaluation** of the 18 network options by undertaking a corridor prioritization process and technology evaluation; and
- **Detailed Evaluation** of 6 network implementation options which includes choosing the optimal technologies, partial implementation and phasing.

This evaluation process is summarized in the flow chart, Figure 4.

Figure 4 Option Evaluation Process



2.3. High Level Evaluation Findings and Conclusions

The four technologies (Tier 4 diesel locomotives, electric locomotives, Electric Multiple Units and dual-mode diesel electric locomotives) and 19 corridor sections were evaluated and the key findings and conclusions from that report were:

- Electric locomotives were identified as the most cost-effective alternative technology in delivering transportation and environmental benefits and were therefore taken forward for detailed evaluation, although noting that EMUs offered significant journey time savings and higher transportation benefits;
- In most cases, with the exception of Hamilton TH+B branch line and the section between Hamilton James and St Catharines, it was more cost effective to electrify the entire corridor (as opposed to just sections of it) so that all trains can be electric. This is because the sections near the downtown area are more costly and the marginal cost of electrifying the end sections was relatively modest;
- Dual-mode locomotives were seen as a potential technology for services on partially electrified corridors. However, given the previous point, there would be limited use of dual-mode locomotives other than on services to Hamilton TH+B and St Catharines. As such, dual-modes would be primarily considered in the longer-term implementation of an electrified network; and
- Having relative performances of each corridor sections, a shortlist of network options were generated for detailed evaluation and are described in summary in Section 3.

3. OPTION DESCRIPTION

3.1. Option Description

Following on from the findings of the High Level Evaluation, a shortlist of six network options were taken forward for detailed evaluation. Table 5 sets out the six selected options. They are colour-coded with respect to the network's schematic diagram illustrated in Figure 3. Lakeshore has been divided into two columns because Options 1-17 do not include electrification of the Lakeshore line extension beyond Hamilton James to St. Catharines and the spur to Hamilton TH+B. Option 18 involves the electrification of the entire network, including Hamilton TH + B and St. Catharines. Georgetown incorporates both the original line heading towards Kitchener and the Air Rail Link to Pearson Airport.

Table 5 The Optimal Service Section Options

Option	Lakeshore		Georgetown and ARL		Milton	Barrie	Richmond Hill	Stouffville
	Hamilton James via Union to Bowmanville	Hamilton James to Hamilton TH+B & St Catharines	Union to Kitchener	Union to Pearson Airport (ARL)	Union to Milton	Union to Allandale	Union to Bloomington	Union to Lincolnville
Reference Case								
Option 1			✓	✓				
Option 2	✓							
Option 3	✓		✓	✓				
Option 11	✓		✓	✓	✓			
Option 15	✓		✓	✓	✓	✓		
Option 18	✓	✓	✓	✓	✓	✓	✓	✓

In summary, the Options taken forward for detailed evaluation were:

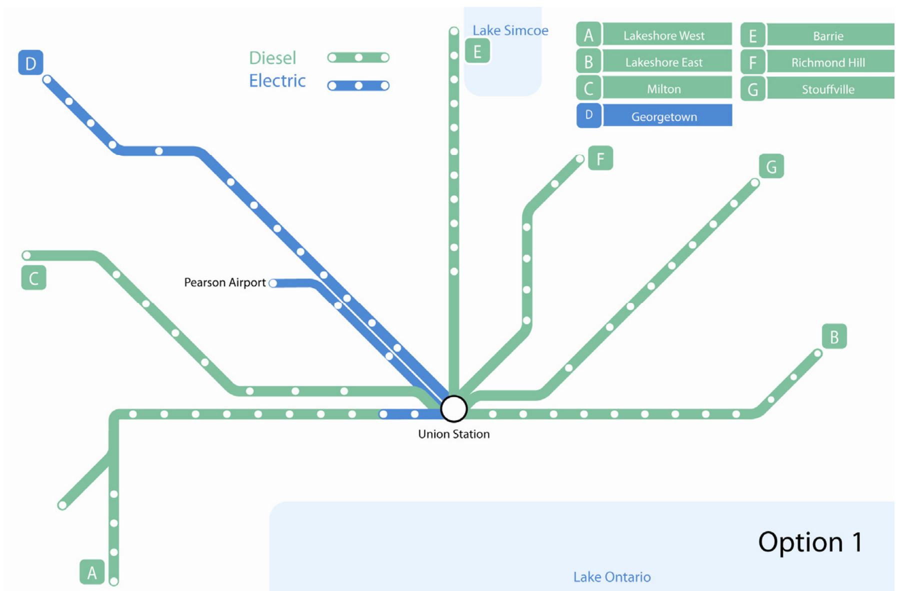
- **Reference Case** – None of the corridors are electrified
- **Option 1** – Electrifying the Georgetown line (including ARL) only
- **Option 2** – Electrifying the Lakeshore line only (East and West, excluding Hamilton TH+B and St Catharines)
- **Option 3** – Electrifying the Georgetown and Lakeshore lines
- **Option 11** – Electrifying the Georgetown, Lakeshore and Milton lines
- **Option 15** – Electrifying the Georgetown, Lakeshore, Milton and Barrie lines
- **Option 18** – Electrifying the entire network (including Hamilton TH+B and St Catharines)

While these are the six network options evaluated in detail as part of this Study, it does not preclude Metrolinx from taking forward an alternative network option based on the findings and conclusions of the evaluation.

Option 1 – Georgetown

Option 1 is the electrification of Georgetown (Union to Kitchener including the ARL to Pearson Airport) and the operation of the remaining line with Tier 4 diesel trains. It is a priority corridor due to its high service levels. The ARL is due to be completed by 2015 in time for the Pan American Games. In the case of the ARL, it is assumed that the initial deployment of Diesel Multiple Units will be replaced by Electric Multiple Units if the Georgetown line is electrified.

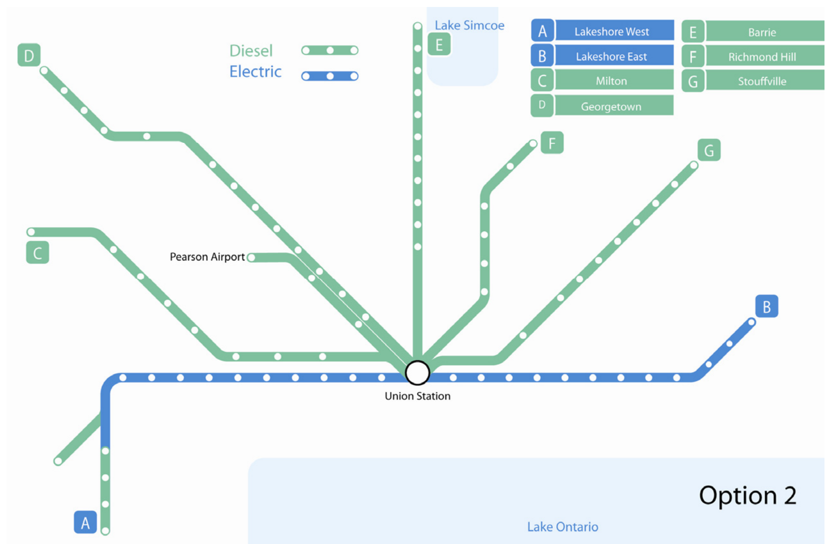
Figure 5 Schematic Diagram of Option 1



Option 2 – Lakeshore

Option 2 is the electrification of Lakeshore (Hamilton James via Union to Bowmanville, see Figure 6) with the operation of Tier 4 diesel trains on the remaining lines. It is a priority corridor due to its high service levels in comparison with other corridors on the network.

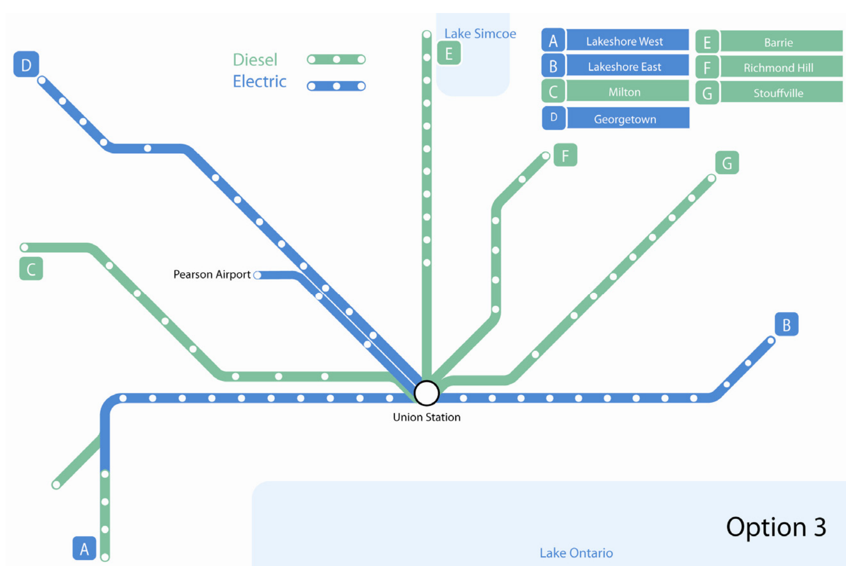
Figure 6 Schematic Diagram of Option 2



Option 3 – Georgetown and Lakeshore

Option 3 is the electrification of two corridors; the combination of Lakeshore (Hamilton James to Bowmanville) and Georgetown. These two corridors have been prioritised due to their high service levels and demand.

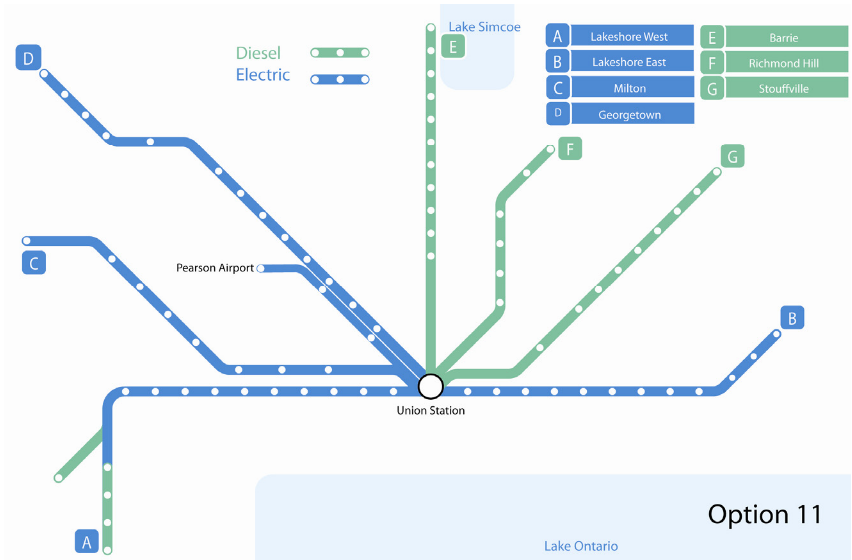
Figure 7 Schematic Diagram of Option 3



Option 11 – Georgetown, Lakeshore and Milton

Based on the Multiple Category Evaluation (MCE) findings from the high level evaluation, the best option for electrifying three corridors is Option 11. Therefore it combines the electrification of Lakeshore (Hamilton James to Bowmanville), Georgetown and Milton lines.

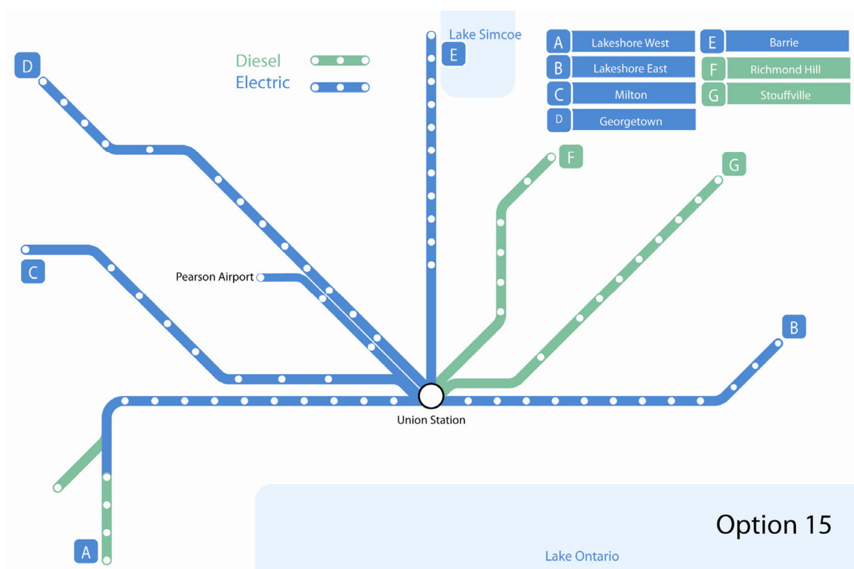
Figure 8 Schematic Diagram of Option 11



Option 15 – Georgetown, Lakeshore, Milton and Barrie

Option 15 is the electrification of four corridors, Georgetown, Lakeshore (Hamilton James to Bowmanville), Milton and Barrie. This was the preferred option if 4 corridors were electrified.

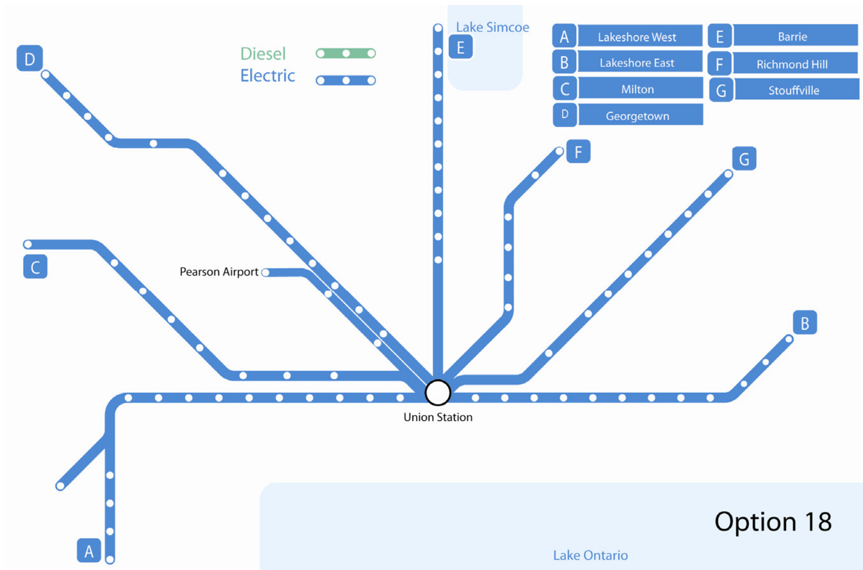
Figure 9 Schematic Diagram of Option 15



Option 18 – Entire Network

Option 18 is the electrification of the full network, which includes the remaining sections which did not perform as strongly as those included in the first five options. This encompasses the Stouffville and Richmond Hill corridors, as well as the Lakeshore West extensions from Hamilton Junction to Hamilton TH+B and beyond Hamilton James to St Catharines.

Figure 10 Schematic Diagram of Option 18



4. DETAILED EVALUATION FRAMEWORK

4.1. Multiple category evaluation Framework

The comparative analysis in the Electrification Study uses a Multiple Category Evaluation (MCE) methodology. The MCE is a framework that provides a systematic identification and analysis of broader implications and criteria of an option. It systematically presents the impacts on costs, users, environment, economy and community and allows the decision maker to make trade-offs among the often conflicting criteria. Further details can be found in the High Level Decision Making Framework Report.

The MCE framework includes a number of evaluation categories that together address the most significant project performance and policy considerations for a transit project. The relevant categories for the analysis of the Electrification Study are:

- Environmental & Health;
- User Benefits / Quality of Life;
- Social Community;
- Economic;
- Financial; and
- Deliverability

The assessment is done by comparing each option to the Reference Case and identifying any incremental costs (e.g. negative impacts) or benefits (e.g. positive impacts) that are generated by each option. Hence, the results should not be interpreted as absolute impacts but rather as the incremental impact (positive or negative) of electrification compared to the Reference Case Tier 4 diesel locomotive trains. Therefore the impacts - potential benefits and costs associated with the enhanced infrastructure and service levels from today to the Reference Case are not included in this Study.

Table 6 sets out the detailed MCE Framework scope and evaluation measures. Where appropriate these have been made consistent with recent Benefits Case Analysis undertaken by Metrolinx. The impacts were quantified over the 30-year life-cycle evaluation. Further details on the methodology and assumptions can be found in Appendix 8-A – Approach to Cost Benefit Analysis.

Table 6 Multiple Category Evaluation (MCE) Framework

MCE Category	Sub Category	Role / Description	Assessment and Measure
Environmental and Health	GHG Emissions and Climate Change	• Total GHG emissions reduced through use of electricity instead of diesel, reductions in energy consumption and engine efficiencies with different rolling stock technologies. Reduction of emissions is one of the key Study objectives. • This criterion also includes changes in auto emissions due to modal shift from car to transit.	• Reduction in regional greenhouse gas (GHG) – primarily carbon emissions (tonnes per annum) • % reduction in GO Rail's GHG Contributions • Qualitative assessment of reduction in criteria air contaminants (CAC)
	Regional Air Quality	Total CAC emissions reduced through use of electricity instead of diesel	Qualitative assessment
	Local Air Quality	Improved local air quality and reduced CAC could reduce health impacts on vulnerable groups.	• Qualitative assessment on health due to air quality • Value of health benefits due to air quality
	Other Health	• If improved journey times promote mode shift from car to transit there are also physical fitness benefits associated with more walking. • Implications of electro-magnetic field (EMF) effects. • Health and safety of the system includes both operational safety, as well as personal safety of using the system.	• Qualitative assessment on physical fitness • Qualitative assessment on EMF impacts • Qualitative assessment on health and safety
	Noise and Vibration	Technology options may have different noise and vibration effects during operation.	Qualitative assessment based on reduction in perceivable local noise and the population who benefits from it
	Terrestrial Ecosystem	Electrification may have different effects on the terrestrial ecology, natural environment and biodiversity during operation.	Qualitative assessment
	Aquatic Ecosystem	Electrification may have different effects on the aquatic ecology, waterways and from surface run-off, during operation.	Qualitative assessment
	Effect on Parks / Public Open Space	Depending on construction requirements, there may be a need to take designated natural areas to build the catenary or power systems and to operate the electric trains, such as depots.	Qualitative assessment
User Benefits / Quality of Life	Transportation Efficiency (Users)	Different rolling stock technologies may deliver faster journey times due to acceleration/deceleration characteristics and passengers will benefit from reduced journey times.	• Average journey time saving of electric train user (mins per passenger) • Total monetized passenger journey time saving over evaluation period ($PV)
	Transportation Efficiency (Non-	If journey times could be improved it would attract additional ridership from auto as modelled by km	• Monetized journey time benefits

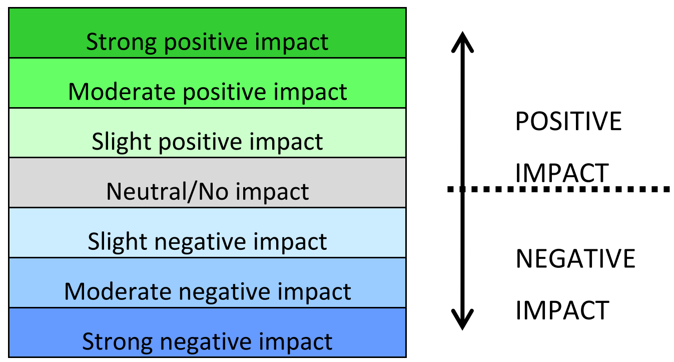
MCE Category	Sub Category	Role / Description	Assessment and Measure
	Users)	travelled by vehicle across the region. Subsequent changes in vehicle operating costs and collisions, while the journey time benefits illustrate the effect of decongestion.	for highway users ($PV) • Reduction in auto operating costs ($PV) • Reduction in vehicle collisions ($PV)
	Reliability	Different rolling stock technologies could perform with different levels of technical reliability and passengers may benefit from reduced delays from fewer technical failures.	Total monetized passenger reliability related time savings over evaluation period ($PV)
	Transit Network/ System Access	Demonstrates the relative accessibility for residents, employees, students, and shoppers of the options.	Qualitative assessment
	Comfort and Expandability	Comfort is primarily measured by the ability of passengers to find a seat when using the transit system. Different technologies may have different carrying capacity, and may have different abilities in adapting to patronage growth.	Qualitative assessment of comfort, crowding and capacity issues and the ability for the system to be expanded or incorporated into a larger network consistent with local context.
Social Community	Land Use Integration	Integration with activity centres and places that people want to go – to work, shop, go to school, eat, recreate or socialize.	Qualitative assessment
	Social and Community	Electrification could potentially cause a displacement of households/ residents, institutional, community and recreation features. It may also result in a change in the use and enjoyment of those features or change the community character. Overhead catenary systems may interfere with electronic equipment and have an impact on the visual characteristics of townscape and landscape in the study area.	Qualitative assessment
Economic	Cost-Effectiveness	To demonstrate the relative value for money of the investment in each electrification option in delivering Study objectives.	• Benefit:Cost ratio • Cost per new rider in 2031 ($m real capital cost per new daily passenger) • Tonnes of GHG saved per annum per $10m capital cost • Long term economic PV benefits per $10m capital cost
	Land Use and Property Development	Improved public transportation accessibility generally leads to increased demand for land which means higher land values and changes in land use to the 'highest and best' use. Impacts on property value due to visual aspect of overhead catenary systems to be considered.	Qualitative assessment
	Property / Land Take	Depending on corridors electrified and infrastructure required, there may be a need to take property.	Qualitative assessment
	Construction Employment	The construction of the infrastructure may create both direct and indirect income and employment.	• Incremental income and GDP ($m real 2010 prices) • Number of regional jobs

MCE Category	Sub Category	Role / Description	Assessment and Measure
			(employment-years)
	Operating Employment	The operation of the electrified network may create both direct and indirect income and employment.	• Incremental income and GDP ($ per annum) • Number of regional jobs (employment-years)
	Taxes	The construction and operation of the rapid transit line may increase the federal and provincial tax base. This will be assessed and if relevant quantified.	Effect/increase provincial and federal taxes in 2031 ($m per annum)
Financial	Capital Cost	The capital cost (funding) required to implement each option.	• Incremental capital cost ($m real 2010 prices) • Incremental capital cost ($m PV 2010 prices discounted over 30 years)
	Total Life Cycle Cost	The total cost of electrification over the 30 year life cycle including total infrastructure and rolling stock capital costs, operations and maintenance costs and revenue.	Life Cycle Cost ($m PV 2010 prices discounted over 30 yrs)
	Operating and Maintenance Cost	Operating costs of the transit network (including maintenance) as well as any savings from reduction/elimination of other services and additional fare revenues collected.	Incremental operating and maintenance cost ($m PV 2010 prices discounted over 30 yrs)
	Total Revenues	If faster journey times can be achieved and additional passengers are forecast, there will be additional revenues generated in the transit system.	Incremental revenues of the transit network ($m PV 2010 prices discounted over 30 yrs)
	Operating Sustainability	The additional money gained over the Reference Case through operations each year; the total of the annual operating cost savings and the annual revenue.	Reduction in Operating Subsidy in 2031 ($m Real 2010 prices per annum)
Deliverability	Constructability	Generally a review of major constraints, including geotechnical, archaeological, environmental remediation measures and physical challenges (gradients, physical constraints, system expandability, etc) that would make building/operating an option overly difficult. This also includes non-environmental construction impacts.	Qualitative assessment
	Acceptability	Description of the likely public and stakeholder response to the option, including local residents, businesses and other railway operators (e.g. CN, CP).	Qualitative assessment informed by public and stakeholder process

4.2. Qualitative Assessment Scoring

In many circumstances, it may not be appropriate or possible to determine a quantitative (monetized or otherwise) assessment of an impact. The impacts would then be assessed qualitatively. Where practical, quantitative measures will be used to inform a qualitative assessment, depending on the magnitude of change, based on the seven-point scale shown in Figure 11.

Figure 11 Qualitative Assessment Seven-Point Scale



Qualitative assessments are, by their nature, subjective and will be undertaken by qualified professionals exercising their objective skill, expertise and judgment to determine the likely, comparative effects of the various options using the assessment matrix shown in Table 7.

Table 7 Qualitative Assessment Matrix

		Number of people or instances affected by the benefit/effect			
		Majority	**Moderate**	**Isolated**	**None**
Scale of benefit/effect	Strong	Strong	Strong	Moderate	Neutral
	Moderate	Strong	Moderate	Slight	Neutral
	Slight	Moderate	Slight	Slight	Neutral
	None	Neutral	Neutral	Neutral	Neutral

The advantage of using such assessment scales is to assist decision makers in understanding, at a glance in a summary table, whether there is a material impact when he or she may not appreciate the implications of a quantitative result or going into the detailed assessment documentation for each sub-category unless it is necessary.

4.3. Remaining Document Structure

Sections 5, 6, 7, 8 and 10 each cover one of the evaluation categories identified in the MCE Framework. Within each Section, the subcategories listed in Table 6 are introduced and elaborated upon. A relevant assessment of the options is presented followed by a conclusion along with a 7-point scale valuation. Section 11 brings Sections 4 to 9 together and summarizes the report, while Section 12 covers the sensitivity tests that potentially affect the transportation efficiency.

5. ENVIRONMENTAL AND HEALTH ASSESSMENT

5.1. Introduction

This section of the report covers the Environment and Health Category of the MCE, and the corresponding sub-categories include the following:

- Greenhouse Gas Emissions and Climate Change;
- Regional Air Quality;
- Local Air Quality;
- Other Health, including:
  - Physical Fitness
  - Electro-Magnetic Fields (EMF)
  - Safety
- Noise and Vibration;
- Terrestrial Ecosystem;
- Aquatic Ecosystem; and
- Parks and Open Space.

5.2. Greenhouse Gas Emissions and Climate Change

Introduction

The averaging temperature of the earth has increased significantly over the past century resulting in a variety of related effects, such as changes in global precipitation patterns, decline of Arctic and Antarctic ice packs, decline of glaciers, rising sea level, etc. The trend of climate change is expected to continue and human activities are implicated. Combustion of fossil fuels, for example, releases carbon dioxide (CO_2) and other greenhouse gases to the atmosphere, which influence the Earth's radiation balance and cause warming. At the same time, global deforestation depletes the Earth's population of trees, reducing their role in removing CO_2 from the atmosphere for photosynthesis.

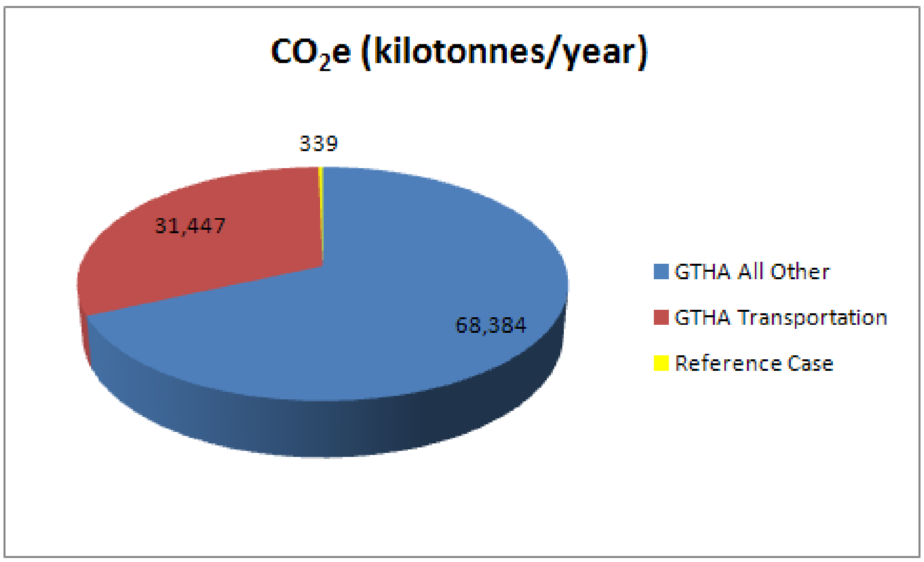
Assessment

Like all combustion equipment, diesel-powered locomotives emit greenhouse gases (GHG's). Electric locomotives may also generate GHG emissions depending on how the electricity used to power them is generated. Compared to the automobile, however, both diesel- and electric-powered passenger rail services offer an efficient way of transporting people, with a net reduction in GHG emissions. The service levels considered in the Reference Case and each of the electrification options reflect increased commuter ridership, meaning fewer cars on the highway. Since the benefits of removing this highway traffic would be similar in magnitude for the Reference Case and each of the electrification options, the key consideration is the reduction in GHG emissions related to powering the locomotives for each option relative to the Reference Case.

The potential to affect greenhouse gas emissions was assessed for each of the six short-listed electrification options. This issue was examined by completing an approximate inventory of GO Transit's direct GHG emissions in the Reference Case and comparing it to the residual emissions for the various electrification options. Annual emissions were calculated based on fuel consumption data, the Reference Case numbers of daily train trips for each corridor of the network, and the distances travelled. Some minor train activity, such as short trips in and out of storage (i.e., "deadhead" trips) at the beginning and end of each day were not included in the calculation.

The results show that the six electrification options lead to progressively lower GHG emissions (represented by CO_2e) in comparison to the Reference Case. However, to put the results into perspective, they have also been compared to GTHA total GHG emissions and GTHA GHG emissions from all transportation sources. Regional totals for the GTHA were estimated from provincial totals, based on relative population. Figure 12 illustrates the relative contribution of GO Transit rail emissions in the Reference Case. From this figure, it is seen that all options, including the Reference Case, have a network-wide GHG emission inventory that is a fraction of 1% of the GTHA's overall regional emission inventory from all sources. Thus, none of the electrification options will significantly reduce regional GHG emissions that contribute to climate change and, as such, none will provide an appreciable benefit at the regional scale.

Figure 12 Current Annual GHG Emissions in GTHA



However, it may be argued that GO Rail alone cannot be expected to significantly reduce the regional GHG emissions; the tackle against climate change should be acted upon by all who contribute towards it, and therefore it is also relevant to compare the reductions in GHG against GO's own GHG footprint. Full details of the assessment can be found in Appendix 8-D – Air Quality & Health Impacts.

Conclusions

Although GO contributes a fraction of the regional GHG emissions and therefore unable to make a notable difference towards climate change, electrifying the entire network could reduce GHG emissions by 319,000 tonnes per year, approximately 94% of the total GO Rail's contribution toward GHG emissions. Furthermore, due to faster transit times and the reduction in highway journeys by private car, a further 11,000 tonnes of GHG per year can be saved.

The key statistics on each option in terms of GHG emission reductions and the overall qualitative assessment against Climate change is set out in Table 8.

Electrification therefore meets one of the main objectives of The Big Move to reduce GHG emissions per passenger by 25% (in all options except Option 1) and produce *'A Smaller Carbon Footprint and*

Lower Greenhouse Gas Emissions'. In addition, it states that '*GHGs and other harmful emissions related to transportation will be reduced*.' This in turn will contribute to '*the achievement of the transportation related GHG reduction targets of Go Green: Ontario's Action Plan for Climate Change*'.

Table 8 GHG Assessment Summary

Option	**Tonnes of GHG Removed per Annum**		**% Reduction in GO Rail's GHG Emissions**	**GHG Reduction and Climate Change Assessment**
	From Rolling Stock Technology	**From Modal Shift (2031)**		
Option 1	51,500	1,700	15%	Slight Positive
Option 2	136,000	5,400	40%	Slight Positive
Option 3	187,500	7,100	55%	Slight Positive
Option 11	217,400	8,400	64%	Slight Positive
Option 15	263,800	9,800	78%	Slight Positive
Option 18	319,300	11,100	94%	Slight Positive

5.3. Regional Air Quality

Introduction

It has been recognized for centuries that air quality can affect human health. Considerable research has been undertaken in the past 50-60 years to better understand these effects. Governmental health and environment agencies have identified chemical compounds within air pollution that have linkages to human health and have implemented policies and regulations aimed at reducing them.

In Canada, the concentrations of many air pollutants have been dramatically reduced over the past several decades as a result of various regulatory programs aimed at vehicle emissions, industrial emissions and other miscellaneous emission sources. Nevertheless, many members of the population still experience a variety of undesirable effects of air pollution.

Collectively, motor vehicles are a major emitter of air pollutants. Passenger trains fall into this category, although their emissions are a relatively small component of all motor vehicle emissions. Furthermore, the emissions from diesel-powered locomotives are gradually declining as older engine and exhaust treatment technology is replaced with newer, cleaner technology mandated by North American regulations.

Assessment

In the present Study, replacement of diesel power with electric power is being considered as a means to reduce locomotive emissions further still. The role of these emissions reductions in terms of regional air quality is the key consideration here.

The potential to affect regional air quality was assessed for each of the electrification options. The significance of GO Transit rail fleet and ARL emissions to regional smog events was estimated by computing an annual emissions inventory for the relevant pollutants, similar to that for GHG emissions mentioned in the preceding section. The most relevant pollutants with respect to regional smog are oxides of nitrogen (NO_X), sulphur dioxide (SO_2), fine particulate matter ($PM_{2.5}$) and hydrocarbons (considered to be similar to volatile organic compounds (VOC's)).

Annual inventories were calculated for the Reference Case and each of the six short-listed electrification options. This is set out in Table 9. The emission reduction associated with each electrification option was then compared against GTHA total emissions from all sources. The results of this analysis are presented in Table 10. Full details of the assessment can be found in Appendix 8-D – Air Quality & Health Impacts.

Table 9 GO Rail's Regional Emissions (Tonnes per annum)

Pollutant	Reference Case	Option 1	Option 2	Option 3	Option 11	Option 15	Option 18
Nitrogen Oxides (NO_x)	515	433	323	241	199	133	55
Carbon Monoxide (CO)	594	492	352	249	196	113	14
Sulphur Dioxide (SO_2)	2.9	2.5	1.9	1.5	1.3	1.0	0.58
Total Hydrocarbons (HC)	55	46	33	24	19	11	1.9
Particulate Matter (PM)	12	10	7.4	5.5	4.5	3.0	1.1
Carbon Dioxide Equivalent (CO_2e)	338,000	287,000	202,000	151,000	121,000	74,000	19,000

Table 10 CAC emissions by Option as a Proportion of Existing Regional Emissions

Pollutant	GTHA Total Emissions (tonnes/year)	Reference Case	Option 1	Option 2	Option 3	Option 11	Option 15	Option 18
		(% of GTHA Total)						
NO_x	239,000	0.22%	0.18%	0.13%	0.10%	0.083%	0.056%	0.023%
CO	1,290,000	0.046%	0.038%	0.027%	0.019%	0.015%	0.0088%	0.0011%
SO_2	218,000	0.0013%	0.0011%	0.00087 %	0.00070 %	0.00060%	0.00045%	0.00027%
HC	2,207,000	0.003%	0.002%	0.001%	0.001%	0.0008%	0.0005%	0.00009%
PM	1,855,000	0.00064%	0.00054 %	0.00040 %	0.00030 %	0.00024%	0.00016%	0.00006%
CO_2e	99,830,000	0.34%	0.29%	0.20%	0.151%	0.121%	0.075%	0.019%

Conclusions

From these results it is seen that all options, including the Reference Case have a network-wide emission inventory that is a fraction of 1% of the GTHA's overall regional emission inventory from all sources. Thus, none of the electrification options will significantly reduce regional emissions that contribute to large scale smog events and, as such, none will provide an appreciable benefit. Therefore all options are assessed as "**Slight Positive**" in the context of regional air quality and climate change. However, compared to GO's CAC emissions, there is a notable reduction in all cases.

5.4. Local Air Quality

Local Air Quality and Associated Health Issues

Introduction

For chemical compounds that have linkages to human health, governmental health and environment agencies have established threshold levels. If the concentration of an airborne pollutant can be maintained below its threshold, then either no health effect is observed or the effect is small enough that it presents an acceptably low risk to the population. This assessment considered thresholds (Ambient Air Quality Criteria or AAQC's) established by the Ontario Ministry of the Environment, but also considered thresholds established by other authorities where they were lower than Ontario's thresholds. Most notably, guidelines established by the World Health Organization for sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and respirable particulate matter ($PM_{2.5}$) were considered.

Assessment

The benefit of electrification for local air quality in the vicinity of the corridors depends on the current state of the air quality in those areas, and also on how large GO Transit's emissions are relative to emissions from other sources in the surrounding area. If the current pollutant levels are already well below desired thresholds and GO Transit's contribution is relatively small, then the benefit of electrification would be small. If, on the other hand, pollutant levels currently exceed one or more desired thresholds and GO transit's contribution is relatively large, then the benefit would be large.

The benefit of electrification also depends on where one is situated. Diesel locomotive emissions are most concentrated within or immediately adjacent to the rail corridor and are less concentrated farther away. Therefore, it is of interest to know how many people live within a certain distance of the corridors, where the benefit is greatest.

This Study examined data on current air quality conditions throughout the GTHA, made predictions of GO Transit and ARL air pollutant contributions in the Tier 4 diesel Reference Case, and considered the size of population located close enough to the rail corridors to experience a measurable change in air quality due to the electrification options.

Current air quality conditions were determined by looking at historical air pollutant monitoring data from stations throughout the GTHA. ARL and GO Transit contributions to local air pollutant levels were predicted using computer dispersion modelling techniques. Key inputs to the dispersion modelling were train traffic information and the estimated rates at which pollutants are emitted from the GO Transit and ARL diesel engines.

The contaminants of greatest concern (COC's) are those having the highest emission rate relative to their background concentrations, and relative to their health-based thresholds. Based on Tier 4 diesel exhaust emission rates, oxides of nitrogen (NO_X) has the highest emission rate relative to its background concentration and threshold, followed by acrolein and 1,3-butadiene. These specific pollutants were carried forward in the dispersion modelling to represent diesel exhaust pollutants in general. Respirable particulate matter ($PM_{2.5}$) was also carried forward, as it has been the subject of much attention in recent years (including diesel particulate matter, specifically), due to its widespread prevalence in the outside air and its linkage to health effects.

Figure 14 and Figure 15 show examples of concentration as a function of distance from the centreline of the corridor, for two the COC's of greatest concern, NO_2 and $PM_{2.5}$. The figures show GO Transit/ARL contribution for the Reference Case and each of the six short-listed electrification options relative to background concentration and the applicable health-based threshold.

Contributions to air pollutant concentrations from GO Transit/ARL engines would vary widely from day to day, depending on weather conditions. The figures show the predicted maximum concentration under worst-case weather conditions, based on a 1 year simulation. The example shown in the plot is for the section of rail corridor located between Union station and the Lakeshore West Junction. This section has the highest Reference Case volume of GO Transit/ARL trains (280 GO + 140 ARL trains/day) of any section of the network and, as a result, has the largest emission contribution from GO Transit/ARL locomotives relative to background concentrations and thresholds. The background concentrations shown in these plots were derived from multiple years of data for monitoring stations located in the downtown area of Toronto (at Bay and Wellesley, and on College Street).

The Figures show that the GO Transit/ARL contributions may be large relative to background levels in some cases, but are always small relative to the health-based thresholds. They have little effect on whether or not the concentrations of COC's in the surrounding area will remain within their thresholds. As such, the significance of the GO Transit/ARL contribution can be considered to be small.

In addition to the populations residing in the vicinity of the rail corridors, passengers using GO Transit on a daily basis may also experience a measurable change in air quality as a result of electrification. Published research has consistently shown that commuter rail passengers are exposed to significantly better air quality than urban motorists. Most of the studies reviewed, however, dealt with electrified rail systems. While one study of a rail system that uses DMU diesel technology had results that were similar to the other studies, it is likely that passenger exposures would be at least somewhat decreased for electric trains compared to diesel trains. Daily one-way passenger trip data for the Reference Case were used to account for this portion of the affected population.

Figure 13 Predicted 1-hr NO2 from GO Transit Operations: Area between Union Station and Lakeshore West Junction

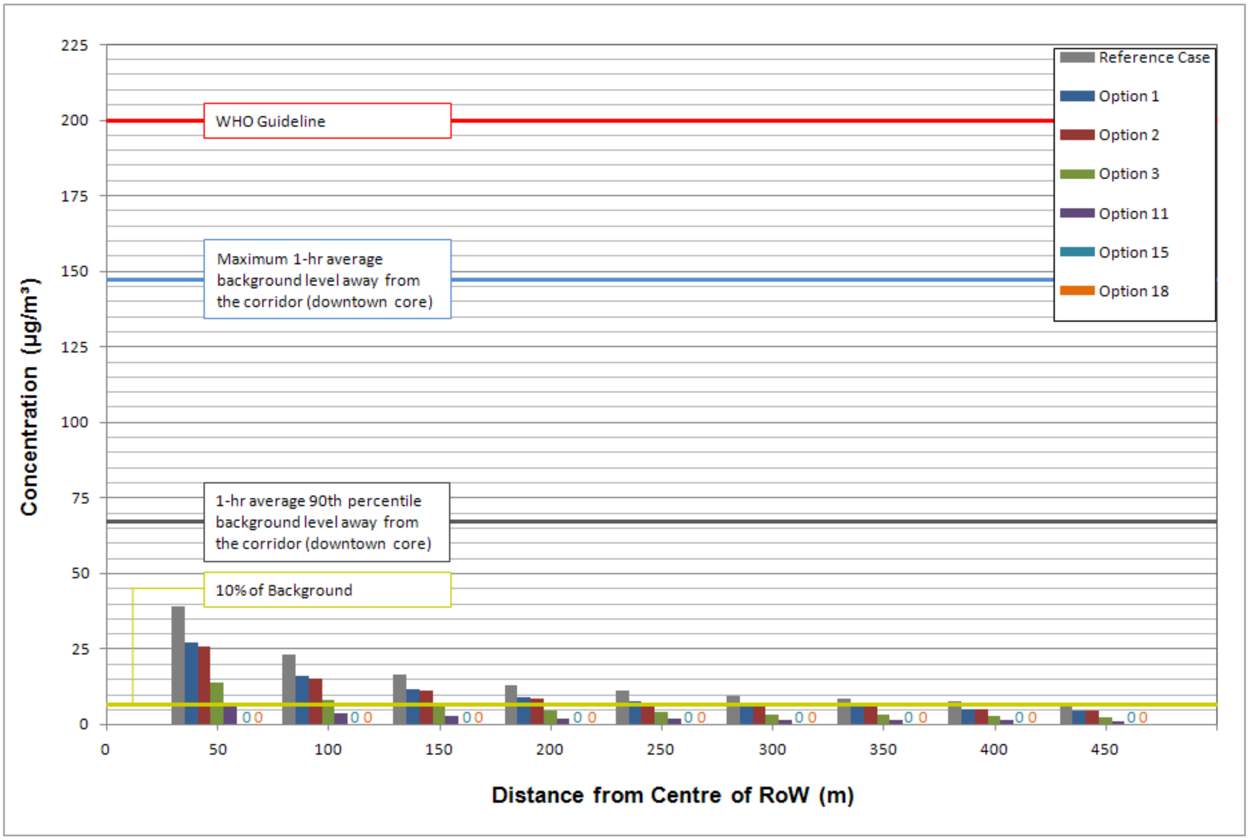
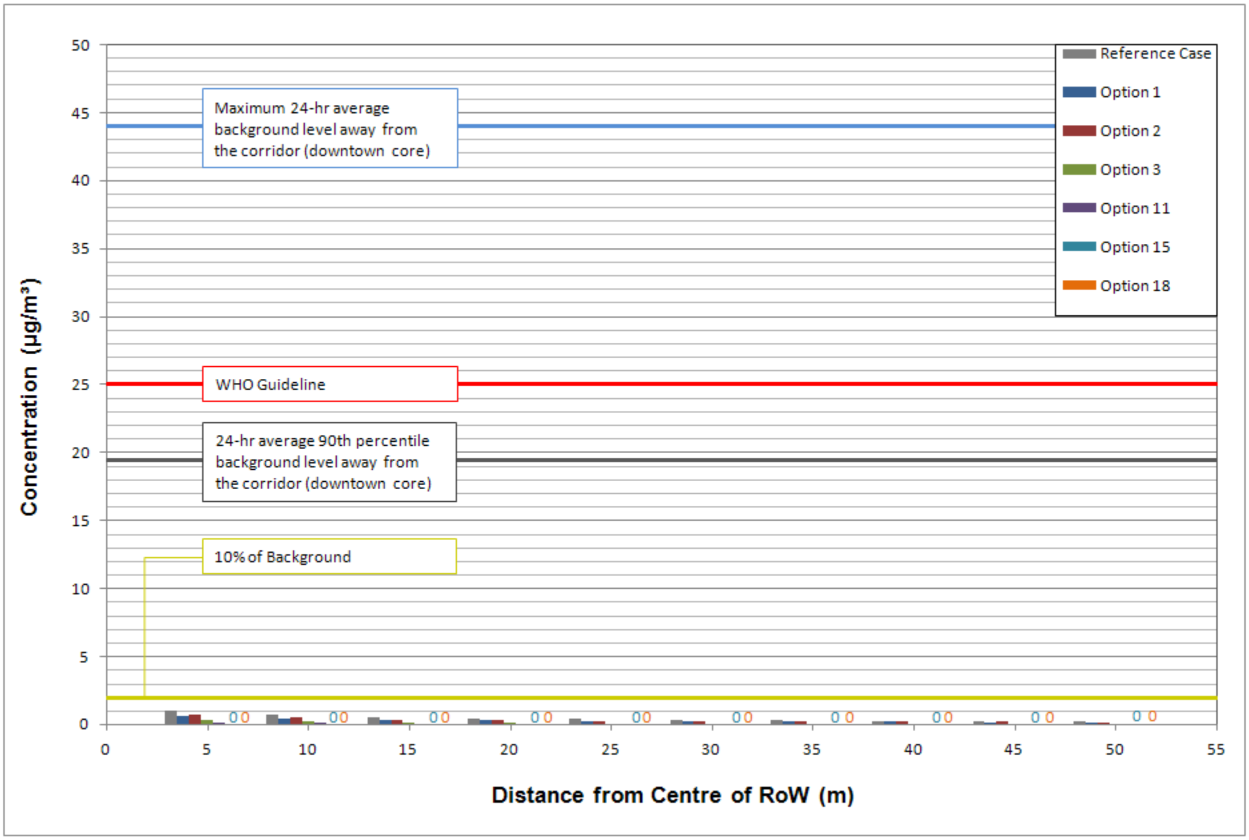


Figure 14 Predicted 24-hr PM2.5: Area from Union Station to Lakeshore West



Healthcare Valuation

Many toxicological and epidemiological studies have identified a relationship between outdoor levels of air pollutants and various indicators of a population's health. For nitrogen dioxide (NO_2), which is the COC of greatest potential concern in the present case, the WHO has identified a possible linkage to effects on respiratory symptoms in children, even at concentrations below 40 µg/m3 (World Health Organization, 2005). However, there remains considerable uncertainty as to whether the effects are attributable to NO_2 or to other combustion-related pollutants that are inevitably present with it.

In the case of respirable particulate matter ($PM_{2.5}$), a linkage to both cardiovascular and respiratory symptoms has been observed, and the WHO has noted that the "low end of the range of concentrations at which adverse effect has been demonstrated is not greatly above the background concentration…". Health Canada has developed a computer tool, the Air Quality Benefits Assessment Tool (AQBAT), as a means of estimating the human health benefits or risks associated with changes in the levels of these pollutants (Health Canada, 2008).

These estimates consider the economic and social consequences of adverse health effects, including medical costs, work loss, out-of-pocket expenses, pain and suffering. These estimates do not represent health care costs. Rather, they are indicative of the value that society places on health benefits. For the present Study, the response factors and economic valuation data within AQBAT have been used to perform a screening-level analysis of the benefit of eliminating diesel emissions associated with the Tier 4 Reference Case.

The total estimated benefit of electrification, from this approximate screening-level analysis, amounts to $17.9 million annually. While this may seem like a large number, it is a small proportion (0.19%) of the overall health and environmental cost of air pollution in Ontario. The MOE estimated that Ontario faces an annual cost of $9.6 billion in health and environmental damages due to O_3 and $PM_{2.5}$ (Ontario Ministry of the Environment, 2005).

Assuming that the CAC emitted at the source of electricity generation does not contribute to the impact on healthcare and that the overall benefit is proportionate to the percentage of the train kilometres operated with a diesel locomotive train, the estimated benefit to healthcare is presented in Table 11. Full details of the assessment can be found in Appendix 8-D – Air Quality & Health Impacts.

Table 11 Value of Healthcare Benefits

Option	Value of Health Benefits ($m per annum in 2010 prices)	% of MOE's Estimated Cost of Air Pollution
Option 1	3.7	0.04%
Option 2	7.1	0.07%
Option 3	10.8	0.11%
Option 11	12.7	0.13%
Option 15	15.1	0.16%
Option 18	17.9	0.19%

Conclusions

For the Tier 4 diesel Reference Case, the estimated population contained within the overall influence area was over 330,000, which includes not just residents who live near the corridors, but also the estimated passengers who use GO Transit daily, although this is only around 5% of the overall population in Greater Toronto. With each electrification option, the influence area is reduced and a portion of the population ceases to be within it, as indicated in Table 12. Although the number of people who benefit from improved air quality is sizable, the overall health benefits that they would experience is not expected to be significant. This is because with the Tier 4 diesel trains the concentration levels of COCs would already be well within World Health Organization standards.

Table 12 Summary of Local Air Quality and Health

Option	Local Air Quality and Health Commentary	Assessment
Option 1	Small positive health effects towards a population of 70,000 due to improved air quality.	Slight Positive
Option 2	Small positive health effects towards a population of 130,000 due to improved air quality.	Slight Positive
Option 3	Small positive health effects towards a population of 200,000 due to improved air quality.	Moderate Positive
Option 11	Small positive health effects towards a population of 250,000 due to improved air quality.	Moderate Positive
Option 15	Small positive health effects towards a population of 280,000 due to improved air quality.	Moderate Positive
Option 18	Small positive health effects towards a population of 330,000 due to improved air quality.	Moderate Positive

5.5. Other Health

Physical Activity

Because of faster transit times, the number of transit riders is expected to increase due to electrification. As passengers stop using their cars and use transit, they will walk or cycle more in their daily life routine (access to/from GO Rail stations) and improve their physical fitness as a result.

Table 13 sets out the number of additional transit riders forecast for each option. For example, if the entire network was electrified, around 2,400 people who previously use auto to get to work would use transit. These people would benefit from improved physical fitness and reduce their risk to heart disease. There will also be additional transit users outside the peak periods who would benefit from physical fitness.

Table 13 New Transit Riders in the 2031 AM Peak Period

Option	Number of Additional Transit Users in 2031 AM Peak Period
Option 1	440
Option 2	1,120
Option 3	1,570
Option 11	1,910
Option 15	2,120
Option 18	2,400

The additional transit users will benefit from improved physical fitness. However, this is a small change in the level of physical fitness for the overall population in Greater Toronto of over 330,000. The assessment for Physical Fitness was therefore deemed as a **Slight Positive** for all options.

Electromagnetic Fields (EMF)

An Electromagnetic Field (EMF) is a flow of ac power produces two types of fields, electric fields and magnetic fields. Both, electric and magnetic fields are present in electric rolling stock, in electrical substations, and along an electrified railroad.

Researchers have not found a consistent relationship between magnetic fields from power lines or appliances and health. Nevertheless, a number of national and international organizations have formulated guidelines establishing limits for occupational and residential exposure the EMF.

The EMF, due to the overhead catenary system, is expected to be well below the guidelines laid out by the Institute of Electrical and Electronics Engineers (IEEE) and therefore the health impact associated with EMF is deemed **Neutral/No Impact** for all options. Further information can be found in Appendix 7 – Conceptual Design of Electrification System.

Safety

Railway safety is a very important consideration for any option and stringent safety standards must be met. The safety of the local community, passengers and employees during construction, operations and maintenance cannot be compromised. This section covers the various safety considerations including any risk mitigation measures deemed necessary.

If designed or maintained incorrectly the implementation of any electrified corridor presents a potential additional risk of electrocution to maintainers, drivers, passengers and residents. However the maturity of electrification design concepts coupled with accepted world design practices serve to reduce risks to acceptable and manageable levels. The implementation of electrification will therefore only have a neutral impact on the corridor safety in comparison with the Tier 4 Diesel Locomotives used in the reference case.

All electrification work will be subject to Canadian codes and practices and appropriate regulations. In additional health and safety shall be in accordance with the Canadian Occupational Health and Safety Regulations (SOR/86-304) which mandates safe working practices, hazard identification and processes working in and around electrical systems.

Measures of safety mitigation require application to the electrified network to take into consideration:

- Normal operational running;
- Potential emergency situations such as fire and derailment;
- Degraded operational running due to system component failure; such as overhead line breakage or train failure; and
- Expected or predictable scenarios such as overloading, climatic effects or trespass.

The considerations were assessed in further detail and the results are summarized in Table 14.

Table 14 Assessment of Considerations to Safety

Consideration	Assessment
Trespass and access	Both the reference case and electrified corridors will suffer from unwanted access across the track. To mitigate this, the corridors will require protection against willful or inadvertent trespass in the form of fencing, signage, public information campaign, changes in law, to assist in public acceptance that previous methods of track accessibility will no longer be available. In public area, such as schools and sports-fields which are in close proximity to the corridors, additional protection or improved segregation may be required to increase safety. Infrastructure, both trackside and in the close proximity to the corridors, shall be designed to prevent climbing and reduce the risk of accessibility to high structures. Fencing may also be provided as part of the reference case to protect against trespass and access if the level of service was high enough to deem this measure appropriate, but this would be irrespective of electrification.
Level Crossings	The corridors already support a number of level crossings which require enforcement of a safe height allowance. Public or private crossings should have a standard clearance which compensates for any necessary vertical clearances on expected loads
Bridges	Bridge modifications should include deterrents to prevent access to live equipment underneath and maintain electrical clearance. Supporting walls and infrastructure in close proximity should not permit accessibility to live equipment.
Communications and warnings	The implementation of electrification increases the necessity to notify people of the potential hazards in the vicinity of the live electrification infrastructure and also provide additional means of communication to the system operator for reasons of isolation and safe working. In accordance with Canadian health and safety regulation, increased signage will be required in areas with higher population densities and higher incidence of public /rail interface such as crossings, vehicles and mobile maintenance equipment. In addition areas that may support ladders roof accessibility, cranes or other devices that assist working at height and reduce electrical clearance should be signed appropriately.
Clearances and Equipment positioning	The positioning of live electrical infrastructure shall take into consideration adequate safe distances to segregate the public from dangerous touch potentials. Any infrastructure necessary to provide power to the electrical system should ideally be located within the trackside boundaries or have suitable methods of preventing access to live equipment. In the maintenance facility, particular attention should be made to the clearances associated with working or maintaining equipment in the vicinity of the overhead wires. Any maintainer shall be protected from accidental electrocution through suitable platforms, walkways and guardrails.

Consideration	Assessment
Grounding and electrical bonding	Where there is risk of high touch potential, suitable detection shall be implemented and any exposed metallic objects in proximity to public areas shall be bonded to either the traction return or common infrastructure as required.
Electrical Fire	Due to the high voltages involved, both trackside equipment and cabling and the vehicles operating on the network should be assessed for potential fire loads in confined areas.
ARL line	The presence of the TPIA in proximity to the proposed ARL electrified line may require special attention due to encroachment of height clearance on approach to runways or EMC. Additional protective measures may be required to reduce risks due to aircraft emergency.

Following the consideration of various aspects on safety, appropriate measures have been proposed to mitigate any increase in risk to safety. As a result, the overall safety assessment of all options is deemed **Neutral/No Impact**.

5.6. Noise and Vibration

Introduction

Noise

Sounds of varying types are present throughout our environment and humans evaluate its influence in a subjective way. Unwanted sounds, or noise, tend to produce annoyance that leads to emotional responses and various social and societal issues.

All modes of transportation generate noise to some degree, particularly those associated with mechanical systems or moving parts, such as wheels or engines. For ground transportation, including automobiles and trains, the main sources of noise emanate from the wheels (i.e., interaction with the road or rail) and the engine.

Vibration

Vibrations travel through solid mediums as waves in a similar way to how sound travels through fluid mediums. Vibration is an oscillating motion with no net movement (i.e., moves positively or negatively around a reference point) that can be described in terms of displacement, velocity or acceleration.

Similar to noise, vibration can also create nuisance effects that lead to annoyance and concern by affected receptors. These can include perceptible movements of structures or effects such as window or picture rattling. Perceptible vibrations are typically generated by large moving masses or very loud sound levels (i.e., sound-induced vibration) at close distances to a receptor. As a result, vibration impacts are normally associated with large or heavy modes of transport, such as trains, airplanes, or large trucks rather than lighter modes of transport such as automobiles. Vibration levels can also differ within a mode of transport; for example trains tend to produce higher vibration emissions than lighter rail vehicles such as Light Rail Transit or Diesel/Electric Motive Units.

Assessment

Compared to the automobile, both diesel- and electric-powered passenger rail services offer an efficient way of transporting people, with a net reduction in noise emissions compared to single-occupancy vehicles. The service levels considered in the Reference Case and each of the electrification options reflect increased commuter ridership, meaning fewer cars on the road. Since the benefits of removing this road traffic would be nearly equal for the Reference Case and each of the electrification options, the key consideration is the reduction in noise emissions related to powering the locomotives for each option relative to the Reference Case.

Screening-level noise and vibration modeling was conducted for the Reference Case and electrification options over all the corridors. Modelling inputs, methodology, and assumptions are detailed in this White Paper. The results of the modeling were used to define “Zones of Influence” based on criteria contained in the MOEE / GO Transit Draft Protocol for Noise and Vibration Assessment (1994). The resulting Zones of Influence were used to identify potentially affected populations. An overall evaluation of each electrification option was then considered based on the affected populations and the predicted changes in the overall sound and vibration levels for each corridor.

Based on the assessment results, there is a slight positive benefit for noise and vibration for two of the options (i.e., total or near-total electrification of the entire rail network) due to the widespread electrification of multiple corridors. Other options remain neutral for noise and vibration, even though individual corridors within each option may see a slight positive benefit in switching from diesel to electric locomotives.

The area and affected population in the Zones of Influence for each option was determined using GIS for each corridor and segment. The average affected area and population across all the corridors were assessed for the overall option. These results are presented in Table 15. Since electrification produces less noise compared to diesel, the Zones of Influence decrease in size with the addition of more electrification in each option. As a result, every option sees a decrease in the overall Zone of Influence compared to the Reference Case. This result is expected as electric locomotives are quieter than diesel locomotives and EMUs quieter than DMUs.

Table 15 also shows the decrease in daytime and night-time sound level and the decrease in pass by vibration level at the Reference Case distance for each option, by corridor and track segment. Similarly to the Zones of Influence, the sound and vibration levels both decrease relative to the Reference Case with increasing electrification. Overall decreases in sound or vibration level for each option were assessed using a weighted average of the corridor values by affected 2021 population. Full details of the assessment can be found in Appendix 8-E –Noise & Vibration Impacts.

Conclusions

Table 16 and Table 17 summarize the findings of the assessment. Although many electrified corridors experience a reduction of 2-3 dB that would be considered a slight positive benefit individually, the overall option network-wide does not see the same result on average until the majority of the corridors are electrified (i.e., Options 15 and 18) due to the influence of the louder diesel trains on non-electrified corridors. This result is expected given the relatively small improvement in sound or vibration offered by switching technologies between diesel and electric locomotives. In practice, the actual sound character could be quite different between a diesel and electric locomotive due to different frequency content characteristics (e.g., less rumbling sound). Such a difference could make the change in technology more noticeable to some people. However, the overall sound levels are not expected to change appreciably in spite of any potential perceived difference in sound character; hence the overall improvement is a slight positive benefit at best.

Based on these results, a slight positive benefit for noise and vibration could be realised for total or near total electrification of the rail network (i.e., Options 15 and 18) due to the wide electrification of multiple corridors. Although other options do not see a notable net overall benefit, individual corridors within each option may also see a slight positive benefit in switching from diesel to electric locomotives.

Table 15 Measure of Noise and Vibration Impacts

Option	Measure of Noise and Vibration [1]	Overall Statistic [2]
Reference Case	Zone of Influence (m^2)	91,937,000
	Population within ZOI 2021	281,000
Option 1	Zone of Influence (m^2)	87,163,000
	% Change in ZOI	-5%
	Population within ZOI 2021	261,000
	% Change in ZOI Population	-7%
	Change in Sound Level, Day (dB)	-0.5
	Change in Sound Level, Night (dB)	-0.4
	Change in Vibration Level (VdB)	-0.3
Option 2	Zone of Influence (m^2)	81,636,000
	% Change in ZOI	-11%
	Population within ZOI 2021	250,000
	% Change in ZOI Population	-11%
	Change in Sound Level, Day (dB)	-1
	Change in Sound Level, Night (dB)	-1
	Change in Vibration Level (VdB)	-1
Option 3	Zone of Influence (m^2)	77,647,000
	% Change in ZOI	-16%
	Population within ZOI 2021	236,000
	% Change in ZOI Population	-16%
	Change in Sound Level, Day (dB)	-1
	Change in Sound Level, Night (dB)	-1
	Change in Vibration Level (VdB)	-1
Option 11	Zone of Influence (m^2)	75,017,000
	% Change in ZOI	-18%
	Population within ZOI 2021	227,000
	% Change in ZOI Population	-19%

	Change in Sound Level, Day (dB)	-1
	Change in Sound Level, Night (dB)	-1
	Change in Vibration Level (VdB)	-1
Option 15	Zone of Influence (m^2)	70,637,000
	% Change in ZOI	-23%
	Population within ZOI 2021	219,000
	% Change in ZOI Population	-23%
	Change in Sound Level, Day (dB)	-2
	Change in Sound Level, Night (dB)	-2
	Change in Vibration Level (VdB)	-2
Option 18	Zone of Influence (m^2)	65,137,000
	% Change in ZOI	-29%
	Population within ZOI 2021	195,000
	% Change in ZOI Population	-30%
	Change in Sound Level, Day (dB)	-2
	Change in Sound Level, Night (dB)	-2
	Change in Vibration Level (VdB)	-3

[1] Changes in sound or vibration level are assessed at the Reference Case setback distance for the Zone of Influence (ZOI); hence they are relative to the Reference Case.

[2] Overall option values associated with ZOI and population figures are based on arithmetic averages across the corridors. Overall option values associated with sound or vibration levels are based on a weighted average by affected population across the corridors.

Table 16 Summary Assessment of Noise

Option	Noise Commentary	Qualitative Assessment
Option 1	Neutral effect from imperceptible (< 2 dB) overall reductions affecting 261,165 people in 2021 (i.e., 7% less than the reference case)	Neutral
Option 2	Neutral effect from imperceptible (< 2 dB) overall reductions affecting 250,362 people in 2021 (i.e., 11% less than the reference case)	Neutral
Option 3	Neutral effect from imperceptible (< 2 dB) overall reductions affecting 236,423 people in 2021 (i.e., 16% less than the reference case)	Neutral
Option 11	Neutral effect from imperceptible (< 2 dB) overall reductions affecting 214,476 people in 2021 (i.e., 24% less than the reference case)	Neutral
Option 15	Slight benefit from just perceptible (i.e. 2-3 dB) overall reductions affecting 206,116 people in 2021 (i.e., 27% less than the reference case)	Slight Benefit
Option 18	Slight benefit from just perceptible (i.e. 2-3 dB) overall reductions affecting 182,489 people in 2021 (i.e., 35% less than the reference case)	Slight Benefit

Table 17 Summary Assessment of Vibration

Option	Vibration Commentary	Qualitative Assessment
Option 1	Neutral effect from negligible reductions in perceptible vibration (< 1 dB) affecting 261,165 people in 2021 (i.e., 7% less than the reference case)	Neutral
Option 2	Neutral effect from negligible reductions in perceptible vibration (< 1 dB) affecting 250,362 people in 2021 (i.e., 11% less than the reference case)	Neutral
Option 3	Neutral effect from negligible reductions in perceptible vibration (< 1 dB) affecting 236,423 people in 2021 (i.e., 16% less than the reference case)	Neutral
Option 11	Neutral effect from negligible reductions in perceptible vibration (< 1 dB) affecting 214,476 people in 2021 (i.e., 24% less than the reference case)	Neutral
Option 15	Slight benefit from minor reductions in perceptible vibration (i.e. 2-3 dB) affecting 206,116 people in 2021 (i.e., 27% less than the reference case)	Slight Benefit
Option 18	Slight benefit from minor reductions in perceptible vibration (i.e., 2-3 dB) affecting 182,489 people in 2021 (i.e., 35% less than the reference case)	Slight Benefit

5.7. Terrestrial Ecosystem

Introduction

The terrestrial ecosystem is defined as the vegetation, wildlife and natural communities that occupy terrestrial (land) environments. These species and their habitats are a critical part of the natural heritage systems across Ontario and provide benefits including carbon uptake, wildlife habitat and filtration of air and water. In determining the feasibility of electrification of all GO Transit railway lines, it is important to assess impacts to the terrestrial environment, to minimize reductions in the quality and function of existing natural areas.

Assessment

An evaluation of the potential impacts to the terrestrial environment was undertaken for each of the electrification alternatives. Each option was evaluated by determining the potential impacts to terrestrial ecosystems based on the number of rail lines that were planned to be electrified, and the potential need to replace infrastructure (e.g. bridge structures) and build new infrastructure (e.g. construct sub-stations). The results of the assessment are documented in Table 18.

Potential impacts to the terrestrial ecosystem associated with the electrification of railway lines include:

- Removal of vegetation outside the existing footprint of the GO Transit lines;
- Increased disturbance to vegetation and/or wildlife habitat outside the existing footprint of the GO Transit lines;
- Removal of, or disturbance to plant species at risk and/or wildlife species at risk habitat; and,
- Removal of any portions of, and/or disturbance to designated natural areas.

In determining the overall impact of each of the electrification options, a number of assumptions were made. It was assumed that the overall footprint of the railway lines and associated electrification infrastructure would not increase substantially and that impacts outside the existing footprint of the railway would be limited to replacement of infrastructure (e.g. bridges, tunnels and other overhead restrictions), and the construction of new infrastructure (e.g. additional sub-stations).

A number of potential bridge replacement locations were reviewed for environmental constraints. The majority of bridge replacements proposed are located within highly urbanized areas, and minor impacts to the terrestrial environment are expected. However, two bridges cross the Don River and will require further assessment to avoid and/or mitigate for any impacts to the terrestrial environment. For the purposes of this assessment, the existing tunnel in the City of Hamilton was assumed to need to be replaced in the future to accommodate increased ridership; therefore, the impacts associated with rebuilding the tunnel were not considered in the assessment of electrification options.

Since information on the final locations of new sub-stations is not available, it is anticipated that sites will be selected in areas with minimal natural heritage features, and that any potential impacts to the terrestrial ecosystem will be avoided or mitigated. A screening will be undertaken to determine environmental constraints at the sub-station sites.

The potential environmental impacts associated with the additional overhead wires were assessed. Given that the existing overhead wires associated with power distribution are located in urban, developed areas and the adaptation of local avian species to the presence of this infrastructure, the additional catenary overhead wires required to power GO trains will have no significant impact on avian species. Full details of the assessment can be found in Appendix 8-F – Natural Environment Impacts.

Table 18 Summary of Assessment – Terrestrial Ecosystem

Shortlist Option	Commentary	Summary Assessment
Option 1	Bridge replacements are required on the Lakeshore West and East GO Transit lines. This is anticipated to have a low impact on the terrestrial environment, as these bridges are located in previously disturbed, urban areas. There may be minor impacts to the terrestrial ecosystem associated with the construction of the sub-station(s) required on the electrified lines. The additional overhead wires required to supply electricity to the trains will have no significant impacts on avian wildlife.	Slight Negative
Option 2	Bridge replacements are required on the Lakeshore West and East GO Transit lines. This is anticipated to have a low impact on the terrestrial ecosystem, as these bridges are located in previously disturbed, urban areas. There may be minor impacts to the terrestrial ecosystem associated with the construction of the sub-station(s) required on the electrified lines. The additional overhead wires required to supply electricity to the trains will have no significant impacts on avian wildlife.	Slight Negative
Option 3	Bridge replacements are required on the Lakeshore West and East GO Transit lines. This is anticipated to have a low impact on the terrestrial ecosystem, as these bridges are located in previously disturbed, urban areas. There may be minor impacts to the terrestrial ecosystem associated with the construction of the sub-station(s) required on the electrified lines. The additional overhead wires required to supply electricity to the trains will have no significant impacts on avian wildlife.	Slight Negative
Option 11	Bridge replacements are required on the Lakeshore West and East GO Transit lines. This is anticipated to have a low impact on the terrestrial ecosystem, as these bridges are located in previously disturbed, urban areas. There may be minor impacts to the terrestrial ecosystem associated with the construction of the sub-station(s) required on the electrified lines. The additional overhead wires required to supply electricity to the trains will have no significant impacts on avian wildlife.	Slight Negative
Option 15	Bridge replacements are required on the Lakeshore West and East GO Transit lines. This is anticipated to have a low impact on the terrestrial ecosystem, as these bridges are located in previously disturbed, urban areas. There may be minor impacts to the terrestrial ecosystem associated with the construction of the sub-station(s) required on the electrified lines. The additional overhead wires required to supply electricity to the trains will have no significant impacts on avian wildlife.	Slight Negative

Shortlist Option	Commentary	Summary Assessment
Option 18	Bridge replacements are required on the Richmond Hill, Lakeshore West and East GO Transit lines. This is anticipated to have a low impact on the terrestrial ecosystem, as these bridges are located in previously disturbed, urban areas. There may be minor impacts to the terrestrial ecosystem associated with the construction of the sub-station(s) required on the electrified lines. The additional overhead wires required to supply electricity to the trains will have no significant impacts on avian wildlife.	Slight Negative

Conclusions

It is anticipated that overall, impacts to terrestrial ecosystems will be minor and that environmental mitigation measures can be implemented to minimize impacts to the terrestrial environment. Impacts to the terrestrial ecosystem may occur where bridge replacements are undertaken, and at the sites of new sub-stations.

The six bridge and two tunnel replacements that have been reviewed are all located along the Lakeshore West and Lakeshore East railway lines. As the electrification of the Georgetown line also requires the Lakeshore West section to be electrified to reach the maintenance facilities, all options have a slightly potential for impacts to the terrestrial ecosystem. In most cases, impacts would be limited to highly disturbed vegetation communities adjacent to the railway corridor. It is unlikely that significant vegetation communities or species at risk are present within these lands; however, the vegetation communities and species composition will need to be determined on a site-specific basis, after selection of the preferred option. Appropriate environmental mitigation measures and monitoring requirements will be determined to minimize impacts to the terrestrial ecosystem.

The locations of the sub-stations are unknown at this time. Therefore, a screening of the environmental constraints at these sites has not been conducted. It is assumed that the sites will be selected based on proximity to the railway lines in urbanized settings, and that significant natural heritage features will be avoided (e.g., Areas of Natural and Scientific Interest, Provincially Significant Wetlands). In some cases, the sites may contain vegetation communities that will be impacted by the footprint of the sub-station. An assessment of the impact of the sub-station on the terrestrial ecosystem should be undertaken during the site selection and design phase to minimize impacts to existing vegetation and wildlife. Appropriate environmental mitigation measures and monitoring requirements will be determined to minimize impacts to the terrestrial ecosystem.

5.8. Aquatic Ecosystem

Introduction

The aquatic ecosystem is defined as the system of waters, including wetlands, which provide habitat for communities of fish, other aquatic organisms, and natural vegetation. These species and their habitats are a critical part of the natural systems that contribute to the quality of water and aquatic species diversity in Ontario. In determining the feasibility of electrification of all GO Transit railway lines, it is important to assess impacts to the aquatic environment, to ensure that aquatic species and habitat are not impacted by the electrification options.

Assessment

An evaluation of the potential impacts to the aquatic environment was undertaken for each of the electrification alternatives. Each option was evaluated by determining the potential impacts to the aquatic ecosystem based on the number of rail lines that were planned to be electrified, and the potential need to replace infrastructure (e.g., bridge structures) and build new infrastructure (e.g., construct sub-stations). The results of the assessment are documented in Table 19.

Potential impacts to the aquatic ecosystem associated with the electrification of railway lines include:

- Construction works that will result in the creation of a harmful alteration, disruption and destruction (HADD) of fish habitat;
- Disturbance to aquatic species at risk and their habitats; and,
- Erosion and sedimentation of materials into watercourses that provide fish habitat during construction and operations.

In determining the overall impact of each of the electrification options, a number of assumptions were made. It was assumed that the overall footprint of the railway lines and associated electrification infrastructure would not increase substantially and that impacts outside the existing footprint of the railway would be limited to replacement of infrastructure (e.g. bridges, tunnels and other overhead restrictions), and the construction of new infrastructure (e.g. additional sub-stations).

A number of potential bridge replacement locations were reviewed for environmental constraints. The majority of bridge replacements proposed are located within highly urbanized areas, and two bridges cross the Don River that will require further assessment to avoid and/or mitigate for any impacts to the aquatic environment. For the purposes of this assessment, the existing tunnel in the City of Hamilton was assumed to need to be replaced in the future to accommodate increased ridership; therefore, the impacts associated with rebuilding the tunnel were not considered in the assessment of electrification options.

Since information on the final locations of new sub-stations is not available, it is anticipated that sites will be selected in areas without significant aquatic features, and that any potential impacts to the aquatic ecosystem will be avoided or mitigated. A screening will be undertaken to determine environmental constraints at the sub-station sites. Full details of the assessment can be found in Appendix 8-F – Natural Environment Impacts.

Table 19 Summary of Assessment – Aquatic Ecosystem

Shortlist Option	Commentary	Summary Assessment
Option 1	Bridge replacements are required on the Lakeshore West GO Transit line. This is anticipated to have no impact on the aquatic ecosystem, as these bridges do not cross watercourses. It is anticipated that the construction of the sub-stations will avoid impacts to the aquatic environment.	Neutral/No Impact
Option 2	Bridge replacements are required on the Lakeshore West and East GO Transit lines. This is anticipated to have no impact on the aquatic ecosystem, as these bridges do not cross watercourses. It is anticipated that the construction of the sub-stations will avoid impacts to the aquatic environment.	Neutral/No Impact
Option 3	Bridge replacements are required on the Lakeshore West and East GO Transit lines. This is anticipated to have no impact on the aquatic ecosystem, as these bridges do not cross watercourses. It is anticipated that the construction of the sub-stations will avoid impacts to the aquatic environment.	Neutral/No Impact
Option 11	Bridge replacements are required on the Lakeshore West and East GO Transit lines. This is anticipated to have no impact on the aquatic ecosystem, as these bridges do not cross watercourses. It is anticipated that the construction of the sub-stations will avoid impacts to the aquatic environment.	Neutral/No Impact
Option 15	Bridge replacements are required on the Lakeshore West and East GO Transit lines. This is anticipated to have no impact on the aquatic ecosystem, as these bridges do not cross watercourses. It is anticipated that the construction of the sub-stations will avoid impacts to the aquatic environment.	Neutral/No Impact
Option 18	Bridge replacements are required on the Lakeshore West, Lakeshore East and Richmond Hill GO Transit lines. This is anticipated to have a slight negative impact on the aquatic ecosystem as the Richmond Hill GO Transit line includes a bridge that crosses the Don River in Toronto. Impacts to this watercourse will need to be assessed in further detail at a later stage but it is anticipated that in-water work will not be required. It is anticipated that the construction of the sub-stations will avoid impacts to the aquatic environment.	Slight Negative

Conclusions

It is anticipated that overall, impacts to aquatic ecosystems can be avoided or mitigated. While bridge replacements are required over the Don River for electrification of the Lakeshore East line, it is anticipated that the construction methods and structural design will avoid in-water work during construction. Further assessment should be undertaken to ensure that impacts to the Don River are avoided, if the Lakeshore East railway line is electrified.

As the locations of the sub-stations are unknown at this time, a screening of the environmental constraints at these sites has not been conducted. It is assumed that the sites will be selected based on proximity to the railway lines in urbanized settings, and that significant watercourses will be avoided. An assessment of the impact of the sub-station on the aquatic ecosystem should be undertaken during the site selection and design phase to minimize impacts to existing natural features. Appropriate environmental mitigation measures and monitoring requirements will be determined to minimize impacts to the aquatic ecosystem.

5.9. Effects on Parks/open spaces

Introduction

Effects on Parks and Open Spaces concerns the temporary and permanent impact on parks and open spaces required to implement any option. A change or loss of parks and open spaces could potentially affect the local community through the way they utilize these amenities.

Assessment

The Study has concluded that all infrastructure required to electrify the GO Rail network can be done within the existing rail corridor with the exception of the substations and transformers which would require sizable areas of land at a number of locations.

There are a number of potential locations in open areas adjacent to the corridor which may be able to accommodate these substations, and it is unlikely that any of them would require significant removal of existing properties. At this stage of the Study, the site location has not been confirmed and any impacts on parks and open spaces not already allocated to development would be assessed during the design phase of any option being taken forward.

Conclusions

The construction of substations is likely to require some land take in the open areas adjacent to the rail corridor, however the impact on parks and open spaces, if any, will depend on the final choice of the substation locations, and any potential impact could be mitigated accordingly. In the absence of any further information, the assessment of Parks and Open Spaces is deemed to be **Neutral/No Impact** for all options.

6. TRANSPORTATION ASSESSMENT

6.1. Introduction

This section of the report covers the Transportation Category of the MCE, and the corresponding sub-categories include the following:

- Transportation efficiency of Users;
- Transportation efficiency of Non-Users;
- Reliability;
- Transit Network / System Access; and
- Comfort and Expandability.

6.2. Transportation Efficiency of Users

Introduction

Transportation Efficiency considers the ease of passenger movement from their desired origin to destination on a specific mode. The key components include access/egress times, waiting time, in-vehicle times and any interchange involved to complete the journey. A reduction in time spent in one or more of those components improves the transportation efficiency for that particular journey which usually also encourages more riders to make that journey.

If journey times are reduced, the time saving is considered a welfare benefit to society and is converted into a monetary value using a value of time assumption. Value of time takes into account people's willingness to pay extra for a faster journey so that they can use their time more productively. If more passengers make a particular journey which has a reduction in journey time, the greater the user benefits will be. Improvement in journey times of public transit is one way of meeting Metrolinx's RTP targets on time spent commuting and increasing the mode shares of transit.

Assessment

Electrification of the GO Rail network is expected to deliver user benefits in the form of journey time savings. Electric locomotive hauled trains can accelerate and decelerate out of and into the stations more rapidly than diesel locomotive hauled trains, thereby shortening the travel time. A detailed network run time simulation model was developed to estimate the journey time savings and this process is documented in Appendix 5 Operating Plan for the reference Case.

The ability for electric locomotives (as well as diesel locomotives) to operate faster will depend on a number of network characteristics such as stopping patterns, maximum track speeds (which are dictated by curvatures, intersections and gradients). Sections of the line with low maximum speeds mean that time spent in the acceleration phase is shorter, and electric locomotives are unable to take advantage of its superior acceleration for a longer period of time which would yield more significant journey time savings. Services with more frequent stops (i.e. local services, as opposed to express) would also benefit from greater time savings because a larger proportion of the overall time is spent in the acceleration/deceleration phase.

Table 20 summarizes typical end-to-end transit time savings for selected local services to Union station. It shows that a journey from Kitchener to Union would be around 9 minutes faster, while a journey from Hamilton or Oshawa would be 6 minutes faster. An electrified ARL is only expected to save 1 minute in the end-to-end journey time, mainly because the performance of the EMU and DMUs are much closer, given the route characteristics.

Figure 16 illustrates the time savings as a percentage. As a percentage reduction, the time savings range up to a 9% reduction in in-vehicle time for local service and the end to end journey time savings per passenger on the Georgetown corridor is expected to be the greatest. The journey time savings for express trains were not found to be significantly different to local trains.

These journey time benefits are expected to be realized regardless of Union station’s ability to accommodate the level of service in the Reference Case. These impacts benefit those currently using the diesel trains and will also encourage new users to travel on the electric trains.

Figure 16 illustrates the existing and future levels of demand on each corridor with the service as forecast by Metrolinx, assuming the Reference Case service levels in 2021 and 2031 demand years and the Big 5 funded transit schemes included. It shows that the Lakeshore East and Lakeshore West lines have the highest ridership.

The actual time savings will depend on the number of passengers boarding at each station and the transit time saving for that journey, and they have been documented in Appendix 8-A (Approach to Benefit Cost Analysis) of the Study Report.

Table 20 Journey Time Savings per Passenger to Union for a Selection of Journeys (Local Services)

Corridor	Service Section (End-to-End Stations)	Journey Times (minutes) Diesel Locomotive	Journey Times (minutes) Electric Locomotive	Journey Time Saving per Passenger (minutes)
Lakeshore West	Oakville - Union	39	36	3
	Hamilton-James - Union	73	67	6
	St. Catharines - Union	119	111	8
	Hamilton-TH&B - Union	76	69	7
Lakeshore East	Pickering North - Union	41	38	3
	Oshawa 2 - Union	68	62	6
	Bowmanville - Union	82	75	7
Georgetown	Pearson International Airport - Union	26	25	1
	Brampton - Union	45	41	4
	Georgetown - Union	59	54	6
	Kitchener - Union	112	103	9
Milton	Meadowvale - Union	42	39	3
	Milton - Union	57	53	4
Barrie	Bradford - Union	69	66	3
	Allandale - Union	103	98	5
Richmond Hill	Richmond Hill - Union	41	41	0
	Bloomington - Union	56	55	1
Stouffville	Mount Joy - Union	50	48	2
	Lincolnville - Union	67	65	2

Figure 15 Percentage End-to-End Journey Time Savings by Corridor

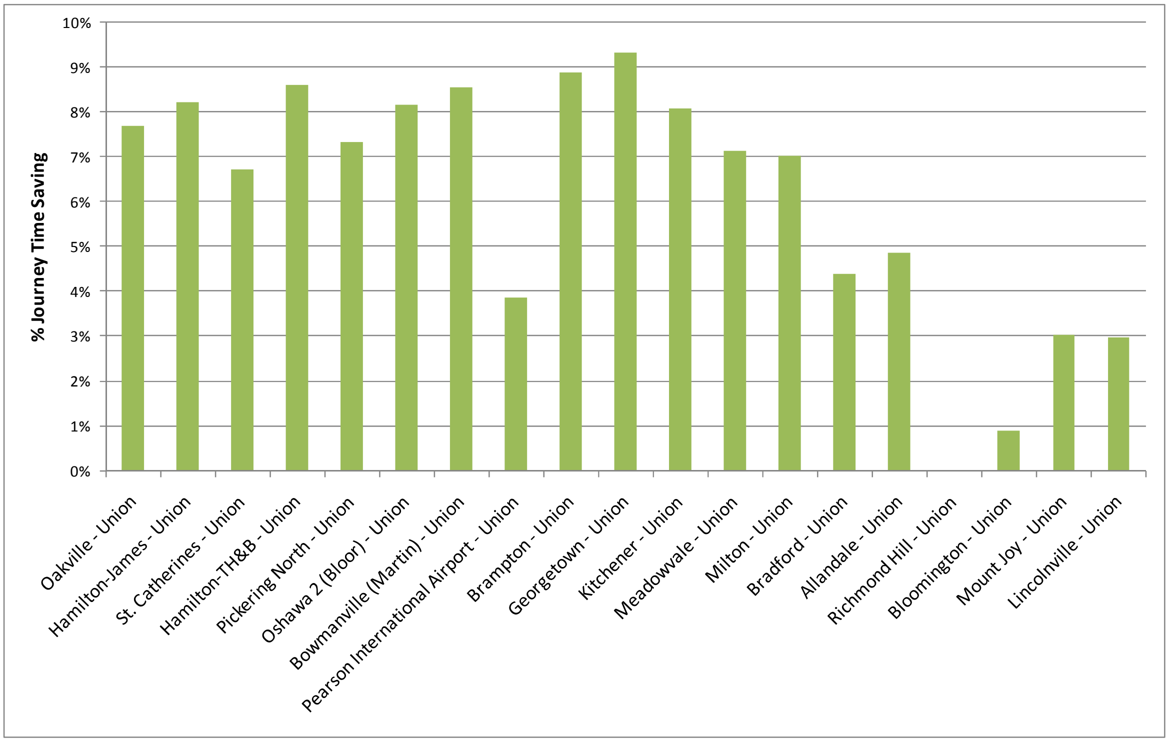


Figure 16 AM Peak Demand Counts and Forecasts by Corridor

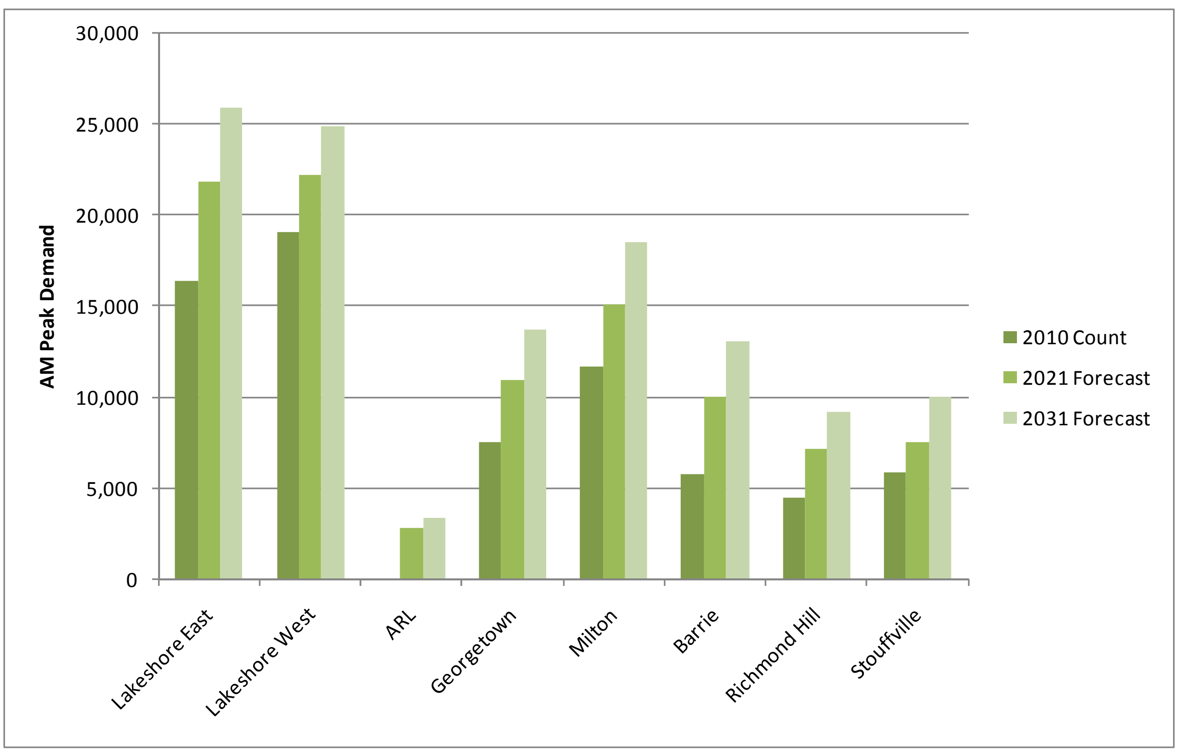


Figure 17 illustrates the total user time saving benefits over the 30-year evaluation period for each corridor, and as expected, the Lakeshore East and West lines deliver the highest transportation benefits due to the high ridership. In the case of the Georgetown line, the proportion of benefits accrued from the ARL is relatively modest. Milton has the next highest levels of benefit followed by Barrie, therefore reinforcing the hierarchy of corridors established in the High Level Evaluation.

Table 21 summarizes the user benefits by option and average journey time savings per passenger on an electric train. Electrifying the Lakeshore East and West corridors would deliver the highest levels of benefits, followed by Georgetown.

It should be noted that while a large proportion of trains on the Georgetown corridor operate to Pearson Airport, the majority of user benefits would accrue to passengers on the main Georgetown line services. There are very few transportation benefits as a result of electrifying the Richmond Hill line because under the particular track characteristics of that corridor (line speed restrictions dictated by characteristics of the route), electric trains are unable to deliver journey time benefits to passengers who travel between Union and Georgetown. As more corridors are electrified, the total user benefits increase. In terms of the average time savings per passenger, all options perform similarly, with an average saving between 2.4 and 2.8 minutes per passenger.

Figure 17 Total User Journey Time Savings by Corridor ($m 2010 Present Values)

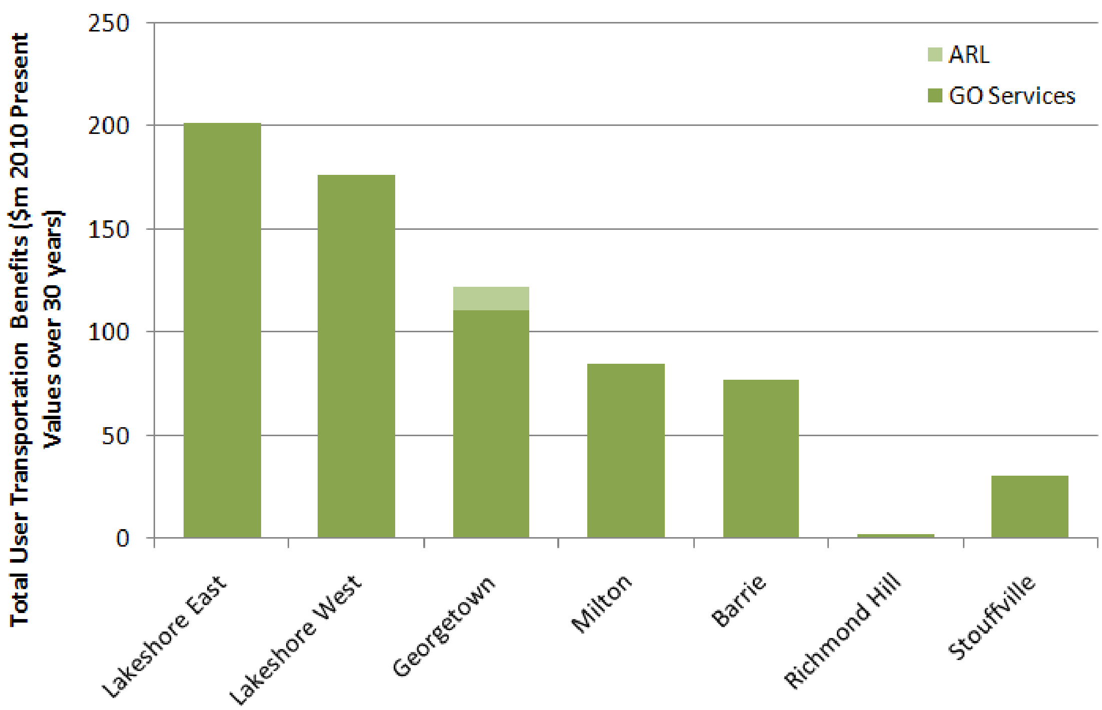


Table 21 User Transportation Efficiency – Journey Time Savings

Shortlist Option	Average Time Saving per Electric Train Passenger (minutes)	Passenger Journey Time Savings ($m 2010 Present Values)
Option 1	2.8	122
Option 2	2.6	334
Option 3	2.7	456
Option 11	2.5	541
Option 15	2.5	617
Option 18	2.4	692

Conclusions

Electric locomotives produce journey time savings because of higher performance characteristics meaning that they accelerate and decelerate more rapidly. For example, the time savings using an electric locomotive train from Hamilton to Union station would save passengers 6 minutes. The more corridors electrified, the greater the time saving benefits, with Option 18 delivering around $700m in user benefits over the evaluation period.

Almost half of the total journey time benefits can be delivered through the electrification of the Lakeshore East and West corridors (Option 2), as these two corridors have the highest ridership. The average journey time savings per passenger on electrified corridors are between 2 to 3 minutes in all options, modestly increasing the overall transportation efficiency of the GO Rail network and meeting the objective of The Big Move to '*lower average trip time for people*'.

6.3. Transportation Efficiency of Non-Users

Introduction

The benefits of improved public transit usually extend beyond those who will use the improved transit system. Of the increased number of passengers who are attracted to the improved public transit, some of those new passengers would have previously taken other transit services or made different journeys, but some of those new passengers would have travelled by private car. The result is that there are fewer highway journeys being made, resulting in highways being less congested, so other highway users who continue to drive will receive non-user benefits in the form of time saving (decongestion) benefits. The more congested the network is, the greater the decongestion benefits to non-users is for every vehicle removed.

In a congested environment, decongestion of the highway network could potentially encourage other auto users who previously did not drive to drive – this is known as induced traffic – but these are less than those taken off the highways and the new highway users will also receive welfare benefits in other forms because they are now able to make that journey.

In addition to decongestion, there are other benefits associated with reduced auto use, namely the reduction in marginal vehicle operating costs (fuel, parking, maintenance) and collision cost savings.

Assessment

Due to reduced journey times associated with electric locomotive trains, passengers are expected to transfer from auto to GO Rail, thereby reducing the traffic on the highway. For those who remain on the highway network, they will benefit from reduced congestion. As background congestion increases over time, the decongestion benefits per vehicle removed also increases.

Table 22 summarizes the number of vehicles removed in the AM Peak Period by 2031, the annual vehicle trips and kilometres removed from the highway and the corresponding decongestion benefits. Option 18 is forecast to deliver around $150m (2010 Present Values) in decongestion benefits.

Table 22 Non-User Transportation Efficiency – Decongestion Benefits

Shortlist Option	Number of Auto Trips Removed in 2031 AM Peak Period	Annual Auto Trips Removed in 2031	Auto Kilometres Removed per annum in 2031 (millions of auto km)	Highway Decongestion Benefits ($m 2010 Present Values)
Option 1	370	295,000	8	23
Option 2	930	737,000	27	75
Option 3	1,310	1,032,000	35	98
Option 11	1,590	1,251,000	42	117
Option 15	1,770	1,399,000	49	135
Option 18	2,000	1,580,000	55	153

The estimated vehicle operating and collision cost savings due to reduced auto journeys on the highway are set out in

. If the entire network was electrified, around $280m (2010 Present Values) in vehicle operating costs and $40m (2010 Present Values) in collision cost savings is forecasted. It should be noted that while those passengers who transfer from auto to transit save on vehicle operating costs, they also have to pay for their transit fare, so the net financial cost saving to those passengers would be less than their vehicle operating cost savings. Further details on the calculations can be found in Appendix 8-A – Approach to Cost Benefit Analysis.

Table 23 Non-User Transportation Efficiency – Vehicle Operating and Collision Cost Savings

Shortlist Option	Vehicle Operating Cost Savings ($m 2010 Present Values)	Vehicle Collision Cost Savings ($m 2010 Present Values)
Option 1	41	6
Option 2	136	20
Option 3	176	26
Option 11	209	30
Option 15	242	35
Option 18	275	40

Conclusions

The faster electric trains will encourage modal shift from car to GO Rail – Option 18 is expected to remove 160,000 auto trips per year by 2031. The reduced vehicle kilometres travelled would result in highway decongestion for non-users and a reduction in vehicle operating and collision costs.

6.4. Reliability

Introduction

The reliability subcategory concerns the ability of the transit service to run to the time as advertised in the schedule without delay or cancellations. There are many potential causes of unreliability, including incidents (on track, on board and on platforms), technical faults (on locomotives, coaches, track, signalling), weather conditions, staff availability or equipment availability. When a delayed service operates outside the scheduled time, it may also have an impact on other services operated by GO or others, thereby propagating the delay. Depending on the recovery time assumed in the schedule, there may be a lag in recovering from the delay on the service originally affected as well as other services.

Assessment

Different rolling stock technologies can perform with different levels of technical reliability. Evidence on other networks has conclusively demonstrated that electric locomotives are more reliable than diesel locomotives, while EMUs are more reliable than DMUs. This is due to the reduced number of mechanical parts in electric trains which is a particular area that causes failures. The electric trains would therefore reduce the number of failures caused by technical faults due to the locomotives. Table 24 sets out the number of rolling stock failures avoided per annum due to the electric trains and the corresponding benefit to passengers. Overall, these benefits are relatively small compared to the user and non-user benefits. These reliability benefits represent the steady-state reliability rates and take into account that the locomotives have bedded into the system and the operations and maintenance staff are experienced in operating the system.

Table 24   Reliability Reduction and Passenger Benefits

Shortlist Option	Rolling Stock Failures Avoided Per Annum	Reliability Benefits ($m 2010 Present Values)
Option 1	8	0.8
Option 2	17	3.1
Option 3	25	3.9
Option 11	30	5.0
Option 15	36	6.1
Option 18	44	7.2

When new rolling stock is planned to be introduced onto the railway network, they will go through extensive testing and acceptance before being put into passenger service. Nevertheless, it is common for teething issues to continue to emerge in the initial months of passenger service and this would result in some initial unreliability that would impact on passengers through delayed journeys. While these risks could be mitigated by initially deploying the new rolling stock in the off-peak, the initial reliability of services may be lower than the diesel trains. Further details on the calculations can be found in Appendix 8-A – Approach to Cost Benefit Analysis.

Conclusions

Electric locomotive trains are slightly more reliable than diesel locomotive trains, but overall the steady state reliability benefits to passengers are not significant given that failures due to locomotives are relatively infrequent. The initial reliability following deployment is likely to be lower than existing diesel locomotive trains as technical issues and the crew become more experienced with handling the new characteristics of the electric trains and the electrified system.

6.5. Transit Network / System Access

Introduction

The sub-category of transit network/system access concerns the ability for potential passengers to access the GO Rail system to/from their origin/destination. If access to the GO Rail system can be improved, it would encourage additional passengers to use transit and those who currently use it would also benefit. It would mean that some potential passengers who previously experienced barriers in accessing stations can now do so. Measures to improve the access to the transit network could include:

- Increased number of GO Rail stations, thereby increasing the catchment of transit;
- Improved park and ride facilities such as additional spaces, vehicle access and proximity to the station;
- Improved local transit feeder services to access GO Rail station; and

- Improved walking, cycling environments to and within the GO Rail station, including information, ambience and safety.

Assessment

The introduction of electric trains offers no material impact in relation to the transit network as no specific measures are being promoted to improve the system access compared to the Reference Case. The GO Rail corridors and station locations will not differ and therefore the relative accessibility for residents, employees, students, and shoppers will not vary between the Reference Case and the Options. The proposed catenary system is not expected to affect the access to stations, and we do not anticipate that electrification would compromise any potential plans to the system improving access in the future.

While air quality, and specifically the concentrations of particulate matters at station platforms, is expected to improve with the deployment of electric trains, we do not expect it to be a barrier to passengers in the Reference Case to an extent that electrification would generate additional passengers.

Because electric trains are faster, it may be possible to introduce additional stations without increasing journey times above current levels. New stations would improve the access to the transit system, but the merit of such initiatives would have to be traded off against other considerations, such as the delay to passengers on the service.

It should also be noted that the increased ridership as a result of improved journey times with electric trains could increase the demand at park and ride sites, feeder services and bicycle storage, or create additional localized congestion. However, given that the increase in ridership levels at around 2% to 6% across stations is fairly modest, we have assumed that as part of Reference Case (where the increase in services itself is expected to generate a larger increase in demand) station access would be considered, and where appropriate, additional capacity will be provided.

Conclusions

Electrification of the GO Rail network is not expected to have any notable impact on the passenger access to the GO Rail system in any of the options. The assessment for Transit Network/System Access was therefore deemed as **Neutral/No Impact** for all options.

6.6. Comfort and Expandability

Introduction

The Comfort and Expandability Sub-Category considers the journey ambience, passenger crowding and the ability to accommodate future increases in ridership. Improved comfort for passengers result in GO offering a better quality of service to its customers. Recently, GO has been lengthening their services from 10-car trains to 12-car trains in order to accommodate more passengers and relieve overcrowding in carriages. However, the future reference case provides a significant increase in service levels and therefore capacity; it is expected that almost all passengers will be able to get a seat in the future with 10-car trains, while platforms are expected to be less congested.

Assessment

The deployment of electric locomotives in place of diesel locomotives will not change the passenger carrying capacity of the service, as both technologies would haul the same 10 passenger coaches. The ambience within the coaches is also unlikely to change as a result of the choice of locomotive technology, although it is possible that the passenger coach adjacent to the locomotive may experience a slight reduction in noise and vibration associated with the noise and vibration characteristics of the locomotives.

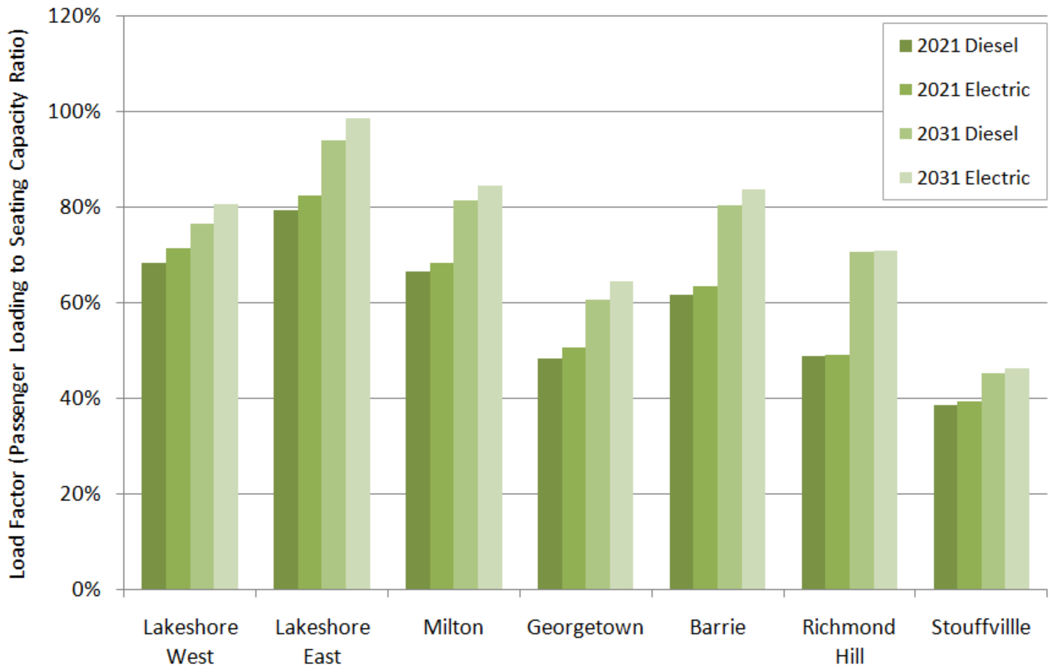
The electric trains do however provide more potential to lengthen trains to 12 passengers coaches without impacting the journey times. Due to the higher horsepower, electric locomotives are able to pull longer, heavier loads, thus the addition of extra carriages would become more attractive in the future relative to the diesel locomotive hauled trains. The introduction of longer electric trains will increase the area's ability to cope with an expanding network and possible demand. In the future, they would benefit potential users who would be crowded off the system or cannot get on a train the first time and have to wait for the next one to arrive at the station.

Electric trains are expected to attract a higher ridership due to faster journey times, so the load factor (peak passenger to capacity ratio) is expected to be marginally higher in comparison to the Reference Case, and as a result there will be a slight passenger discomfort associated with more riders. This effect in turn could be offset by the slightly shorter transit times experienced by passengers.

The load factors with diesel and electric trains are set out in Figure 19. It shows that even with an increased ridership due to faster journey times, the peak period demand is similar or less than the seating capacity provided, so on occasion passengers may be required to stand due to daily variances, but this is likely to only affect boarders near downtown towards Union and who would not need to stand for a significant duration.

It should also be noted Metrolinx's longer term aspirations in terms of providing for future capacity is to run a more frequent service. It is likely that other infrastructure enhancements, particularly around Union station, would be required to significantly increase the level of service. This can be achieved with either diesel or electric locomotive trains. However, due to the higher acceleration/deceleration capabilities of electric locomotives and therefore the ability to run trains closer together, it may be more likely, in marginal circumstances, to operate a slightly higher level of service with electric trains with the same infrastructure without compromising service reliability. This would require the optimization of the service schedule to fully exploit the capabilities of electric trains.

Figure 18 Passenger Crowding – Forecast Peak Load Factors by Forecast Year and Technology



Conclusions

Electrification of the GO Rail network is not expected to have any notable impact on the passenger comfort. Given that there are no significant passenger capacity issues anticipated under the Reference Case service levels even with the slightly higher passenger loadings. Electric locomotives are also more effective in hauling longer trains and potentially slightly more frequent trains; therefore have a better ability to expand in capacity in any of the options. The more corridors electrified, the more potential there is to expand capacity on those corridors. The assessment on Comfort and Expandability is therefore deemed as **Neutral/No Impact** for all options.

7. SOCIAL COMMUNITY ASSESSMENT

7.1. Introduction

This section of the report covers the Social and Community Category of the MCE, and the corresponding sub-categories include the following:

- Land Use Integration; and
- Social and Community.

7.2. Land Use Integration

Introduction

Land Use Integration considers the role of transit in connecting people to where they want to go, particularly to encourage Transit Oriented Developments (TOD) and connecting them with key activity centres such as employment areas, retail centres, leisure, education and health services. The provision of transit would reduce the dependency on the private car and promote a sustainable way of living.

The current GO Rail system connects the suburban communities to the heart of Toronto at Union station, where passengers can continue on the TTC subway to other downtown destinations. At present the service is predominantly for commuters with inbound services in the mornings and outbound services in the evenings only, but the Reference Case assumes two-way all day services to most destinations which integrate land use more effectively.

Assessment

In 2006, the Government of Ontario released its “Growth Plan for the Greater Golden Horseshoe”, which outlines the regional land use strategy for growth management. The document identifies 25 “Urban Growth Centers”, existing or emerging downtown areas with minimum density targets and other policies to encourage more intense land use and downtown revitalization. In other words, regional growth is being directed towards these Urban Growth Centers and conversely, away from other areas in the region. It should be noted that the plan does not expressly limit growth in other areas, but since demand for growth is finite, directing growth to certain areas leaves less growth to occur in others.

A number of Urban Growth Centers are also in communities with Metrolinx endpoints, or with proposed new stations/endpoints, including the Urban Growth Centers as follows:

Table 25 Urban Growth Centres Electrified

Shortlist Option	Urban Growth Centers
Option 1	Downtown Kitchener and Downtown Guelph
Option 2	Downtown Hamilton and Downtown Oshawa
Option 3	Downtowns of Kitchener, Guelph, Hamilton and Oshawa
Option 11	Downtowns of Kitchener, Guelph, Hamilton, Oshawa and Milton
Option 15	Downtowns of Kitchener, Guelph, Hamilton, Oshawa, Milton and Barrie
Option 18	Downtowns of Kitchener, Guelph, Hamilton, Oshawa, Milton, Barrie, Richmond Hill/Langstaff Gateway and St. Catharines

The electrification of existing transit corridors and train stations will have little impact on the network's integration with activity centres and places that people want to go – either to work, shop, go to school, eat, recreate or socialize as there are no new routes or stations being proposed as part of electrification over and above those assumed in the Reference Case.

However, slightly faster journey times will mean that existing connections are marginally improved. For example, with an electric locomotive train, a journey from Hamilton to Union would reduce from 73 minutes to 67 minutes, a 6 minute time saving. This effectively brings Hamilton and the City of Toronto closer together, so people would have an increased choice of locations regarding living, employment, shopping and use of services. Other urban centres on electrified corridors would also benefit in this way. However, this is a marginal improvement rather than a step change (as the Reference Case would provide) in terms of integrating land use and development and these improvements are unlikely to be sufficient to stimulate TOD in any significant quantity.

Given that the air quality is expected to improve with an electrified network, Metrolinx could find that TOD associated with air rights above stations becoming more attractive. At this stage of the Study it would be premature to identify these potential sites and assess the likelihood of development taking place due to electrification.

Conclusions

Electrification of the GO Rail network improves journey times between key journey origins and destinations, which gives a slight improvement in integrating the urban environment. The more corridors electrified the more locations benefit from this improved connectivity, but the overall impact is not expected to be significant given the magnitude of time savings. The assessment for Land Use Integration was therefore deemed as **Slight Positive** for all options.

7.3. Social And Community

Introduction

Social Community Impact Assessment (SCIA) is a systematic assessment used to identify and evaluate the potential effects and impacts on the day-to-day lives of people (individuals/households); institutions, community and recreation features; and communities. The impacts may be positive or negative. The assessment can provide information used to assist in decision-making with respect to comparison/selection of options or alternatives or the detailed assessment of a preferred option. SCIA complements and integrates the studies of other specialized disciplines with information on the social environment likely to be affected by a proposed development.

The construction and operation of alternative rail transportation technologies can result in social community impacts – some positive, others negative. Changes in noise and vibration levels, air quality and visual effects can affect the use and enjoyment of property, resulting in a change in satisfaction by residents, alteration in community character, or the operation of institutional, community and recreation features in the study area. Displacement of residents and institutional, community and recreation features may also occur if land is required for an option, with implications for residents, users and operators or community facilities and networks in the community. However, using the data on predicted effects, examined with case study experience and professional judgement, it is possible to provide an indication of what will most likely happen.

Assessment

The criteria identified for use for the assessment of social community impacts for the six options are listed below:

- Displacement of households/residents
- Displacement of institutional, community and recreation features
- Change in the use and enjoyment of property by residents
- Change in the use and enjoyment of institutional, community and recreation features
- Change in community character

Given that there will be no displacement of residents or institutional, community and recreation features related to the electrification options, the first two criteria were not applicable. In order to assess the remaining three social community impacts, a number of impacts are considered, including:

- Noise and vibration;
- Dust during construction and operations;
- Odour during operations;
- Visual impacts; and
- Construction effects.

Noise and Vibration

Generally, electrification of a specific corridor reduces the sound levels by the overall difference between the sound emissions of the diesel and electric technologies (i.e., 3 dB between diesel and electric locomotives, and 3 dB between DMUs and EMUs on the ARL) with some reduction due to the influence of wheel noise from the coaches (i.e., most corridors will not see the full 3 dB reduction, but something closer to 2 dB). As most options only see electrification of a single corridor, the overall sound level reduction generally becomes smaller again due to those corridors that see no change from the diesel locomotives (i.e., on the order of 1-2 dB). Similar results can be seen for vibration. No changes greater than 3 dB are seen for any corridor, segment, or option. Importantly, changes of this magnitude are small and generally remain imperceptible to most people.

Dust

Electrification under any of the short-listed options would reduce PM emissions relative to the Reference Case. However, since these emissions are not likely to result in significant visibility or soiling impacts under even the Reference Case, the benefits of further reducing PM emissions, from the standpoint of soiling and visibility, would be minimal.

Odour

The occurrence of detectable odours from the diesel locomotives in the Reference Case is expected to be limited to within short distances from the centre of the right of way and is not expected to be a significant nuisance effect for populations near the corridors. Therefore, the potential benefit of electrification options in this respect is small.

Visual Impacts

Visual changes related to electrification may be experienced as a result of overhead contact systems (OCS, as shown in Figure 19), substations and autotransformer stations built to accommodate electrification of the GO rail system. Residents and users of institutional, community and recreation features will experience a degree of visual impact related to the catenary infrastructure associated with electrification; the extent will vary based on site-specific circumstances (e.g., distance from the tracks, nature and extent of the views, topography, vegetation, nearby land uses, and the subjective experience of individuals).

The main driver on community character from electrification will be visual effects resulting from the structural/electrical support systems that will be required. This will likely be most visible and pronounced in suburban and rural areas.

Figure 19 Typical Overhead Contact Systems

Construction

Electrification requires the construction of new infrastructure that would otherwise not be required. The construction activity will have the potential to produce significant dust emissions during, especially activities that involve traffic of heavy equipment on unpaved areas, excavation and handling of soil, and sand blasting. The potential for dust emissions can be mitigated to a certain extent through implementation of effective dust management plans during construction, based on industry best practices. Overall, the potential for extra dust emissions during construction phase represents a slight negative effect for electrification options.

Full details on the assessment can be found in Appendix 8-G – Social/Community Impacts.

Conclusions

The assessment of social and community impacts of each option is summarized in Table 26. For the social community, the slight positive impacts achieved through reduced noise and vibration effects will be offset somewhat by the visual and construction effects. All options will have residents, and community, institutional and recreation features within the zones of influence experiencing some negative social impacts due to visual and construction effects.

Table 26 Social and Community Impact Assessment Summary

Option	Commentary	Assessment
Option 1	In Option 1 there is no noticeable change in the levels of noise and vibration due to electrification. The visual changes due to overhead catenary systems are expected to be experienced by 19% of the population and 17% of community, institutional and recreation features above Reference Case conditions. Development of 5 sub-stations and autotransformer stations will contribute slightly to the visual impact. Construction impacts for reconstruction of three bridges contribute a slight negative impact for Option 1. The overall social community impact rating is moderate negative.	Moderate Negative
Option 2	In Option 2 there is no noticeable change in the levels of noise and vibration due to electrification. The visual changes due to overhead catenary systems are expected to be experienced by 39% of the population and 36% of community, institutional and recreation features above Reference Case conditions. Development of 5 sub-stations and autotransformer stations will contribute slightly to the visual impact. Construction impacts for reconstruction of four bridges contribute a slight negative impact. The overall social community impact rating is moderate negative.	Moderate Negative
Option 3	In Option 3 there is no noticeable change in the levels of noise and vibration due to electrification. The visual changes due to overhead catenary systems are expected to be experienced by 53% of the population and 50% of community, institutional and recreation features above Reference Case conditions. Development of 10 sub-stations and autotransformer stations will contribute slightly to the visual impact. Construction impacts for reconstruction of four bridges contribute a slight negative impact. The overall social community impact rating is moderate negative.	Moderate Negative
Option 11	In Option 11 there is no noticeable change in the levels of noise and vibration due to electrification. The visual changes due to overhead catenary systems are expected to be experienced by 57% of the population and 51% of community, institutional and recreation features above Reference Case conditions. Development of 13 sub-stations and autotransformer stations will contribute slightly to the visual impact. Construction impacts for reconstruction of four bridges contribute a slight negative impact. The overall social community impact rating is moderate negative.	Moderate Negative
Option 15	In Option 15 there is a slight benefit in the change in levels of noise and vibration due to electrification. The visual changes due to overhead catenary systems are expected to be experienced by 63% of the population and 60% of community, institutional and recreation features above Reference Case conditions. Development of 17 sub-stations and autotransformer stations will contribute to the visual impact. Construction impacts for reconstruction of four bridges contribute a slight negative impact. The overall social community impact rating is slight negative.	Slight Negative
Option 18	In Option 18 there is a slight benefit in the change in levels of noise and vibration due to electrification. The visual changes due to overhead catenary systems are expected to be experienced by 70% of the population and 69% of community, institutional and recreation features above Reference Case conditions. Development of 25 sub-stations and autotransformer stations will contribute to the visual impact. Construction impacts for reconstruction of nine bridges and a major tunnel contribute a moderate negative impact. The overall social community impact rating is moderate negative.	Moderate Negative

8. ECONOMIC ASSESSMENT

8.1. Introduction

This section of the report covers the Economic Category of the MCE, and the corresponding sub-categories include the following:

- Cost Effectiveness;
- Land Use, Development and Land Value;
- Property Effects; and
- Wider Economic Impacts.

8.2. Cost Effectiveness

Introduction

Cost Effectiveness measures have been developed to compare the relative costs and outcomes (effects) of the options, illustrating value for money of the investment in each electrification option in delivering key objectives defined in the Study. These objectives include reductions in Greenhouse Gases (GHG) and Criteria Air Contaminants (CAC).

The three primary purposes of the Cost Effectiveness measure are:

- To compare options within the Electrification Study to identify the most cost effective option in delivering the transportation, environmental and economic benefits desired;
- To compare and prioritize electrification options with alternative initiatives/projects which may or may not involve electrification to identify the most cost effective initiative in delivering the benefits desired; and
- To assess the value for money and provide a justification of investment.

Traditionally, the value for money of a project is typically judged through the **Transportation Benefit Cost Ratio (BCR)**. The BCR is an indicator of transportation efficiency comprising of monetized impacts, calculated by the sum of the life cycle transportation benefits (time savings, auto cost and accident savings) divided by the life cycle costs (capital, operating and maintenance). The evaluation period is assumed to be 30 years from opening, and employs a discount rate of 5% per annum. A BCR greater than 1 indicates that the benefits of the investment generates are more than the costs put into the investment, and is usually the indicator of value for money.

As transit also offers to contribute to other wider objectives other than transportation efficiency, other cost effectiveness measures (where benefits are not monetized and therefore not captured in the BCR) included in the assessment are:

- **Tonnes of GHG reduced per $10m capital cost** – a measure of how cost effective each option is in delivering GHG reductions and contribute towards Metrolinx's emission reduction targets and in addressing climate change;
- **Capital cost per new daily rider in 2031** – a measure of how cost effective each option is in promoting modal shift to transit and contribute towards Metrolinx's transit mode share targets; and

- **Long term economic benefits per $10m capital cost** – a measure of how cost effective each option is in delivering long term economic benefits associated with GDP and wage increases, as transportation has a role in stimulating the economy of Ontario.

As there is limited health benefits associated with CAC reductions and the relativity of CAC performance of each option is similar to GHG, a cost effectiveness measure for CAC has not been employed in the evaluation.

Assessment

The 30 year life-cycle transportation benefits and costs of each option were assessed and the results are set out in Table 27. Option 2 (Lakeshore) has the highest BCR at 1.1:1, followed by Options 3 (Lakeshore, Georgetown) and 11 (Lakeshore, Georgetown, Milton), both at 0.9:1. This means that for every dollar invested, these options would generate around a dollar of transportation benefits over the evaluation period. Option 1 and Option 18 both have low BCRs of 0.5:1 or lower.

Option 2 is the only option with a positive Net Present Value (NPV, the difference between benefits and costs). The NPV can be viewed as the cost which non-monetized benefits would have to be valued at for that option to be justified. For example, Option 3 has an NPV of -$44m in 2010 present values; for the total benefits to outweigh the total costs, the non-monetized benefits would have to be perceived as $44m in 2010 present values or more over the life-cycle for Option 3 to be fully justified in cost benefit terms. Option 18 has a significantly lower NPV than any other option. It means that the electrification of the entire network is least likely to be justified when monetized transportation benefits and other non-monetized benefits are all taken into consideration.

Of the total costs, the infrastructure capital cost is the largest component. The sum of the infrastructure capital cost of Options 1 and 2 is $1,285m in 2010 present values, notably higher than the cost of Option 3 at $1,089m in 2010 present values. This is because the costs within each of Option 1 and Option 2 include significant overlap in infrastructure works (e.g. along Union station Rail Corridor), therefore Option 3 (and subsequent options) take advantage of the cost synergies.

It should also be noted that there are significant O&M cost savings associated with electric trains, and together with the incremental revenues to the transit network as more passengers take advantage of faster journey times, the life-cycle cost savings/revenues offset a significant proportion of the initial capital expenditure (39% for Option 2 and 24% for Option 18).

Of the total benefits, user and non-user journey time savings due to faster electric trains is the largest component, accounting for approximately 80% of the total, with the remaining benefits predominantly from auto operating and collision cost savings due to reduced auto use, and a small amount of reliability benefits as electric trains are less prone to technical failures.

In terms of other cost effectiveness indicators on promoting modal shift, GHG and delivering wider economic benefits, the results are set out in Table 28. Option 2 performs best against all three measures. Option 3 performs next best on GHG and wider economic performance per dollar invested, while Option 11 is marginally better than Option 2 on promoting modal shift. It shows that overall the performance of the top 3 options in BCR terms are also most cost effective in delivering other benefits.

Conclusions

The life-cycle cost benefit analysis undertaken has suggested that Option 2 provides the highest value for money in terms of delivering transportation benefits with a benefit cost ratio (BCR) of 1.1:1 giving a positive overall net present value of $50m in 2010 present values over the life cycle. This option is also the most cost effective in delivering GHG reductions, delivering modal shift and promoting wider economic benefits (GDP and wages). Options 3 and Option 11 perform similarly in terms of cost effectiveness but offer a marginal transportation case with a BCR of 0.9:1. Options 1, 15 and 18 offer notably lower value for money in delivering transportation benefits.

Table 27 Detailed 30 Year Life-Cycle Transportation Appraisal of Electric Locomotive Trains (All Figures in $m and Discounted at 5% p.a. to 2010 Present Values)

Electric Locomotives: Transportation Appraisal Impacts (All figures in $m and Discounted at 5% p.a. to 2010 Present Values)	**Option 1**	**Option 2**	**Option 3**	**Option 11**	**Option 15**	**Option 18**
	Georgetown + ARL	**Lakeshore:** Hamilton James to Bowmanville	**Option 1+2**	**Option 3 plus Milton**	**Option 11 plus Barrie**	**Full Network**
Infrastructure Capital Costs	521	764	1,089	1,251	1,584	2,369
Rolling Stock Capital Costs	62	91	139	212	310	543
Operations & Maintenance Costs	-88	-337	-424	-506	-595	-697
Incremental Revenues	-23	-50	-73	-86	-96	-109
TOTAL PRESENT VALUE COSTS	**473**	**467**	**731**	**871**	**1,204**	**2,106**
Journey Time Saving Benefits	145	409	554	657	752	845
Reliability Benefits	1	3	4	5	6	7
Auto Cost Savings	24	105	129	154	181	206
TOTAL PRESENT VALUE BENEFITS	**169**	**518**	**687**	**816**	**939**	**1,058**
Net Present Value (NPV)	**-303**	**50**	**-44**	**-55**	**-265**	**-1,048**
BENEFIT COST RATIO (BCR)	**0.36**	**1.11**	**0.94**	**0.94**	**0.78**	**0.50**

*Capital Costs were revised subsequent to the completion of the cost benefit analysis; however, this did not affect the results of the cost benefit analysis – see section 12.4 for further information.

Table 28 Cost Effectiveness in GHG Reductions and Attracting New Transit Riders

Cost Effectiveness Indicator	**Option 1**	**Option 2**	**Option 3**	**Option 11**	**Option 15**	**Option 18**
Cost per New Rider ($m capex/ new daily passenger in 2031)	0.44	0.26	0.27	0.26	0.30	0.41
Tonnes of GHG saved per annum per $10m capital cost	620	1,120	1,080	1,050	980	770
Present Value Wider Economic Benefits (GDP and wages) per $10m capital cost	3.0	6.6	6.0	5.8	5.3	3.8

8.3. Land Use, Development and Land Value

Introduction

Transit stations commonly shape and influence nearby land use patterns. Adjacent development responds to characteristics about the station itself, such as whether it is underground, at grade, or on raised platform; whether it is enclosed or exposed, how it is lit, the hours it is open and peak hour levels of traffic, and how ingress/egress areas are situated relative to surrounding uses. Land use by stations is also shaped by municipal land use policies as well as regional land use plans and strategies.

Land near existing stations close to the economic centre of a region tends to be built-out. Though opportunities for redevelopment may exist, the cost of redevelopment is usually high, and may include the opportunity cost of demolishing something that is viable, though less than highest-and-best-use. In contrast, stations farther out towards suburban and suburbanizing areas tend to have less densely developed station areas, with land available for development and fewer barriers to re-development.

Assessment

Land Use

The most significant land use changes are found near station areas with land available for development and/or where redevelopment is economically feasible and significant numbers of new riders are attracted for passenger boardings and alightings. Development patterns can be expected to respond to electrification of existing service to the extent that the technology shift renders service to and operation of existing stations less intrusive (faster transit times, quieter, improved air quality). However, the most significant land use changes occur when new transit stations are established, and the changes are brought about by the introduction of transit service itself. The nature and magnitude of land use shifts will depend primarily on:

- The success of the new service in attracting ridership;
- The degree of change in noise, congestion (vehicle/foot traffic), and emissions (real or perceived);
- Regional job and population growth and related factors driving market demand for housing, retail and employment space;
- The availability and cost of vacant land, or underutilized land available for redevelopment in 400 to 800 metre radii from stations; and
- Regional and municipal land use plans and zoning regulations that allow, support and direct new development patterns.

As with station area development, impacts would be greater in suburban areas, as more urbanized areas tend to have land uses compatible with noise and emissions (office, retail, high density residential, institutional) and less likely to benefit from reduced noise and emissions from Metrolinx. It is important to note that development near rail stations are usually a mix between new economic development for a region or municipality, and existing jobs that are being relocated to take advantage of transit oriented development opportunities that have been created.

In 2006, the Government of Ontario released its “Growth Plan for the Greater Golden Horseshoe”, which outlines the regional land use strategy for growth management. The document identifies 25 “Urban Growth Centers”, existing or emerging downtown areas with minimum density targets and other policies to encourage more intense land use and downtown revitalization. In other words, regional growth is being directed towards these Urban Growth Centers and conversely, away from other areas in the region. It should be noted that the plan does not expressly limit growth in other areas, but since demand for growth is finite, directing growth to certain area leaves less growth to occur in others.

A number of Urban Growth Centers are also in communities with Metrolinx endpoints, or with proposed new stations/endpoints, including the Urban Growth Centers as follows:

Table 29 Urban Growth Centres Electrified

Shortlist Option	Urban Growth Centers
Option 1	Downtown Kitchener and Downtown Guelph
Option 2	Downtown Hamilton and Downtown Oshawa
Option 3	Downtowns of Kitchener, Guelph, Hamilton and Oshawa
Option 11	Downtowns of Kitchener, Guelph, Hamilton, Oshawa and Milton
Option 15	Downtowns of Kitchener, Guelph, Hamilton, Oshawa, Milton and Barrie
Option 18	Downtowns of Kitchener, Guelph, Hamilton, Oshawa, Milton, Barrie, Richmond Hill/Langstaff Gateway and St. Catharines

To the extent that existing and future stations are located within these target areas the station areas can be expected to experience greater land use impacts than stations in non-growth target areas. Documents from some municipalities identified vacant parcels suitable for development and underutilized parcels suitable for redevelopment. For example, the Richmond Hill Downtown Design & Land Use Strategy (2009) indicated a number of developable and re-developable parcels in the downtown area within a 5-10 minute walking distance of the Richmond Hill GO Station, the current endpoint of the Richmond Hill (F) line. Similarly, Georgetown GO Station Land Use Study (2008) identifies parcels suitable for station-related redevelopment in four areas surrounding the station (the current end of the Georgetown line).

Other municipalities may also have vacant and/or re-developable land in their station areas that was not readily apparent from the information available online. For example, an amendment to the Town of Lincolnville's bylaws indicates that the land surrounding the station area that is reserved for station-related employment development (Lincolnville station is the current end of the Stouffville line). However the document does not indicate whether the area is vacant or currently developed for another use. Land use documents from the Town of Innisfil, which lies just south of the Barrie South station (the current end of the Barrie line), indicate large parcels of land south of the station area reserved special agricultural development. It is unclear whether this land might be available for station-related development.

None of the studies reviewed contained specific amounts (hectares) of land available for development/ redevelopment or how many units of residential/square meters of retail/office/industrial could be accommodated.

Land use changes due to electrification of the GO network are facilitated by multiple factors, including actual or perceived noise reductions/air quality improvements at station areas and along rail lines, developable land parcels near stations, land use policies that enables/encourages development and new riders boarding or alighting at stations. Minimal changes in noise and air quality may not be sufficient enough to encourage some housing or other noise-sensitive land uses sensitive land uses such as schools and religious institutions.

Similarly, the minor noise reduction and air quality improvements due to electrification is unlikely to be influence other develop types, such as retail, commercial service storefronts, office space, health services, public sector uses and (possibly) above ground level apartments.

Land Value Uplift

Higher land values may be expected from the following three-part dynamic, any one of which may bid-up the price of land:

- More demand for services by station areas from additional riders of Metrolinx will lead to development or expansion of commercial and retail services that cater to these needs;
- Opportunities due to improved market access may increase the development potential of land near station areas;
- Noise and air quality improvements that occur, or are perceived, as part of electrification, will be particularly encouraging for housing development, as well as other noise sensitive land uses. However, given the relatively small improvements in noise and air quality expected, land values may only be affected in a few isolated sites.

However, despite these potential drivers for higher land values, some properties immediately adjacent to the rail corridor that could potentially reduce due to the visual impact of the overhead catenary system.

Conclusions

Given the relatively modest journey time improvements, limited noise and air quality improvements anticipated by the deployment of electric trains, it is unlikely that electrification on any corridor would have a significant positive impact on property development regardless of the status of land adjacent to stations. Regarding land values, there are likely to be increases due to improved accessibility, noise and air quality but possible decreases from the visual intrusion of the catenary system. Land Use, Development and Land Value impacts for each option is therefore concluded **Slight Positive**.

8.4. Property Effects

Introduction

Property Effects concern the temporary and permanent change in land use required to implement any option which results in property acquisition. Acquisition of property can potentially increase the risk (or cost) of implementing any option, as well as affect the local community economically and socially.

Assessment

The Study has concluded that all infrastructures required to electrify the GO Rail network can be done within the existing rail corridor with the exception of the major substations which would require land take at a number of locations. A typical substation is 40mx64m in size (illustrated in Figure 21), while a typical auto transformer station would be approximately 18m x 34m (illustrated in Figure 21).

Figure 20 Typical 2x25 KV System Sub-Station

Figure 21 Typical 2x25 KV System Autotransformer Station

There are a number of potential areas in open areas adjacent to the corridor which may be able to accommodate these substations, and it is unlikely that any of them would require significant removal of existing properties. At this stage of the Study, the site location has not been confirmed and the property effects would be assessed during the design phase of any option being taken forward.

Conclusions

The construction of substations is likely to require some land take in the open areas adjacent to the rail corridor, however the impact will depend on the final choice of the substation locations. In the absence of any further information, the assessment of Property Effects is deemed to be **Slight Negative** for all options.

8.5. Wider Economic Impacts

Introduction

This category measures the economic impacts for each scenario relative to the reference case, including impacts from construction and economic impacts incurred from implementation of project options. These impacts are reported in terms of GDP, the change in jobs and the change in the associated labour income, and are stated in 2010 $. Results reflect how the electrification of Metrolinx will:

- directly affect households and businesses in the regional economy and, and
- total provincial economic impacts that are derived by applying multipliers designed for the Greater Golden Horseshoe (GGH) region to derive indirect effects of employment, wages and GDP generated by the direct impacts of construction and improvements to the Metrolinx network.

These impacts include goods and services purchased by firms directly working on construction projects to support this work and impacts of household expenditures from the income earned by workers in directly or indirectly affected industries.

Assessment

Temporary Economic Impacts Generated by Construction

Construction impacts are temporary shocks to an economy that will occur during the spending of the construction budget for Metrolinx electrification projects. For example Alternative 1 is assumed to generate 1,500 construction related jobs. If construction takes five years and investment is evenly allocated, this is 300 jobs per year over the five year construction period. Also, construction impacts follow the budget. In general, the more expensive the alternative, the greater construction investment is required, and therefore the economic impacts from construction are larger. This varies slightly by the mix of materials and services per alternative, and the amount of spending that is likely to occur in the GGH versus elsewhere in Canada or the world.

As planned, Options 1, 2 and 3 are anticipated to cost between $890 million and $1.5 billion and costs of Options 11, 15 and 18 are expected to be between $1.7 billion and $3.2 billion, including contingencies. Construction associated with the electrification options will generate direct impacts of $155 million to nearly $1 billion in GDP, supporting 900 to 6,200 direct (but temporary) jobs associated with construction that will pay $60 million to $400 in aggregate wages. In addition, total regional impacts including spin-off effects is expected to account from $275 million to $1.8 billion of additional GDP in the GGH over the spans of the construction periods of the various alternatives. The direct impacts and full regional impacts from construction of the six alternatives are shown below in Table 30. Full details of the assessment can be found in Appendix 8-H – Economic Impacts.

Long-term Economic Impacts

Direct economic benefits stemming from electrification reflect both households' freed up vehicle operating expenditures and transportation cost savings to area businesses. The former effect is simply a redirected consumption demand by households away from purchases of gas, parking, automotive parts and services and into other consumer goods/services. The latter reflects improved regional competitiveness for metro-area businesses that now have lower costs of doing businesses, including access to a larger labour market and encountering less congestion on the highways because people are choosing to use the improved Metrolinx system instead of driving.

Table 30 Economic Impacts during Construction Period

Option	Direct Impacts			Regional Impacts Including Multipliers		
	Employment – person years	Wages ($millions)	GDP ($millions)	Employment – person years	Wages ($millions)	GDP ($millions)
Option 1	900 – 1,500	60 - 100	150 - 260	2,100 - 3,500	120 - 200	270 - 460
Option 2	1,000 – 1,600	70 - 110	180 - 280	2,400 - 3,800	140 - 220	320 - 490
Option 3	1,600 – 2,400	110 - 160	290 - 420	3,600 - 5,800	210 - 330	480 - 750
Option 11	1,900 – 2,800	120 - 190	320 - 490	4,500 - 6,800	260 - 390	580 - 870
Option 15	2,200 – 3,400	150 - 230	380 - 590	5,200 - 8,200	300 - 470	680 - 1,060
Option 18	4,100 – 6,200	270 - 400	660 - 1,000	9,700 - 14,800	550 - 840	1,210 - 1,850

The low ends of the ranges assume no contingency spending. The high ends of the ranges assume that all contingency budgets are expended. Calculations are based on data from Statistics Canada, input/output framework of the Organization for Economic Cooperation and Development and the Minnesota Implan Group.

Each industry that experiences part of the direct economic benefit will have a unique response in terms of how much a better functioning public transportation system affects their business outlook. In addition, the electrification improvements to Metrolinx will generate social benefits that can be compared in monetary terms, including valuing time savings and emission benefits. These are not listed as economic benefits because the actual exchange of dollars does not take place.

Economic impacts are summarized in terms of direct transportation savings by households and industries in the Metrolinx region, and by gross domestic product (GDP), jobs and wages. Table 31 summarizes the direct economic impacts of the six alternatives that are expected to be realized by the year 2031. Full details of the assessment can be found in Appendix 8-H – Economic Impacts.

Table 31 Economic Impacts in 2031

	Net Direct Cost Savings to Regional Households & Businesses (Millions $2010)	Total Economic Benefits		
		GDP (Millions $2010)	Jobs	Wages (Millions $2010)
Option 1	19	15	160	13
Option 2	63	49	500	42
Option 3	81	64	660	55
Option 11	95	74	770	64
Option 15	110	87	890	75
Option 18	127	97	1,000	84

Annual Federal/ Provincial Tax Impacts

The key tax impacts analyzed are Harmonized Sales Tax (HST) and Personal Income Taxes, which reflect the purchases of goods and services and wages that are expected to be generated due to economic impacts of the electrification options. Provincial and Federal Tax impacts by alternative are shown in Table 32 for 2031. Estimated tax revenues range from $4 million (Option 1) to almost $28 million (Option 18) in 2031.

Table 32 Estimated Provincial/Federal HST and Income Tax (Millions of 2010$ per annum)

Network Option	**Tax Impacts in 2031**
Option 1	4
Option 2	14
Option 3	19
Option 11	22
Option 15	25
Option 18	28

Conclusions

The electrification of the GO network, which improves journey times, can result in significant short term economic growth (GDP, jobs and wages) due to construction and long term economic growth due to improved transit allowing businesses to function more competitively.

9. FINANCIAL ASSESSMENT

9.1. Introduction

This section of the report covers the Financial Category of the MCE, and the corresponding sub-categories include the following:

- Capital Costs;
- Operating and Maintenance Costs; and
- Farebox Revenues.

9.2. Capital Costs

Introduction

The capital costs cover the major one-off, up-front expenses required to design, construct and test each option prior to the full operations of electric services. The capital costs are broadly broken down into the following categories:

- **Infrastructure capital costs** – the engineering works of constructing the power supply system (e.g. sub-stations), erecting the catenary system, bridge/tunnel modification/rework, signalling protection from magnetic interference or grounding, professional services and contingency; and
- **Rolling stock capital costs** – the initial cost of procuring new rolling stock, including spare units for maintenance, spare parts as well as costs associated with testing and acceptance process.

It is important to note that the capital costs considered in the context of the Electrification Study only consider the incremental costs associated with changing the rolling stock technology and does not capture the additional costs required on infrastructure and rolling stock to deliver the Reference Case service levels. This allows the additional costs of electrification to be compared to the additional benefits that could be delivered through electrification.

Assessment

Infrastructure Capital Costs

The key infrastructure requirements identified for each option is summarized in Table 33. Further details on how these were identified can be found in Appendix 8-B - Capital Cost Estimates.

The base infrastructure capital costs in 2010 prices for each option are presented in Table 34. These costs include contingency but not future cost escalation. Option 1 requires the least infrastructure work, as only 20% of the network is electrified. The electrification of the entire network would see a total of 7 major traction power substations, 4 switching stations and 17 autotransformer stations, as well as 51 bridges replaced or reworked and 2 tunnel sections to be reconstructed.

As more corridors are electrified, the capital cost increases. The cost to electrify the entire network is in the region of $3.2 billion in 2010 prices (excluding inflation), while Option 1 has the lowest capital cost at $710m in 2010 prices. Although Option 3 is essentially the combination of Option 1 and Option 2, the capital cost is notably lower than the sum of the individual parts because in the separate options, the significant costs associated with the sections around Union station have been included, and when both Lakeshore and Georgetown is electrified, there are cost synergies. Option 18 is particularly costly because it includes the reconstruction of the tunnel at Hamilton TH+B, by far the most expensive element associated with the electrification of the GO Rail network.

Table 33 Infrastructure Requirements by Option

Infrastructure Requirements	**Option**					
	1	**2**	**3**	**11**	**15**	**18**
Catenary System						
Electrified route (km)	104	132	238	277	374	509
Electrified route as % of total	*20%*	*26%*	*47%*	*54%*	*73%*	*100%*
Power Supply System						
Traction Power Substations	2	4	6	6	7	7
Switching Stations	2	3	4	4	4	4
Autotransformer Stations	3	1	4	7	10	17
Infrastructure Re-work						
Tunnels Replaced	0	0	0	0	0	2
Bridges Replaced	3	4	4	4	4	9
Bridges Reworked	8	19	24	24	30	42

Table 34 Infrastructure Capital Cost by Option ($m in 2010 prices)

Cost Breakdown (2010 $m)	**Option**					
	1	**2**	**3**	**11**	**15**	**18**
Catenary System	221	369	511	581	711	861
Power Supply System	100	166	230	262	320	388
Maintenance & Layover Facilities	16	27	28	31	37	40
Overhead Structures/Infrastructure Re-work	87	97	117	136	183	666
Sitework & Special Conditions	230	309	489	569	743	980
Professional Services	53	67	100	116	153	275
Total Infrastructure Capital Cost	**706**	**1,035**	**1,476**	**1,695**	**2,147**	**3,210**

Each option includes a significant proportion of contingency (in the order of 50% overall), given that this Study is at the indicative cost estimate phase of project development. The infrastructure capital estimates have been constructed for a large number of corridor sections and further details on the cost breakdown can be found in Appendix 8-B - Capital Cost Estimates.

Table 35 sets out the total infrastructure capital cost per route kilometre electrified. It shows that Option 3 is cheaper per route km than either Options 1 or 2 due to synergies, while Option 11 and 15 continue to benefit from cost synergies and the overall cost per route kilometre continue to decrease.

Table 35 Infrastructure Capital Cost per Route km by Option ($m in 2010 prices)

Cost per Route km ($m/km 2010 prices)	Option					
	1	2	3	11	15	18
Cost per Route km Electrified	6.8	7.8	6.2	6.1	5.7	6.3

Rolling Stock Capital Costs

The electrification options considered in the detailed evaluation involve replacing diesel locomotives with electric locomotives. The estimated cost of each type of rolling stock is set out in Table 36. It shows that the electric locomotive costs $3.4m more than the Tier 4 diesel locomotive, while it is assumed to cost $1.6m to convert each DMU into an EMU on the ARL service. There is an allowance of $15,000 assumed to convert each cab car to be compatible with the electric operations. It is assumed that the passenger coaches hauled by the electric locomotive would be identical to those in the Reference Case and therefore no additional costs have been assumed for passenger coaches. Further information on the assumptions underpinning these rolling stock costs is documented in Appendix 8-B - Capital Cost Estimates.

Table 36 Rolling Stock Capital Costs by Technology ($m 2010 prices)

Technology	Unit Cost ($m 2010 prices)	Incremental Unit Cost ($m 2010 prices)
Tier 4 Diesel Locomotive (new)	7.8	-
Existing Diesel Locomotive (salvage value by 2020)	1.0	-
Electric Locomotive	11.2	3.4
ARL DMU	4.0	-
ARL DMU + conversion to EMU	5.6	1.6

In order to determine the number of electric locomotives on each option, the number of trains required to operate each corridor as identified in the operating plan was used. The Study also assumes that the 6 ARL train sets (a total of 12 DMU) would be converted to EMUs. Figure 22 illustrates the mix of existing diesel locomotives (that will be converted to Tier 4), future Tier 4 diesel locomotives as part of the reference case and electric locomotives. Where the total number of locomotives exceeds the red line, existing locomotives will be surplus to requirements and sold off. Table 37 summarizes this per option.

Figure 22 Number of Locomotives Required/Surplus by Option

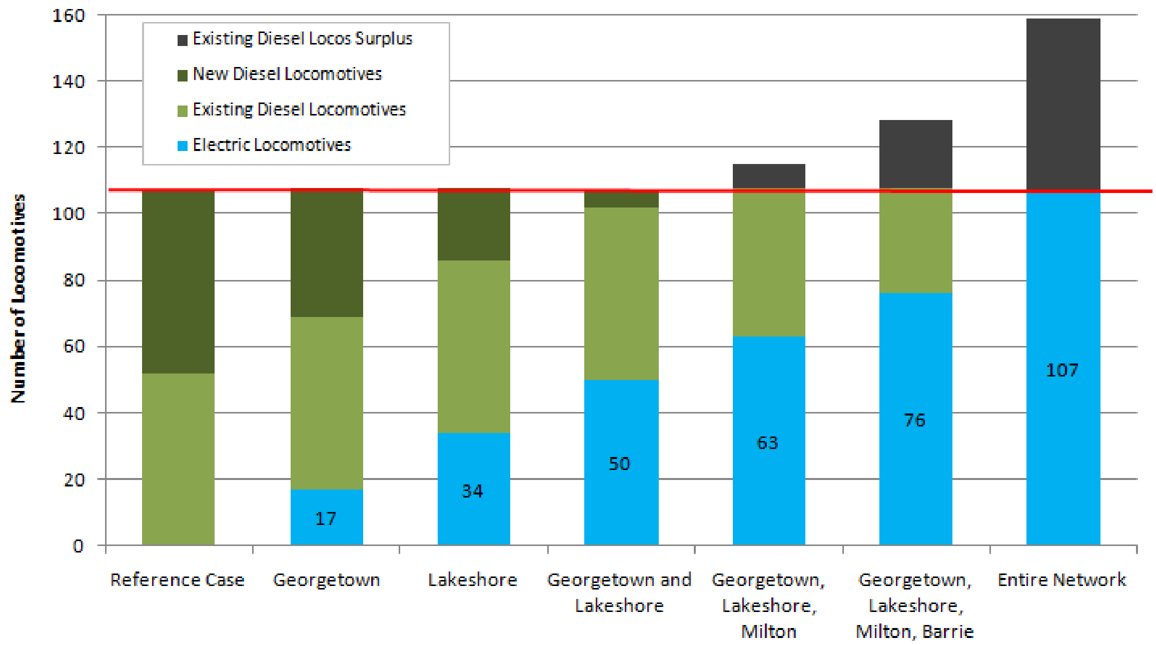


Table 37 Rolling Stock Requirements by Option (Including Spares)

Technology	**Option**					
	1	**2**	**3**	**11**	**15**	**18**
Electric Locomotives	17	34	50	63	76	107
Existing Diesel Locomotives (as part of the Reference Case)	*52*	*52*	*52*	*52*	*52*	*52*
New Tier 4 Diesel Locomotive (as part of the Reference Case)	*39*	*22*	*5*	*0*	*0*	*0*
Existing Diesel Locomotives to be sold off	*0*	*0*	*0*	*-7*	*-20*	*-52*
Total Locomotives	***107***	***108***	***108***	***107***	***108***	***107***
DMU to EMU conversion (ARL)	6	0	6	6	6	6

Table 38 below summarizes the incremental rolling stock capital costs by option. The key assumptions underpinning these estimates include the following:

- GO are in a position to either purchase diesel locomotives, electric locomotives or a mixture of both in order to expand from the current 52 locomotives to the 107 required to operate the Reference Case service levels;
- The difference in cost of the electric locomotive compared to the diesel locomotive is the incremental rolling stock cost of electrification provided that no existing diesel locomotives would

become redundant (which is the case in Options 11, 15 and 18), whereby the new electric locomotive cost is offset by the salvage value;

- The minimum spare requirement of 16% on locomotives would be applicable on both diesel and electric locomotives; as a result, Options 1, 2, 11 and 15 the total fleet of locomotives is 108 compared to 107 for Options 11 and 18, increasing the overall cost of those options.

Overall, the incremental rolling stock cost is in the region of $740m in 2010 prices if the entire network was electrified.

Table 38 Incremental Rolling Stock Capital Costs by Option ($m 2010 prices)

Technology	**Rolling Stock Costs ($m 2010 prices)**					
	1	**2**	**3**	**11**	**15**	**18**
Diesel Locomotive	-328	-678	-1,014	-1,220	-1,392	-1,764
Electric Locomotive	-48	0	-48	-48	-48	-48
DMU (ARL)	394	802	1,184	1,489	1,794	2,481
EMU (ARL)	67	0	67	67	67	67
Total Rolling Stock Capital Costs	**84**	**123**	**188**	**288**	**421**	**736**

Conclusions

The total estimated capital cost is set out in Table 39, and it shows that the electrification of the entire network would cost $4 billion in 2010 prices, excluding future inflation. This includes in the order of 50% contingency for the infrastructure capital costs, reflecting the fact that the cost estimates are indicative and subject to substantial variations in advance of any detailed design work.

Table 39 Total Incremental Capital Costs by Option ($m 2010 prices)

Cost Item	**Incremental Costs ($m 2010 prices)**					
	1	**2**	**3**	**11**	**15**	**18**
Infrastructure Capital Costs	706	1,035	1,476	1,695	2,147	3,210
Rolling Stock Capital Costs	84	123	188	288	421	736
Total Capital Costs	**790**	**1,158**	**1,664**	**1,983**	**2,568**	**3,946**

9.3. Operating and Maintenance Costs

Introduction

The Operating and Maintenance (O&M) costs concern the cost of the day to day operations of the GO Rail network such as drivers, cleaning as well as routine checking, maintaining and replacement of equipment. The larger the fleet of trains and the farther the trains run, the greater the O&M costs.

The O&M costs are a significant part of GO's operating budget – they are partially offset by the farebox revenues from passengers but an operational subsidy is also required. The level of subsidy available is a significant consideration in terms of the level of service being offered.

Assessment

The electrification of the GO Rail network would result in a change in O&M costs. While some cost items, such as locomotive engineers, crew and track maintenance are not affected, there are some notable differences:

- The cost of energy for diesel is significantly higher compared to electricity – this is because electric locomotives are significantly more energy efficient in hauling the passenger coaches compared to diesel, electric locomotives also recover 15% of energy through regenerative breaking and the price of electricity is lower than diesel for the same energy output;
- Electric locomotives are cheaper to maintain than diesel locomotives because the mechanical characteristics (e.g. number of moving parts) are different which means that the cost of inspection and/or periodic replacement is lower; and
- An electrified network requires new costs associated with the power supply and overhead catenary maintenance costs – this is considered as wayside maintenance.

Table 40 sets out the annual incremental O&M costs in 2010 prices for each option. If the entire network was electrified today, the annual cost saving as a result of electrification is estimated at around $29m per annum, a significant cost saving. It also shows that the majority of the cost savings associated with electrification is due to the difference in costs spent on diesel and electricity. Full details of the O&M cost estimates are set out in Appendix 8-C – Operations & Maintenance Cost Estimates.

Table 40 Incremental Operating and Maintenance Costs ($m per annum 2010 Prices)

O&M Cost Category ($m per annum 2010 Prices)	**Option**					
	1	**2**	**3**	**11**	**15**	**18**
Rolling Stock Maintenance	-0.7	-1.1	-2.3	-2.6	-3.1	-4.6
Wayside Maintenance	2.8	4.5	7.2	8.0	9.6	11.2
Energy	-4.7	-18.1	-22.8	-26.9	-31.4	-35.6
Annual Incremental Rolling Stock Operating and Maintenance Costs	**-2.6**	**-14.6**	**-17.9**	**-21.5**	**-24.9**	**-29.0**

Over the evaluation period, the cost of diesel is assumed to increase 5% per annum in nominal terms until 2031 (where it is assumed to be constant in real terms in the future) while the price of electricity is assumed to increase 2.5% per annum in nominal terms. Figure 23 illustrates these increases in real terms, i.e. excluding background inflation.

The differential in inflation rate of 2.5% is driven by the concept of “Peak Oil” – where at some point in time the rate of oil extraction would level off and as demand continues to rise, the cost of oil would also rise. In today’s prices, diesel would reach around $1.40/Litre by 2031, just less than double of today’s prices – while electricity will only be marginally more expensive. The consequence would be that the use of alternative energy sources (e.g. electric cars) would become more economically viable, and demand for oil is managed accordingly, but at a cost. This means that over time, the cost of diesel will increase significantly more than electricity and the cost savings increase dramatically.

Figure 23 Assumed Diesel and Electricity Real 2010 Costs (Excluding background Inflation)

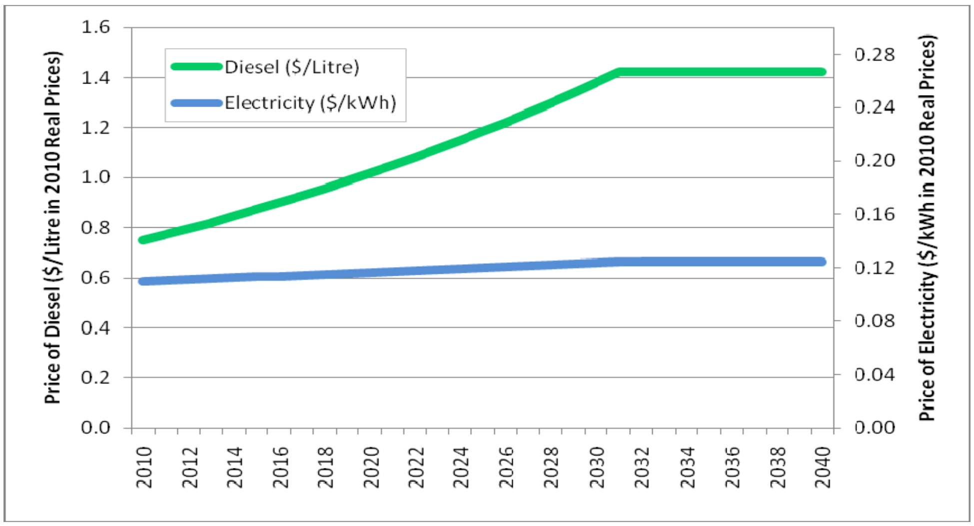


Table 41 below illustrates how the annual O&M cost savings increase over time, primarily due to the relative real inflation of diesel and electricity in the future.

Table 41 Future Incremental Operating and Maintenance Costs ($m per annum 2010 Real Prices)

O&M Cost Savings ($m per annum 2010 Real Prices)	Option					
	1	**2**	**3**	**11**	**15**	**18**
Estimated O&M savings base 2010 values	-3	-15	-18	-22	-25	-29
Estimated O&M savings 2021 with real inflation	-7	-26	-33	-39	-45	-53
Estimated O&M savings 2031 with real inflation	-10	-38	-48	-57	-67	-79

There are significant uncertainties over the cost of electricity and diesel in the future, as desktop studies concluded that only short term fuel price forecasts are common and there are varying views on how prices would evolve in the time frame of the Study. The US Energy Information Administration provided energy forecasts over the next 40 years and suggested that the difference in the rate of increase between diesel and electricity is 2%. Given that Canada is potentially less protected from fuel prices than the US, the differential of 2.5% was deemed appropriate for the central case assumption of the Study; however it only represents one of many possible outcomes. The sensitivity tests in section 12.1 examines this in further detail.

Conclusions

One of the major benefits of electrification is the reduction in operating and maintenance costs, and in particular, the reduction of energy costs. This is because electricity is a significantly cheaper source of energy and electric trains also save approximately 15% in energy through regenerative breaking.

The price of diesel is expected to increase at a greater rate than electricity in the future, so the operating costs are set to increase significantly in the future. The inflation of energy is highly speculative, and sensitivity tests are carried out in section 12.1. While it is possible that the differential in inflation would not materialize to the same extent as forecast, this could be a direct result of federal policies put in place to limit the use of non-renewable energy sources which may have a wider cost to society.

Electric trains are also typically cheaper to maintain, but this is largely offset by the increased maintenance cost of the OCS and power supply system.

9.4. Farebox Revenues

Introduction

Revenue considered in this Study is related to the income of GO directly from fare-paying passengers. These revenues, together with subsidies from the Province, offset the day to day operating and maintenance costs of the service.

In general, the fare paid per passenger is dependent on the journey (distance) travelled and the type of ticket product purchased (concessions, season tickets). As part of the Electrification Study, we have assumed that the fare structure paid by passengers would not change, and future fares have been assumed to increase in line with inflation (CPI). Therefore the only major factor associated with changes in revenues is ridership.

Assessment

Revenue is directly related to the number of passengers using the transit network. If journey times can be shortened and the forecast of additional passengers ensues, the revenues will increase. As electric trains accelerate and decelerate more rapidly, the electrification of each corridor is expected to increase the ridership and therefore revenues.

Figure 24 illustrates how the ridership on each corridor increases with the faster electric trains. It should be noted that in the case of Lakeshore West, the revenue increase include the electrification of Hamilton TH+B and St Catharines sections and excludes build-up effects in the 2021 forecast year (i.e. ignores the fact that it takes time for additional riders to change to their optimal mode). As shown in the figure, the Georgetown corridor generates the highest percentage increase in demand because the journey time savings are the greatest. Most travellers on the Richmond Hill corridor would not gain journey time benefits so the increase is very modest.

Figure 25 illustrates the forecast incremental revenue by corridor. It should be noted that in the case of Lakeshore West, the revenue increases include the electrification of Hamilton TH+B and St Catharines sections and excludes build-up effects in the 2021 forecast year, though this is included in the life-cycle evaluation. It clearly shows that Lakeshore corridors generate the largest share of incremental revenues, primarily because they are the most mature corridors in terms of ridership.

Table 42 summarizes the incremental demand and revenues, including the overall life cycle. Similarly, the 2021 forecasts presented here ignore build up effects. The Lakeshore corridors (Option 2) capture almost half of all the incremental revenues compared to electrifying the entire network.

These revenue increases forecast assume that the additional ridership can be accommodated. While the load factors presented in Figure 19 earlier suggest that the trains themselves will have sufficient capacity to accommodate an increased ridership, there are other factors such as park and ride and station access that also needs to be considered. However, given that the overall increase in riders at each station is up to 4%, the risk of not delivering the revenue growth is not considered significant.

Given that passengers are expected to benefit from increased service levels and capacity, leading to an overall improvement in quality, GO would be able to increase the fare levels as part of the Reference Case. This could potentially increase the level of incremental revenues generated.

It should be noted that in the context of transportation economic appraisal, fares are essentially a transfer of resources from passengers (negative benefit) to the public sector as an income (negative cost) and therefore does not affect the Net Present Value of any option.

Further details on how the revenues were determined can be found in Appendix 8-A – Approach to Cost Benefit Analysis.

Figure 24 Percentage Increase in Demand by Corridor

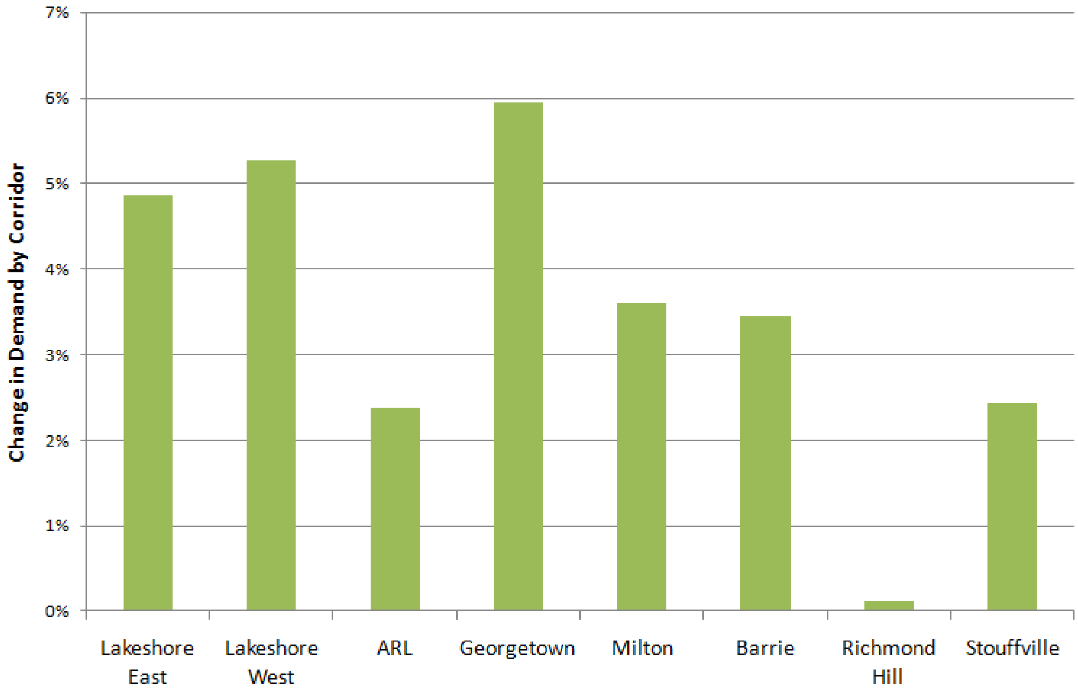


Figure 25 Incremental Revenue by Corridor

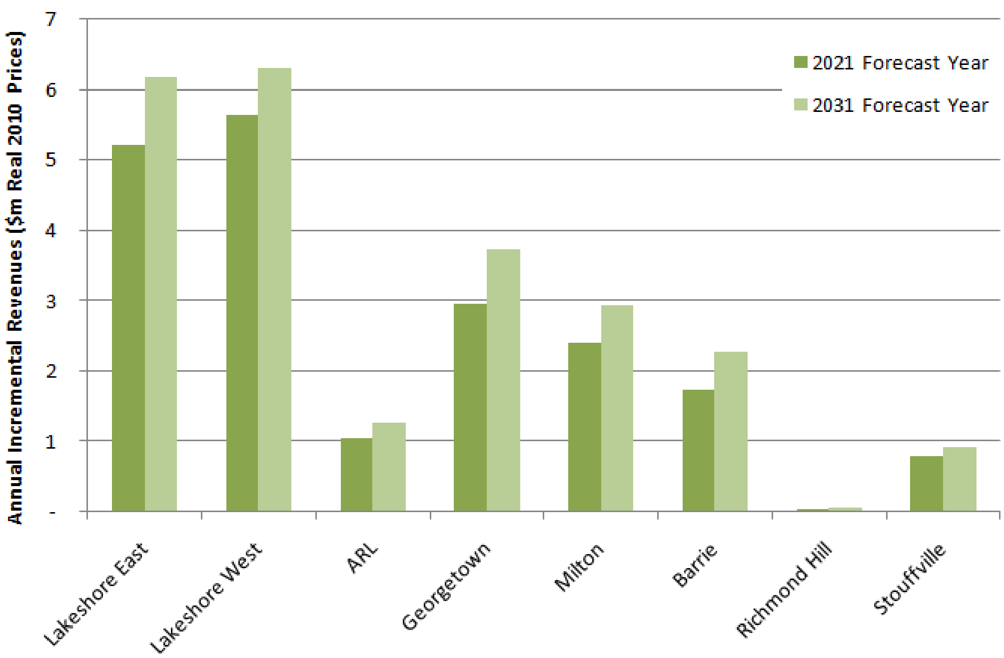


Table 42 Incremental Demand and Revenue by Option

Shortlist Option	Incremental Demand (m passengers p.a.)		Incremental Revenue ($m p.a.)		Incremental Revenue (2010 $m Present Values Discounted at 5% p.a. over 30 years)
	2021	2031	2021	2031	
Option 1	0.6	0.7	4.0	5.0	22.6
Option 2	1.5	1.8	9.3	10.8	50.0
Option 3	2.1	2.5	13.3	15.7	72.6
Option 11	2.5	3.0	15.7	18.7	85.9
Option 15	2.8	3.4	17.5	20.9	96.1
Option 18	3.2	3.8	19.8	23.6	108.6

Conclusions

The faster electric trains reduce journey times for passengers travelling on the electrified corridors which attract additional riders and generate increased farebox revenue for GO. Passengers would pay a fare (negative benefit) to the operator as an income (negative cost) and it is therefore neutral impact in terms of resources.

As more corridors are electrified, the more revenues are generated. The electrification of the entire network (Option 18) would generate around $24m per annum additional revenue by 2031, or $110m Present Value incremental revenue over the evaluation period.

The increase in revenues to GO means that in the longer term GO can use the increased revenues to reduce the operating subsidy, partially recover the cost of investment in electrification, or fund future improvements.

10. DELIVERY ASSESSMENT

10.1. Introduction

This section covers the Delivery Category of the MCE, and the sub-categories include the following:

- Constructability
- Acceptability

10.2. Constructability

Introduction

The issue of constructability and corridor selection is closely related to the overall assessment of corridor construction cost. Care has been taken not to double count any financial benefits. The ease of constructability of the corridor options should take into account the following:

- Space and accessibility.
- Construction activity next to populated areas (short term noise, light pollution and dust).
- Infrastructure affected.
- Impacts on existing commuter services.

Assessment

Space and Accessibility

Space and accessibility are extremely important to the construction activities as adequate space is required for staging, temporary offices, equipment storage and construction personnel safety. Space should be provided alongside the track at regular intervals and appropriate large temporary storage should be available in close proximity to the corridors to assist with the construction activities.

In higher density areas, the worksite will be reliant on equipment being shipped by rail to the construction area, therefore appropriate height and width restrictions will require consideration; as the line is sized for double height containers and dual track, this is not perceived as a major issue.

A cursory overview of the track areas has been conducted taking into account track widths, number of tracks, potential storage facilities along the track and track access. It should also be noted that Lakeshore East and West currently carry 60% of commuter traffic and therefore have a bigger impact on constructability.

Table 43 represents a perceived ranking of corridors.

Table 43   Space and Accessibility Assessment by Corridor

Corridor	Space and Accessibility Assessment
Lakeshore west	Slight Negative
Lakeshore East	Slight Negative
Milton	Moderate Negative
Georgetown and ARL	Slight Negative
Barrie	Significant Negative
Richmond Hill	Significant Negative
Stouffville	Slight Negative

Construction Activity

Construction activity is closely linked to acceptability of the corridor options. Construction activity within the corridor tends to be short-lived but the potential disruption can feed public resentment without appropriate planning and mitigation. In the instances of high traffic areas or existing commuter services, work may only be accomplished during off peak hours which tend to be in the time period between midnight and 06:00 next morning.

Careful staging is required to minimise impact to residents in the near vicinity. The process of electrification is in its very nature work intensive and has the potential of impacting a great number of people over and above that of the reference case and in particular in the more densely populated areas of the city. As such and evaluation of the corridor construction can only surmise that a reduction in potential electrification will have less impact and disruption.

However as it is extremely unlikely that with such an extensive project such as this, that all corridors as per Option 18 will be electrified the same time. Therefore an assessment of the construction activity should only consider the likelihood of disruption on a corridor by corridor basis rather than as corridor options.

Infrastructure

While infrastructure has been factored into the overall corridor costs, an assessment of construction activities required for corridor conversion permits a ranking of difficulty in implementing the options. As the amount of infrastructure affected is directly proportional to the number of corridors that are electrified, the ranking is ordered from Option 1 to Option 18 in increasing complexity.

Impacts on Existing Commuter Services

Any construction activity will tend to disrupt existing traffic and as such the most affected corridors will be Lakeshore East and West and the ARL corridors. However the conversion and working practices to support conversion alongside mixed traffic are proven and understood.

In terms of long term planning and meeting the objectives of the mobility hubs within the GO 'Big move' transportation planning the greatest proportion or recommended mobility hubs are served by the East and West Lakeshore and Milton lines. In terms of strategic planning there may be some merit in implementing shorter and potentially lower ridership lines such as Richmond and Stouffville, so that experience and knowledge can be gained more rapidly, before undertaking the major conversion of the more disruptive and commuter intensive lines.

Conclusions

Having considered the space and access, construction activity, infrastructure and impacts on commuter services, the overall assessment on constructability is set out in Table 44 for each option.

Table 44 Overall Constructability Assessment by Option

Option	Corridors Electrified	Assessment
Option 1	Georgetown and ARL	Slight Negative
Option 2	Lakeshore East and West (excluding Hamilton TH+B and St Catharines)	Moderate Negative
Option 3	Georgetown, Lakeshore East and West	Moderate Negative
Option 11	Georgetown, Lakeshore East and West, Milton	Moderate Negative
Option 15	Georgetown, Lakeshore East and West, Milton, Barrie	Strong Negative
Option 18	All Corridors (including Hamilton TH+B and St Catharines)	Strong Negative

10.3. Acceptability

Introduction

The acceptability category considers the appetite of key stakeholders towards the electrification of the corridors or sections involved under each option. The acceptability of the following stakeholders is considered:

- Public acceptance – the community adjacent to corridors;
- Stakeholder acceptance – the ownership of corridors; and
- Stakeholder acceptance – the impacts on other operators, particularly freight.

Assessment

Public Acceptance

Public acceptance of a new transit system is highly dependent on a number of variables and not necessarily the corridor selection. Acceptance criteria for a city wide scheme such as the electrification of the corridors will be subject to a number of intangibles that will not all be captured by this Study, for example multimodal integration and fare pricing schemes.

As a result of the Study's interaction with the public and based on the feedback for the Georgetown line, there is an indication that the more socially acceptable form of motive power for vehicles operating in close proximity to residential housing within a section of the Georgetown corridor, is that provided by electrified overhead catenary. The remaining corridors, including other sections of the Georgetown line, are less conclusive. More importantly, despite some potential mitigation through judicious planting of trees and shrubs, the public may be more sensitive to the encroachment of electrified overhead catenary infrastructure in areas where there are currently no obstructed views of open countryside."

The qualitative assessments provide an indication of public sentiment rather than actual net benefits. Given this preference the corridor options can be ranked accordingly. The electrification of Georgetown and Lakeshore corridors would mean that more than half of the services into Union station would be electrified; therefore it is assessed as moderate positive. As the services of some other corridors are less frequent, the environmental issues would be less of a consideration and the visual impact of the overhead catenary system could have an opposing effect. The overall assessment is set out in Table 45.

Table 45 Percentage of Services Electrified

Option	Percentage of Services into Union Station Electrified
Option 1	32%
Option 2	30%
Option 3	62%
Option 11	71%
Option 15	80%
Option 18	100%

Stakeholder Acceptance

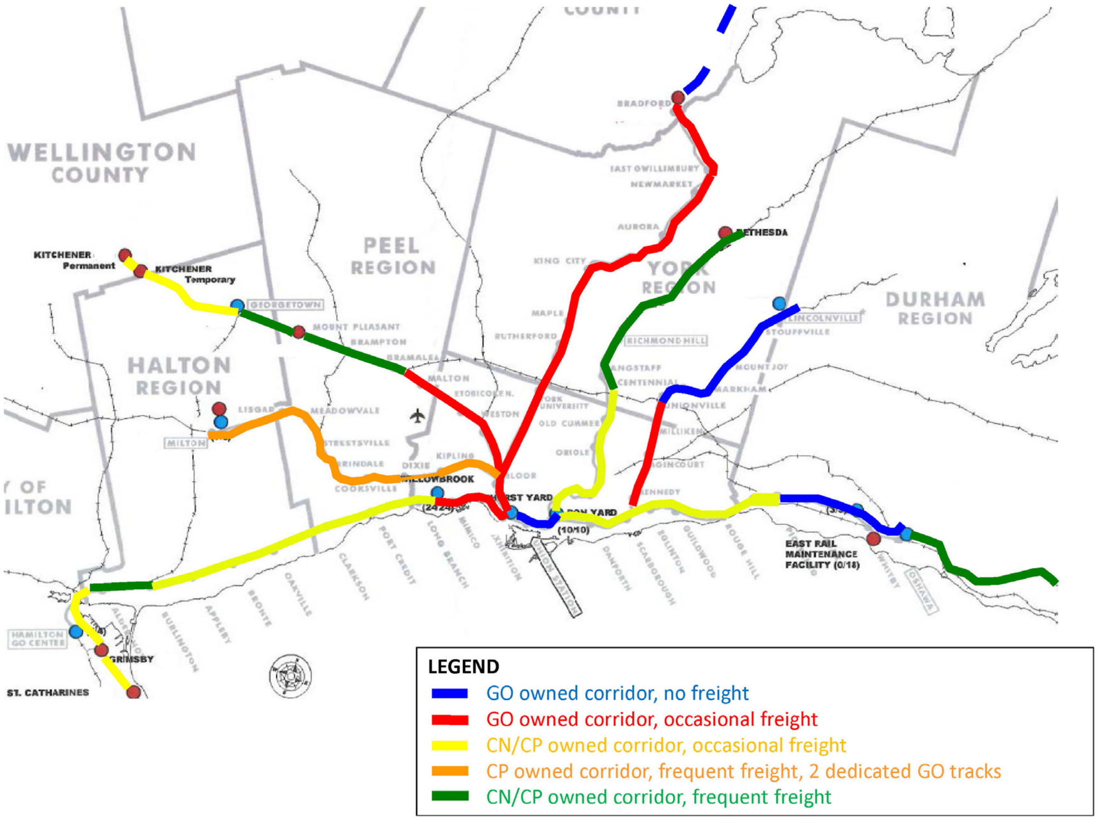
In terms of the acceptability of Stakeholders, the primary consideration is the operators of the corridor traffic, track ownership and the ease of diversion of existing freight.

Table 46 below provides a qualitative assessment of GO owned track in relation to the overall corridor.

Table 46 Percentage of GO Ownership

Option	Percentage of GO Ownership
Option 1	67%
Option 2	50%
Option 3	50%
Option 11	46%
Option 15	52%
Option 18	61%

Figure 26 - Track Ownership of Corridors



It can be seen that there is little difference between Option 1 (single electrified corridor) and Option 18 (all corridors electrified) in terms of ownership of the lines, although the total distance of track not owned by GO increases by option.

In assessing freight activity within the corridors, consideration should be given to the ability of the existing rail network to temporarily divert freight when construction activities are in progress. Fortunately heavy freight activity is already diverted out of the main corridors along routes north of the city, which may assist in reducing the total traffic during a potential corridor conversion. It should be noted that some lines do not have the benefit of easy diversionary capability as they become more remote from the centre of Toronto.

The assessment in Table 47 is based on potential impact to traffic and implications for construction activities, it should be noted that this is a highly subjective assessment and should not be used in isolation without additional or supplementary in-depth corridor surveys. As expected the disruption of corridor traffic due to freight diversion is proportional to the number of corridors affected in each option.

Table 47 Potential Impacts on Freight Services

Corridor	**Traffic and construction commentary**
Lakeshore West	Occasional freight with higher freight movements between Burlington and Aldershot; may require consideration of temporary diversions on to other lines during construction.
Lakeshore East	Higher freight movement at Oshawa; may require temporary diversions on to other lines. This is a partially GO owned route, therefore there may be some track segregation possibility.
Milton	Higher freight movements. There are two dedicated GO tracks therefore good track segregation possibility during construction.
Georgetown and ARL	Long route to convert with high freight movements; may require temporary diversions on to other lines during construction.
Barrie	Lower freight traffic and likely limited ability to divert on to other lines during construction.
Richmond Hill	Higher freight traffic north of Centennial with likely limited ability to divert on to other lines during construction.
Stouffville	No freight north of Unionville. South of Unionville may require temporary diversions on to other lines during construction.

Conclusions

Table 48 below provides a summary of the acceptability attributes, including public acceptability, stakeholder acceptability in the form of GO and non-GO ownership as well as impacts on freight.

Table 48 Overall Assessment on Acceptability

Option	Summary	Qualitative Assessment
Option 1	32% of services electrified, 67% of track to be electrified currently owned by GO, significant freight movements with diversions possible	Slight Negative
Option 2	30% of services electrified, 50% of track to be electrified currently owned by GO, significant freight movements with diversions possible	Moderate Negative
Option 3	62% of services electrified, 50% of track to be electrified currently owned by GO, significant freight movements with diversions possible	Moderate Negative
Option 11	71% of services electrified, 46% of track to be electrified currently owned by GO, significant freight movements with diversions possible	Moderate Negative
Option 15	80% of services electrified, 52% of track to be electrified currently owned by GO, significant freight movements with diversions possible, except on the Barrie line.	Strong Negative
Option 18	100% of services electrified, 61% of track to be electrified currently owned by GO, significant freight movements with diversions possible, except on the Barrie, Stouffville and Richmond Hill lines.	Strong Negative

11. DETAILED EVALUATION SUMMARY

11.1. Multiple Category Evaluation Summary Table

The detailed MCE described throughout this report in Sections 5 to 10 makes an assessment under each sub-category. For the purpose of summarizing key impacts and information into one single matrix, the MCE summary table has been developed. The Detailed Evaluation Summary Table is set out in Table 49. The colour coding for the various impacts is as follows:

Impact Scale
Strong Positive
Moderate Positive
Slight Positive
Neutral/No Impact
Slight Negative
Moderate Negative
Strong Negative

In addition, a summary Multiple Category Evaluation scorecard has been produced for each of the final six options. In addition to providing the qualitative and quantitative assessment results, the scorecard also describes the key impacts associated with each option. These are set out in Table 50 to Table 55.

Table 49 Multiple Category Evaluation Summary Table

			Option 1	Option 2	Option 3	Option 11	Option 15	Option 18
Category	**Sub-Category**	**Measure**	Georgetown	Lakeshore (excl.TH+B/St Cat)	Lakeshore* + Georgetown	Lakeshore*, Georgetown, Milton	Lakeshore*, Georgetown, Milton, Barrie	All Corridors (incl. TH+B and St Cat)
Environmental and Health	Greenhouse Gas and Climate Change	Regional Greenhouse Gases Reductions - Qualitative assessment based on the overall impact on climate change	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive
		Percentage reduction in GO Rail's total GHG contributions (note: excludes modal shift emission reductions)	15%	40%	55%	64%	78%	94%
	Regional Air Quality	Regional Air Quality - Qualitative assessment based on reduced CACs emitted by GO Rail to the region	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive
	Local Air Quality	Local Air Quality - Qualitative Assessment based on the impact on reduced CAC and the population who benefit from it	Slight Positive	Slight Positive	Moderate Positive	Moderate Positive	Moderate Positive	Moderate Positive
		Value of Health Benefits due to Air Quality - reduction of GO Rail's contribution to regional smog ($m per annum 2010 prices)	4	7	11	13	15	18
	Other Health	Physical Fitness - Qualitative assessment based on the number of additional transit users	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive
		Electro-Magnetic Fields (EMF) - Qualitative assessment based on guidelines by the Institute of Electrical & Electronics Engineers	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact
		Qualitative assessment based on the change in safety hazard of the railway network after mitigation measures are in place	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact
	Noise and Vibration	Noise - Qualitative assessment based on the change in noise levels and the population who benefit from it	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Slight Positive	Slight Positive
		Vibration - Qualitative assessment based on the change in vibration levels and the population who benefit from it	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Slight Positive	Slight Positive
	Terrestrial Ecosystem	Qualitative assessment based on the impacts towards the terrestrial ecosystem's natural heritage	Slight Negative	Slight Negative	Slight Negative	Slight Negative	Slight Negative	Slight Negative
	Aquatic Ecosystem	Qualitative assessment based on the impacts towards the aquatic ecosystem's natural heritage	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Slight Negative
	Effect on Parks / Public Open Space	Qualitative assessment based on the likely impacts towards parks and open spaces used by the local community	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact
User Benefits / Quality of Life	Transportation Efficiency	Average Journey Time Saving of Electric Train User (mins per passenger)	2.8	2.6	2.7	2.5	2.5	2.4
		Total Journey Time Saving ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	122	334	456	541	617	692
		Journey time benefits for highway users ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	23	75	98	117	135	153
		Reduction in Auto operating costs ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	41	136	176	209	242	275
		Reduction in vehicle collisions ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	6	20	26	30	35	40
	Reliability	Passenger Reliability Benefits ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	0.8	3.1	3.9	5.0	6.1	7.2
	Transit Network/ System Access	Qualitative assessment based on the improvement of accessibility of transit	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact
	Comfort and Expandability	Qualitative assessment based on the change in crowding levels on the trains and GO's ability to expand capacity accordingly	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact	Neutral/No Impact
Social Community	Land Use Integration	Qualitative assessment based on how improved transit can help shape communities and link up key activity centres	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive
	Social and Community	Qualitative assessment based on the perceived impacts towards the local communities	Moderate Negative	Moderate Negative	Moderate Negative	Moderate Negative	Slight Negative	Moderate Negative
Economic	Cost-	Transportation Benefit:Cost Ratio (BCR)	0.4 :1	1.1 :1	0.9 :1	0.9 :1	0.8 :1	0.5 :1

	Effectiveness	Cost per New Rider in 2031 ($m Capex/new daily passenger)	0.44	0.26	0.27	0.26	0.30	0.41
		Tonnes of GHG saved (from technology and modal shift) per annum per $10m capital cost	670	1,220	1,170	1,140	1,060	840
		Long Term Economic (GDP+Wages) PV Benefits per $10m capital cost	3.2	7.2	6.5	6.4	5.7	4.2
	Land Use and Property Development	Qualitative assessment based on the influence on land use and potential for development	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive	Slight Positive
	Property / Land Take	Qualitative assessment based on the property/land required to implement the option	Slight Negative	Slight Negative	Slight Negative	Slight Negative	Slight Negative	Slight Negative
	Wider Economic Impacts During Construction	Incremental GDP and wages due to construction ($m Real 2010 prices)	270-460	310-500	470-760	570-870	680-1,060	1,210-1,850
		Number of regional jobs created due to construction (Employment-years)	2,100-3,500	2,400-3,800	3,600-5,800	4,500-6,800	5,200-8,200	9,700-14,800
	Wider Economic Impacts During Operations	Incremental GDP and wages in the long term due to improved transit times ($ per annum in 2031)	15	49	64	74	87	97
		Number of regional jobs in the long term due to improved transit times (Employment-years in 2031)	160	500	660	770	890	1,000
	Taxes	Effect/increased provincial and federal taxes in 2031 ($m per annum)	4	14	19	22	25	28
Financial	Capital Cost	Incremental Capital Cost ($m 2010 prices, i.e. excluding inflation)	790	1,160	1,660	1,980	2,570	3,950
		Incremental Capital Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	580	850	1,230	1,460	1,890	2,910
	Total Life Cycle Cost	Life Cycle Present Value Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	470	470	730	870	1,200	2,110
	Operating Cost	Incremental Operating and Maintenance Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	-90	-340	-420	-510	-590	-700
	Total Revenues	Incremental revenues of the transit network ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	23	50	73	86	96	109
	Operating Sustainability	Reduction in Operating Subsidy in 2031 ($m Real 2010 prices per annum)	-15	-49	-64	-76	-88	-103
Deliverability	Constructability	Qualitative assessment of the construction constraints, techniques and impacts to transit users	Slight Negative	Moderate Negative	Moderate Negative	Moderate Negative	Strong Negative	Strong Negative
	Acceptability	Qualitative assessment of public and stakeholder (owner and operator) acceptance of each option	Slight Negative	Moderate Negative	Moderate Negative	Moderate Negative	Strong Negative	Strong Negative

Table 50 Multiple Category Evaluation Scorecard – Option 1: Electrify Georgetown (including ARL)

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 1 Electrifying the Georgetown corridor (including ARL)*
Environmental and Health	Greenhouse Gas Emissions and Climate Change	Regional Greenhouse Gases Reductions - Qualitative assessment based on the overall impact on climate change	Slight Positive	The GHG emission inventory is a fraction of 1% of the GTHA's overall regional emission inventory from all sources.
		Percentage reduction in GO Rail's total GHG contributions (note: excludes modal shift emission reductions)	15%	Electrification could reduce GHG emissions by 51,500 tonnes per year. Furthermore, due to faster transit times and the reduction in highway journeys by private car, a further 1,700 tonnes of GHG per year can be saved.
	Regional Air Quality	Regional Air Quality - Qualitative assessment based on reduced CACs emitted by GO Rail to the region	Slight Positive	Option 1 produces an emission reduction of 51,547 Tonnes from the reference case, a fraction of 1% of the GTHA's overall regional emission inventory from all sources.
	Local Air Quality	Local Air Quality - Qualitative Assessment based on the impact on reduced CAC and the population who benefit from it	Slight Positive	Small positive health effects towards a population of 70,000 due to improved air quality. 440 additional transit users in the morning peak improving physical fitness.
		Value of Health Benefits due to Air Quality - reduction of GO Rail's contribution to regional smog ($m p.a. 2010 prices)	4	A small proportion (0.04%) of the overall health and environmental cost of air pollution in Ontario.
	Other Health	Physical Fitness - Qualitative assessment based on the number of additional transit users	Slight Positive	440 additional transit users in the morning peak improving physical fitness, a small proportion of the overall population of Greater Toronto.
		Electro-Magnetic Fields (EMF) - Qualitative assessment based on guidelines by the Institute of Electrical & Electronics Engineers	Neutral/No Impact	The EMF is expected to be well below the guidelines due to the overhead catenary system
		Qualitative assessment based on the change in safety hazard of the railway network after mitigation measures are in place	Neutral/No Impact	Appropriate measures have been proposed to mitigate any increase in risk to safety therefore, the overall safety assessment of all options is deemed neutral.
	Noise and Vibration	Noise - Qualitative assessment based on the change in noise levels and the population who benefit from it	Neutral/No Impact	Electrification produces negligible effect from imperceptible (< 2 dB) overall reductions affecting 261,165 people in 2021 (i.e., 7% less than the reference case)
		Vibration - Qualitative assessment based on the change in vibration levels and the population who benefit from it	Neutral/No Impact	Electrification produces negligible reductions in perceptible vibration (< 1 dB) affecting 261,165 people in 2021 (i.e., 7% less than the reference case)
	Terrestrial Ecosystem	Qualitative assessment based on the impacts towards the terrestrial ecosystem's natural heritage	Slight Negative	Bridge replacements required in previously disturbed, urban areas therefore low impact anticipated on terrestrial ecosystem. Additional minor impacts may be caused with the construction of the sub-station(s).

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 1 Electrifying the Georgetown corridor (including ARL)*
	Aquatic Ecosystem	Qualitative assessment based on the impacts towards the aquatic ecosystem's natural heritage	Neutral/No Impact	No bridges or infrastructure replacements required therefore no anticipated impacts to watercourses.
	Effect on Parks / Public Open Space	Qualitative assessment based on the likely impacts towards parks and open spaces used by the local community	Neutral/No Impact	Deemed neutral due to lack of information on the final choice of sub-station locations.
User Benefits / Quality of Life	Transportation Efficiency	Average Journey Time Saving of Electric Train User (mins per passenger)	2.8	The time savings from Georgetown to Union station would save passengers 6 minutes.
		Total Journey Time Saving ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	122	Approximately 77.6 million passenger journeys per year benefit from an average of 2.8 minutes.
		Journey time benefits for highway users ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	23	The reduced journey time of electric locomotives creates a passenger transfer from auto to rail, by 370 trips in 2031 am peak period, reducing highway congestion and consequently improving journey time for highway users.
		Reduction in Auto operating costs ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	41	Reduced operating costs due to reduced auto km travelled; a reduction of 8.3 million auto km per annum in 2031.
		Reduction in vehicle collisions ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	6	Reduced collision costs due to reduced auto km travelled; a reduction of 8.3 million auto km per annum in 2031.
	Reliability	Passenger Reliability Benefits ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	0.8	The use of the more reliable electric trains avoids 8 rolling stock failures per annum.
	Transit Network/ System Access	Qualitative assessment based on the improvement of accessibility of transit	Neutral/No Impact	No specific measures are being promoted to improve the system access compared to the Reference Case.
	Comfort and Expandability	Qualitative assessment based on the change in crowding levels on the trains and GO's ability to expand capacity accordingly	Neutral/No Impact	No notable impact on passenger comfort. Electric trains have a greater potential to expand in capacity but there are no significant passenger capacity issues anticipated.
Social Community	Land Use Integration	Qualitative assessment based on how improved transit can help shape communities and link up key activity centres	Slight Positive	Improved journey times between key journey origins and destinations give a slight improvement in integrating the urban environment.
	Social and Community	Qualitative assessment based on the perceived impacts towards the local communities	Moderate Negative	The visual changes due to overhead catenary systems will concern 19% of the population and 17% of community, institutional and recreation features. Development of 5 sub-stations and autotransformer stations will contribute slightly to the visual impact. Construction impacts for reconstruction of 3

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 1 Electrifying the Georgetown corridor (including ARL)*
				bridges.
Economic	Cost-Effectiveness	Transportation Benefit:Cost Ratio (BCR)	0.4 : 1	Costs outweigh the benefits with Present Value Benefits of $169 million and Present Value Costs of $473 million, giving a Net Present Value -$303 million (2010 $)
		Cost per New Rider in 2031 ($m Capex/new daily passenger)	0.44	Total capital costs of $790 million (PV 2010) and a new user demand in 2031 of 1,900 passengers per day.
		Tonnes of GHG saved (from technology and modal shift) per annum per $10m capital cost	670	A measure of how cost effective the option is in delivering GHG reductions and contributing towards Metrolinx's emission reduction targets and addressing climate change. In 2031, 53,200 tonnes of GHG will be saved at the cost of $790 million.
		Long Term Economic (GDP+Wages) PV Benefits per $10m capital cost	3.2	GDP and wage benefits of $254 million over the evaluation period at the cost of $790 million (PV 2010 $)
	Land Use and Property Development	Qualitative assessment based on the influence on land use and potential for development	Slight Positive	Anticipated modest journey time improvements and limited noise and air quality improvements produces a significant positive impact on property development.
	Property / Land Take	Qualitative assessment based on the property/land required to implement the option	Slight Negative	The substations will require land take in the open areas adjacent to the rail corridor, however the quantifiable impact will depend on the final choice of locations.
	Wider Economic Impacts During Construction	Incremental GDP and wages due to construction ($m Real 2010 prices)	270 - 460	Construction will generate direct impacts of $150 million to $260 million in GDP.
		Number of regional jobs created due to construction (Employment-years)	2,100 - 3,500	The direct GDP can support 900 to 1,500 direct (but temporary) jobs associated with construction that will pay $60 million to $100 in aggregate wages.
	Wider Economic Impacts During Operations	Incremental GDP and wages in the long term due to improved transit times ($ per annum in 2031)	15	Industry that experiences part of the direct economic benefit will have a unique response in terms of how much a better functioning public transportation system affects their business outlook. Electrification will generate social benefits that can be compared in monetary terms, including valuing time savings and emission benefits.
		Number of regional jobs in the long term due to improved transit times (Employment-years in 2031)	160	
	Taxes	Effect/increased provincial and federal taxes in 2031 ($m per annum)	4	The key tax impacts analyzed are Harmonized Sales Tax and Personal Income Taxes, which reflect the purchases of goods and services and wages generated.
Financial	Capital Cost	Incremental Capital Cost ($m 2010 prices, i.e. excluding	790	The Total Incremental Capital Cost comprises of $706 million in Infrastructure Capital Costs and $84 million in Rolling Stock Capital Costs (both in 2010 prices) to procure 14 Electric Locomotives and 4

Category	Sub Category	Measure	Results	Performance – Option 1 Electrifying the Georgetown corridor (including ARL)
		inflation)		EMUs.
		Incremental Capital Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	580	
	Total Life Cycle Cost	Life Cycle Present Value Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	470	Taking into account: Infrastructure costs of $521.2, Rolling stock costs of $62, Operation and Maintenance Costs of -$88 and Revenue of -$22.6 (all prices PV 2010 $million)
	Operating Cost	Incremental Operating and Maintenance Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	-90	The cost savings in 2021 and 2031 will be $7 million and $10 million (both real prices) respectively. These are significant cost savings. The majority of the cost savings associated with electrification is due to the difference in costs spent on diesel and electricity.
	Total Revenues	Incremental revenues of the transit network ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	23	Assuming additional ridership can be accommodated, the greater the extent of electrification, the more additional riders and the greater the revenue generated for GO. 0.7 million passengers per year in 2031 are generated.
	Operating Sustainability	Reduction in Operating Subsidy in 2031 ($m Real 2010 prices per annum)	-15	GO can operate more cost-effectively with a reduced net operating cost, leading to a reduction in operating subsidy.
Deliverability	Constructability	Qualitative assessment of the construction constraints, techniques and impacts to transit users	Slight Negative	Taking into account: Space and accessibility, construction activity next to populated areas (short term noise, light pollution and dust), infrastructure affected and impacts on existing commuter services.
	Acceptability	Qualitative assessment of public and stakeholder (owner and operator) acceptance of each option	Slight Negative	A slight negative considering that 32% of services are electrified, 67% of track to be electrified is currently owned by GO and there are significant freight movements.

Table 51 Multiple Category Evaluation Scorecard – Option 2: Lakeshore (Excluding Hamilton TH+B and St Catharines)

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 2 Electrifying the Lakeshore excluding Hamilton TH+B and St Cat.*
Environmental and Health	Greenhouse Gas Emissions and Climate Change	Regional Greenhouse Gases Reductions - Qualitative assessment based on the overall impact on climate change	Slight Positive	The GHG emission inventory is a fraction of 1% of the GTHA's overall regional emission inventory from all sources.
		Percentage reduction in GO Rail's total GHG contributions (note: excludes modal shift emission reductions)	40%	Electrification could reduce GHG emissions by 136,000 tonnes per year. Furthermore, due to faster transit times and the reduction in highway journeys by private car, a further 5,400 tonnes of GHG per year can be saved.
	Regional Air Quality	Regional Air Quality - Qualitative assessment based on reduced CACs emitted by GO Rail to the region	Slight Positive	Option 2 produces an emission reduction of 135,986 Tonnes from the reference case, a fraction of 1% of the GTHA's overall regional emission inventory from all sources.
	Local Air Quality	Local Air Quality - Qualitative Assessment based on the impact on reduced CAC and the population who benefit from it	Slight Positive	Small positive health effects towards a population of 130,000 due to improved air quality. 1,120 additional transit users in the morning peak improving physical fitness.
		Value of Health Benefits due to Air Quality - reduction of GO Rail's contribution to regional smog ($m p.a. 2010 prices)	7	A small proportion (0.07%) of the overall health and environmental cost of air pollution in Ontario.
	Other Health	Physical Fitness - Qualitative assessment based on the number of additional transit users	Slight Positive	1,120 additional transit users in the morning peak improving physical fitness, a small proportion of the overall population of Greater Toronto.
		Electro-Magnetic Fields (EMF) - Qualitative assessment based on guidelines by the Institute of Electrical & Electronics Engineers	Neutral/No Impact	The EMF is expected to be well below the guidelines due to the overhead catenary system
		Qualitative assessment based on the change in safety hazard of the railway network after mitigation measures are in place	Neutral/No Impact	Appropriate measures have been proposed to mitigate any increase in risk to safety therefore, the overall safety assessment of all options is deemed neutral.
	Noise and Vibration	Noise - Qualitative assessment based on the change in noise levels and the population who benefit from it	Neutral/No Impact	Electrification produces negligible effect from imperceptible (< 2 dB) overall reductions affecting 250,362 people in 2021 (i.e., 11% less than the reference case)
		Vibration - Qualitative assessment based on the change in vibration levels and the population who benefit from it	Neutral/No Impact	Electrification produces reductions in perceptible vibration (< 1 dB) affecting 250,362 people in 2021 (i.e., 11% less than the reference case)
	Terrestrial Ecosystem	Qualitative assessment based on the impacts towards the terrestrial ecosystem's natural heritage	Slight Negative	Bridge replacements required in previously disturbed, urban areas therefore low impact anticipated on terrestrial ecosystem. Additional minor impacts may be caused with the construction of the sub-station(s).

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 2 Electrifying the Lakeshore excluding Hamilton TH+B and St Cat.*
	Aquatic Ecosystem	Qualitative assessment based on the impacts towards the aquatic ecosystem's natural heritage	Neutral/No Impact	Bridge replacements required which do not cross watercourses with the exception of two bridges that cross the Don River in Toronto. Therefore no impact anticipated on aquatic ecosystem.
	Effect on Parks / Public Open Space	Qualitative assessment based on the likely impacts towards parks and open spaces used by the local community	Neutral/No Impact	Deemed neutral due to lack of information on the final choice of sub-station locations.
User Benefits / Quality of Life	Transportation Efficiency	Average Journey Time Saving of Electric Train User (mins per passenger)	2.6	The time savings from Hamilton James to Union station would save passengers 6 minutes. The time savings from Bowmanville to Union station would save passengers 7 minutes.
		Total Journey Time Saving ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	334	Approximately 78.5 million passenger journeys per year benefit from an average of 2.6 minutes.
		Journey time benefits for highway users ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	75	The reduced journey time of electric locomotives creates a passenger transfer from auto to rail, by 930 trips in 2031 am peak period, reducing highway congestion and consequently improving journey time for highway users.
		Reduction in Auto operating costs ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	136	Reduced operating costs due to reduced auto km travelled; a reduction of 27 million auto km per annum in 2031.
		Reduction in vehicle collisions ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	20	Reduced collision costs due to reduced auto km travelled; a reduction of 27 million auto km per annum in 2031.
	Reliability	Passenger Reliability Benefits ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	3.1	The use of the more reliable electric trains avoids 17 rolling stock failures per annum.
	Transit Network/ System Access	Qualitative assessment based on the improvement of accessibility of transit	Neutral/No Impact	No specific measures are being promoted to improve the system access compared to the Reference Case.
	Comfort and Expandability	Qualitative assessment based on the change in crowding levels on the trains and GO's ability to expand capacity accordingly	Neutral/No Impact	No notable impact on passenger comfort. Electric trains have a greater potential to expand in capacity but there are no significant passenger capacity issues anticipated.
Social Community	Land Use Integration	Qualitative assessment based on how improved transit can help shape communities and link up key activity centres	Slight Positive	Improved journey times between key journey origins and destinations give a slight improvement in integrating the urban environment.
	Social and Community	Qualitative assessment based on the perceived impacts towards the local communities	Moderate Negative	The visual changes due to overhead catenary systems will concern 39% of the population and 36% of community, institutional and recreation features. Development of 5 sub-stations and autotransformer stations will contribute slightly to the visual impact. Construction impacts for reconstruction of 4

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 2 Electrifying the Lakeshore excluding Hamilton TH+B and St Cat.*
				bridges.
Economic	Cost-Effectiveness	Transportation Benefit:Cost Ratio (BCR)	1.1 : 1	Benefits outweigh the costs with Present Value Benefits of $518 million and Present Value Costs of $467 million, giving a Net Present Value $50 million (2010 $).
		Cost per New Rider in 2031 ($m Capex/new daily passenger)	0.26	Total capital costs of $1,158 million (PV 2010) and a new user demand in 2031 of 4,800 passengers per day.
		Tonnes of GHG saved (from technology and modal shift) per annum per $10m capital cost	1,220	A measure of how cost effective the option is in delivering GHG reductions and contributing towards Metrolinx's emission reduction targets and addressing climate change. In 2031, 141,400 tonnes of GHG will be saved at the cost of $1,158 million.
		Long Term Economic (GDP+Wages) PV Benefits per $10m capital cost	7.2	GDP and wage benefits of $832 million over the evaluation period at the cost of $1,158 million (PV 2010 $)
	Land Use and Property Development	Qualitative assessment based on the influence on land use and potential for development	Slight Positive	Anticipated modest journey time improvements and limited noise and air quality improvements produces a significant positive impact on property development.
	Property / Land Take	Qualitative assessment based on the property/land required to implement the option	Slight Negative	The substations will require land take in the open areas adjacent to the rail corridor, however the quantifiable impact will depend on the final choice of locations.
	Wider Economic Impacts During Construction	Incremental GDP and wages due to construction ($m Real 2010 prices)	310 - 500	Construction will generate direct impacts of $180 million to $280 million in GDP.
		Number of regional jobs created due to construction (Employment-years)	2,400 – 3,800	The direct GDP can support 1,000 to 1,600 direct (but temporary) jobs associated with construction that will pay $70 million to $110 in aggregate wages.
	Wider Economic Impacts During Operations	Incremental GDP and wages in the long term due to improved transit times ($ per annum in 2031)	49	Industry that experiences part of the direct economic benefit will have a unique response in terms of how much a better functioning public transportation system affects their business outlook. Electrification will generate social benefits that can be compared in monetary terms, including valuing time savings and emission benefits.
		Number of regional jobs in the long term due to improved transit times (Employment-years in 2031)	500	
	Taxes	Effect/increased provincial and federal taxes in 2031 ($m per annum)	14	The key tax impacts analyzed are Harmonized Sales Tax and Personal Income Taxes, which reflect the purchases of goods and services and wages generated.

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 2 Electrifying the Lakeshore excluding Hamilton TH+B and St Cat.*
Financial	Capital Cost	Incremental Capital Cost ($m 2010 prices, i.e. excluding inflation)	1,158	The Total Incremental Capital Cost comprises of $1,035 million in Infrastructure Capital Costs and $123 million in Rolling Stock Capital Costs (both in 2010 prices) to procure 29 Electric Locomotives.
		Incremental Capital Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	850	
	Total Life Cycle Cost	Life Cycle Present Value Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	470	Taking into account: Infrastructure costs of $763.5, Rolling stock costs of $90.9, Operation and Maintenance Costs of -$337.1 and Revenue of -$50 (all prices PV 2010 $million)
	Operating Cost	Incremental Operating and Maintenance Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	-340	The cost savings in 2021 and 2031 will be $26 million and $38 million (both real prices) respectively. These are significant cost savings. The majority of the cost savings associated with electrification is due to the difference in costs spent on diesel and electricity.
	Total Revenues	Incremental revenues of the transit network ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	50	Assuming additional ridership can be accommodated, the greater the extent of electrification, the more additional riders and the greater the revenue generated for GO. 1.8 million passengers per year in 2031 are generated.
	Operating Sustainability	Reduction in Operating Subsidy in 2031 ($m Real 2010 prices per annum)	-49	GO can operate more cost-effectively with a reduced net operating cost, leading to a reduction in operating subsidy.
Deliverability	Constructability	Qualitative assessment of the construction constraints, techniques and impacts to transit users	Moderate Negative	Taking into account: Space and accessibility, construction activity next to populated areas, infrastructure affected and impacts on existing commuter services.
	Acceptability	Qualitative assessment of public and stakeholder (owner and operator) acceptance of each option	Moderate Negative	A moderate negative considering that 30% of services are electrified, 50% of track to be electrified is currently owned by GO and there are significant freight movements.

Table 52 Multiple Category Evaluation Scorecard – Option 3: Georgetown and Lakeshore

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 3 Electrify Georgetown and Lakeshore*
Environmental and Health	Greenhouse Gas Emissions and Climate Change	Regional Greenhouse Gases Reductions - Qualitative assessment based on the overall impact on climate change	Slight Positive	The GHG emission inventory is a fraction of 1% of the GTHA's overall regional emission inventory from all sources.
		Percentage reduction in GO Rail's total GHG contributions (note: excludes modal shift emission reductions)	55%	Electrification could reduce GHG emissions by 187,500 tonnes per year. Furthermore, due to faster transit times and the reduction in highway journeys by private car, a further 7,100 tonnes of GHG per year can be saved.
	Regional Air Quality	Regional Air Quality - Qualitative assessment based on reduced CACs emitted by GO Rail to the region	Slight Positive	Option 3 produces an emission reduction of 187,532 Tonnes from the reference case, a fraction of 1% of the GTHA's overall regional emission inventory from all sources.
	Local Air Quality	Local Air Quality - Qualitative Assessment based on the impact on reduced CAC and the population who benefit from it	Moderate Positive	Small positive health effects towards a population of 200,000 due to improved air quality. 1,570 additional transit users in the morning peak improving physical fitness.
		Value of Health Benefits due to Air Quality - reduction of GO Rail's contribution to regional smog ($m p.a. 2010 prices)	11	A small proportion (0.11%) of the overall health and environmental cost of air pollution in Ontario.
	Other Health	Physical Fitness - Qualitative assessment based on the number of additional transit users	Slight Positive	1,570 additional transit users in the morning peak improving physical fitness, a small proportion of the overall population of Greater Toronto.
		Electro-Magnetic Fields (EMF) - Qualitative assessment based on guidelines by the Institute of Electrical & Electronics Engineers	Neutral/No Impact	The EMF is expected to be well below the guidelines due to the overhead catenary system
		Qualitative assessment based on the change in safety hazard of the railway network after mitigation measures are in place	Neutral/No Impact	Appropriate measures have been proposed to mitigate any increase in risk to safety therefore, the overall safety assessment of all options is deemed neutral.
	Noise and Vibration	Noise - Qualitative assessment based on the change in noise levels and the population who benefit from it	Neutral/No Impact	Electrification produces negligible effect from imperceptible (< 2 dB) overall reductions affecting 236,423 people in 2021 (i.e., 16% less than the reference case)
		Vibration - Qualitative assessment based on the change in vibration levels and the population who benefit from it	Neutral/No Impact	Electrification produces negligible reductions in perceptible vibration (< 1 dB) affecting 236,423 people in 2021 (i.e., 16% less than the reference case)
	Terrestrial Ecosystem	Qualitative assessment based on the impacts towards the terrestrial ecosystem's natural heritage	Slight Negative	Bridge replacements required in previously disturbed, urban areas therefore low impact anticipated on terrestrial ecosystem. Additional minor impacts may be caused with the construction of the sub-station(s).

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 3 Electrify Georgetown and Lakeshore*
	Aquatic Ecosystem	Qualitative assessment based on the impacts towards the aquatic ecosystem's natural heritage	Neutral/No Impact	Bridge replacements required which do not cross watercourses with the exception of two bridges that cross the Don River in Toronto. Therefore no impact anticipated on aquatic ecosystem.
	Effect on Parks / Public Open Space	Qualitative assessment based on the likely impacts towards parks and open spaces used by the local community	Neutral/No Impact	Deemed neutral due to lack of information on the final choice of sub-station locations.
User Benefits / Quality of Life	Transportation Efficiency	Average Journey Time Saving of Electric Train User (mins per passenger)	2.7	The time savings from Georgetown to Union station and Hamilton James to Union station would save passengers 6 minutes. The time savings from Bowmanville to Union station would save passengers 7 minutes.
		Total Journey Time Saving ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	456	Approximately 79.1 million passenger journeys per year benefit from an average of 2.7 minutes.
		Journey time benefits for highway users ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	98	The reduced journey time of electric locomotives creates a passenger transfer from auto to rail, by 1,310 trips in 2031 am peak period, reducing highway congestion and consequently improving journey time for highway users.
		Reduction in Auto operating costs ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	176	Reduced operating costs due to reduced auto km covered; a reduction of 35 million auto km per annum in 2031.
		Reduction in vehicle collisions ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	26	Reduced collision costs due to reduced auto km covered; a reduction of 35 million auto km per annum in 2031.
	Reliability	Passenger Reliability Benefits ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	3.9	The use of the more reliable electric trains avoids 25 rolling stock failures per annum.
	Transit Network/ System Access	Qualitative assessment based on the improvement of accessibility of transit	Neutral/No Impact	No specific measures are being promoted to improve the system access compared to the Reference Case.
	Comfort and Expandability	Qualitative assessment based on the change in crowding levels on the trains and GO's ability to expand capacity accordingly	Neutral/No Impact	No notable impact on passenger comfort. Electric trains have a greater potential to expand in capacity but there are no significant passenger capacity issues anticipated.
Social Community	Land Use Integration	Qualitative assessment based on how improved transit can help shape communities and link up key activity centres	Slight Positive	Improved journey times between key journey origins and destinations give a slight improvement in integrating the urban environment.
	Social and Community	Qualitative assessment based on the perceived impacts towards the local communities	Moderate Negative	The visual changes due to overhead catenary systems will concern 55% of the population and 50% of community, institutional and recreation features. Development of 10 sub-stations and autotransformer stations will contribute slightly to the visual impact. Construction impacts for

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 3 Electrify Georgetown and Lakeshore*
				reconstruction of 4 bridges.
Economic	Cost-Effectiveness	Transportation Benefit: Cost Ratio (BCR)	0.9 : 1	Costs outweigh the benefits with Present Value Benefits of $687 million and Present Value Costs of $731 million, giving a Net Present Value -$44 million (2010 $).
		Cost per New Rider in 2031 ($m Capex/new daily passenger)	0.27	Total capital costs of $1,664 million (PV 2010) and a new user demand in 2031 of 6,800 passengers per day.
		Tonnes of GHG saved (from technology and modal shift) per annum per $10m capital cost	1,170	A measure of how cost effective the option is in delivering GHG reductions and contributing towards Metrolinx's emission reduction targets and addressing climate change. In 2031, 194,600 tonnes of GHG will be saved at the cost of $1,664 million.
		Long Term Economic (GDP+Wages) PV Benefits per $10m capital cost	6.5	GDP and wage benefits of $1080 million over the evaluation period at the cost of $1,664 million (PV 2010 $)
	Land Use and Property Development	Qualitative assessment based on the influence on land use and potential for development	Slight Positive	Anticipated modest journey time improvements and limited noise and air quality improvements produces a significant positive impact on property development.
	Property / Land Take	Qualitative assessment based on the property/land required to implement the option	Slight Negative	The substations will require land take in the open areas adjacent to the rail corridor, however the quantifiable impact will depend on the final choice of locations.
	Wider Economic Impacts During Construction	Incremental GDP and wages due to construction ($m Real 2010 prices)	470 – 760	Construction will generate direct impacts of $290 million to $420 million in GDP.
		Number of regional jobs created due to construction (Employment-years)	3,600 – 5,800	The direct GDP can support 1,600 to 2,400 direct (but temporary) jobs associated with construction that will pay $110 million to $160 in aggregate wages.
	Wider Economic Impacts During Operations	Incremental GDP and wages in the long term due to improved transit times ($ per annum in 2031)	64	Industry that experiences part of the direct economic benefit will have a unique response in terms of how much a better functioning public transportation system affects their business outlook. Electrification will generate social benefits that can be compared in monetary terms, including valuing time savings and emission benefits.
		Number of regional jobs in the long term due to improved transit times (Employment-years in 2031)	660	
	Taxes	Effect/increased provincial and federal taxes in 2031 ($m per annum)	19	The key tax impacts analyzed are Harmonized Sales Tax and Personal Income Taxes, which reflect the purchases of goods and services and wages generated.

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 3 Electrify Georgetown and Lakeshore*
Financial	Capital Cost	Incremental Capital Cost ($m 2010 prices, i.e. excluding inflation)	1,664	The Total Incremental Capital Cost comprises of $1,476 million in Infrastructure Capital Costs and $188 million in Rolling Stock Capital Costs (both in 2010 prices) to procure 43 Electric Locomotives and 4 EMUs.
		Incremental Capital Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	1,230	
	Total Life Cycle Cost	Life Cycle Present Value Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	730	Taking into account: Infrastructure costs of $1,089, Rolling stock costs of $138.9, Operation and Maintenance Costs of -$424.5 and Revenue of -$72.6 (all prices PV 2010 $million)
	Operating Cost	Incremental Operating and Maintenance Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	-420	The cost savings in 2021 and 2031 will be $33 million and $48 million (both real prices) respectively. These are significant cost savings. The majority of the cost savings associated with electrification is due to the difference in costs spent on diesel and electricity.
	Total Revenues	Incremental revenues of the transit network ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	73	Assuming additional ridership can be accommodated, the greater the extent of electrification, the more additional riders and the greater the revenue generated for GO. 2.5 million passengers per year in 2031 are generated.
	Operating Sustainability	Reduction in Operating Subsidy in 2031 ($m Real 2010 prices per annum)	-64	GO can operate more cost-effectively with a reduced net operating cost, leading to a reduction in operating subsidy.
Deliverability	Constructability	Qualitative assessment of the construction constraints, techniques and impacts to transit users	Moderate Negative	Taking into account: Space and accessibility, construction activity next to populated areas, infrastructure affected and impacts on existing commuter services.
	Acceptability	Qualitative assessment of public and stakeholder (owner and operator) acceptance of each option	Moderate Negative	A moderate negative considering that 62% of services are electrified, 50% of track to be electrified is currently owned by GO and there are significant freight movements.

Table 53 Multiple Category Evaluation Scorecard – Option 11: Georgetown, Lakeshore and Milton

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 11 Electrify Georgetown, Lakeshore and Milton*
Environmental and Health	Greenhouse Gas Emissions and Climate Change	Regional Greenhouse Gases Reductions - Qualitative assessment based on the overall impact on climate change	Slight Positive	The GHG emission inventory is a fraction of 1% of the GTHA's overall regional emission inventory from all sources.
		Percentage reduction in GO Rail's total GHG contributions (note: excludes modal shift emission reductions)	64%	Electrification could reduce GHG emissions by 217,400 tonnes per year. Furthermore, due to faster transit times and the reduction in highway journeys by private car, a further 8,400 tonnes of GHG per year can be saved.
	Regional Air Quality	Regional Air Quality - Qualitative assessment based on reduced CACs emitted by GO Rail to the region	Slight Positive	Option 11 produces an emission reduction of 217,421 Tonnes from the reference case, a fraction of 1% of the GTHA's overall regional emission inventory from all sources.
	Local Air Quality	Local Air Quality - Qualitative Assessment based on the impact on reduced CAC and the population who benefit from it	Moderate Positive	Small positive health effects towards a population of 250,000 due to improved air quality. 1,910 additional transit users in the morning peak improving physical fitness.
		Value of Health Benefits due to Air Quality - reduction of GO Rail's contribution to regional smog ($m p.a. 2010 prices)	13	A small proportion (0.13%) of the overall health and environmental cost of air pollution in Ontario.
	Other Health	Physical Fitness - Qualitative assessment based on the number of additional transit users	Slight Positive	1,910 additional transit users in the morning peak improving physical fitness, a small proportion of the overall population of Greater Toronto.
		Electro-Magnetic Fields (EMF) - Qualitative assessment based on guidelines by the Institute of Electrical & Electronics Engineers	Neutral/No Impact	The EMF is expected to be well below the guidelines due to the overhead catenary system
		Qualitative assessment based on the change in safety hazard of the railway network after mitigation measures are in place	Neutral/No Impact	Appropriate measures have been proposed to mitigate any increase in risk to safety therefore, the overall safety assessment of all options is deemed neutral.
	Noise and Vibration	Noise - Qualitative assessment based on the change in noise levels and the population who benefit from it	Neutral/No Impact	Electrification produces negligible effect from imperceptible (< 2 dB) overall reductions affecting 214,476 people in 2021 (i.e., 24% less than the reference case)
		Vibration - Qualitative assessment based on the change in vibration levels and the population who benefit from it	Neutral/No Impact	Electrification produces negligible reductions in perceptible vibration (< 1 dB) affecting 214,476 people in 2021 (i.e., 24% less than the reference case)
	Terrestrial Ecosystem	Qualitative assessment based on the impacts towards the terrestrial ecosystem's natural heritage	Slight Negative	Bridge replacements required in previously disturbed, urban areas therefore low impact anticipated on terrestrial ecosystem. Additional minor impacts may be caused with the construction of the sub-station(s).

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 11 Electrify Georgetown, Lakeshore and Milton*
	Aquatic Ecosystem	Qualitative assessment based on the impacts towards the aquatic ecosystem's natural heritage	Neutral/No Impact	Bridge replacements required which do not cross watercourses with the exception of two bridges that cross the Don River in Toronto. Therefore no impact anticipated on aquatic ecosystem.
	Effect on Parks / Public Open Space	Qualitative assessment based on the likely impacts towards parks and open spaces used by the local community	Neutral/No Impact	Deemed neutral due to lack of information on the final choice of sub-station locations.
User Benefits / Quality of Life	Transportation Efficiency	Average Journey Time Saving of Electric Train User (mins per passenger)	2.5	The time savings from Milton to Union station would save passengers 4 minutes.
		Total Journey Time Saving ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	541	Approximately 79.5 million passenger journeys per year benefit from an average of 2.5 minutes.
		Journey time benefits for highway users ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	117	The reduced journey time of electric locomotives creates a passenger transfer from auto to rail, by 1,590 trips in 2031 am peak period, reducing highway congestion and consequently improving journey time for highway users.
		Reduction in Auto operating costs ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	209	Reduced operating costs due to reduced auto km covered; a reduction of 42 million auto km per annum in 2031.
		Reduction in vehicle collisions ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	30	Reduced collision costs due to reduced auto km covered; a reduction of 42 million auto km per annum in 2031.
	Reliability	Passenger Reliability Benefits ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	5.0	The use of the more reliable electric trains avoids 30 rolling stock failures per annum.
	Transit Network/ System Access	Qualitative assessment based on the improvement of accessibility of transit	Neutral/No Impact	No specific measures are being promoted to improve the system access compared to the Reference.
	Comfort and Expandability	Qualitative assessment based on the change in crowding levels on the trains and GO's ability to expand capacity accordingly	Neutral/No Impact	No notable impact on passenger comfort. Electric trains have a greater potential to expand in capacity but there are no significant passenger capacity issues anticipated.
Social Community	Land Use Integration	Qualitative assessment based on how improved transit can help shape communities and link up key activity centres	Slight Positive	Improved journey times between key journey origins and destinations give a slight improvement in integrating the urban environment.
	Social and Community	Qualitative assessment based on the perceived impacts towards the local communities	Moderate Negative	The visual changes due to overhead catenary systems will concern 57% of the population and 51% of community, institutional and recreation features. Development of a bridge and 13 sub-stations and autotransformer stations will contribute slightly to the visual impact. Construction impacts for

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 11 Electrify Georgetown, Lakeshore and Milton*
				reconstruction of 4 bridges.
Economic	Cost-Effectiveness	Transportation Benefit:Cost Ratio (BCR)	0.9 : 1	Costs outweigh the benefits with Present Value Benefits of $816 million and Present Value Costs of $871 million, giving a Net Present Value -$55 million (2010 $).
		Cost per New Rider in 2031 ($m Capex/new daily passenger)	0.26	Total capital costs of $1,983 million (PV 2010) and a new user demand in 2031 of 8,200 passengers per day.
		Tonnes of GHG saved (from technology and modal shift) per annum per $10m capital cost	1,140	A measure of how cost effective the option is in delivering GHG reductions and contributing towards Metrolinx's emission reduction targets and addressing climate change. In 2031, 225,800 tonnes of GHG will be saved at the cost of $1,983 million.
		Long Term Economic (GDP+Wages) PV Benefits per $10m capital cost	6.4	GDP and wage benefits of $1262 million over the evaluation period at the cost of $1,983 million (PV 2010 $)
	Land Use and Property Development	Qualitative assessment based on the influence on land use and potential for development	Slight Positive	Anticipated modest journey time improvements and limited noise and air quality improvements produces a significant positive impact on property development.
	Property / Land Take	Qualitative assessment based on the property/land required to implement the option	Slight Negative	The substations will require land take in the open areas adjacent to the rail corridor, however the quantifiable impact will depend on the final choice of locations.
	Wider Economic Impacts During Construction	Incremental GDP and wages due to construction ($m Real 2010 prices)	570 – 870	Construction will generate direct impacts of $320 million to $490 million in GDP.
		Number of regional jobs created due to construction (Employment-years)	4,500 – 6,800	The direct GDP can support 1,900 to 2,800 direct (but temporary) jobs associated with construction that will pay $120 million to $190 in aggregate wages.
	Wider Economic Impacts During Operations	Incremental GDP and wages in the long term due to improved transit times ($ per annum in 2031)	74	Industry that experiences part of the direct economic benefit will have a unique response in terms of how much a better functioning public transportation system affects their business outlook. Electrification will generate social benefits that can be compared in monetary terms, including valuing time savings and emission benefits.
		Number of regional jobs in the long term due to improved transit times (Employment-years in 2031)	770	
	Taxes	Effect/increased provincial and federal taxes in 2031 ($m per annum)	22	The key tax impacts analyzed are Harmonized Sales Tax and Personal Income Taxes, which reflect the purchases of goods and services and wages generated.

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 11 Electrify Georgetown, Lakeshore and Milton*
Financial	Capital Cost	Incremental Capital Cost ($m 2010 prices, i.e. excluding inflation)	1,983	The Total Incremental Capital Cost comprises of $1,695 million in Infrastructure Capital Costs and $288 million in Rolling Stock Capital Costs (both in 2010 prices) to procure 54 Electric Locomotives and 4 EMUs.
		Incremental Capital Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	1,460	
	Total Life Cycle Cost	Life Cycle Present Value Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	870	Taking into account: Infrastructure costs of $1,250.7, Rolling stock costs of $212.4, Operation and Maintenance Costs of -$505.9 and Revenue of -$85.9 (all prices PV 2010 $million)
	Operating Cost	Incremental Operating and Maintenance Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	-510	The cost savings in 2021 and 2031 will be $39 million and $57 million (both real prices) respectively. These are significant cost savings. The majority of the cost savings associated with electrification is due to the difference in costs spent on diesel and electricity.
	Total Revenues	Incremental revenues of the transit network ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	86	Assuming additional ridership can be accommodated, the greater the extent of electrification, the more additional riders and the greater the revenue generated for GO. 3.0 million passengers per year in 2031 are generated.
	Operating Sustainability	Reduction in Operating Subsidy in 2031 ($m Real 2010 prices per annum)	-76	GO can operate more cost-effectively with a reduced net operating cost, leading to a reduction in operating subsidy.
Deliverability	Constructability	Qualitative assessment of the construction constraints, techniques and impacts to transit users	Moderate Negative	Taking into account: Space and accessibility, construction activity next to populated areas, infrastructure affected and impacts on existing commuter services.
	Acceptability	Qualitative assessment of public and stakeholder (owner and operator) acceptance of each option	Moderate Negative	A moderate negative considering that 71% of services are electrified, 46% of track to be electrified is currently owned by GO and there are significant freight movements.

Table 54 Multiple Category Evaluation Scorecard – Option 15: Georgetown, Lakeshore, Milton and Barrie

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 15 Electrify Georgetown, Lakeshore, Milton and Barrie*
Environmental and Health	Greenhouse Gas Emissions and Climate Change	Regional Greenhouse Gases Reductions - Qualitative assessment based on the overall impact on climate change	Slight Positive	The GHG emission inventory is a fraction of 1% of the GTHA's overall regional emission inventory from all sources.
		Percentage reduction in GO Rail's total GHG contributions (note: excludes modal shift emission reductions)	78%	Electrification could reduce GHG emissions by 263,800 tonnes per year. Furthermore, due to faster transit times and the reduction in highway journeys by private car, a further 9,800 tonnes of GHG per year can be saved.
	Regional Air Quality	Regional Air Quality - Qualitative assessment based on reduced CACs emitted by GO Rail to the region	Slight Positive	Option 15 produces an emission reduction of 263,842 Tonnes from the reference case, a fraction of 1% of the GTHA's overall regional emission inventory from all sources.
	Local Air Quality	Local Air Quality - Qualitative Assessment based on the impact on reduced CAC and the population who benefit from it	Moderate Positive	Small positive health effects towards a population of 280,000 due to improved air quality. 2,120 additional transit users in the morning peak improving physical fitness.
		Value of Health Benefits due to Air Quality - reduction of GO Rail's contribution to regional smog ($m p.a. 2010 prices)	15	A small proportion (0.16%) of the overall health and environmental cost of air pollution in Ontario.
	Other Health	Physical Fitness - Qualitative assessment based on the number of additional transit users	Slight Positive	2,120 additional transit users in the morning peak improving physical fitness, a small proportion of the overall population of Greater Toronto.
		Electro-Magnetic Fields (EMF) - Qualitative assessment based on guidelines by the Institute of Electrical & Electronics Engineers	Neutral/No Impact	The EMF is expected to be well below the guidelines due to the overhead catenary system
		Qualitative assessment based on the change in safety hazard of the railway network after mitigation measures are in place	Neutral/No Impact	Appropriate measures have been proposed to mitigate any increase in risk to safety therefore, the overall safety assessment of all options is deemed neutral.
	Noise and Vibration	Noise - Qualitative assessment based on the change in noise levels and the population who benefit from it	Slight Positive	Electrification produces slight benefit from just perceptible (i.e. 2-3 dB) overall reductions affecting 206,116 people in 2021 (i.e., 27% less than the reference case)
		Vibration - Qualitative assessment based on the change in vibration levels and the population who benefit from it	Slight Positive	Electrification produces slight benefit from minor reductions in perceptible vibration (i.e. 2-3 dB) affecting 206,116 people in 2021 (i.e., 27% less than the reference case)
	Terrestrial Ecosystem	Qualitative assessment based on the impacts towards the terrestrial ecosystem's natural heritage	Slight Negative	Bridge replacements required in previously disturbed, urban areas therefore low impact anticipated on terrestrial ecosystem. Additional minor impacts may be caused with the construction of the sub-station(s).

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 15 Electrify Georgetown, Lakeshore, Milton and Barrie*
	Aquatic Ecosystem	Qualitative assessment based on the impacts towards the aquatic ecosystem's natural heritage	Neutral/No Impact	Bridge replacements required which do not cross watercourses with the exception of two bridges that cross the Don River in Toronto. Therefore no impact anticipated on aquatic ecosystem.
	Effect on Parks / Public Open Space	Qualitative assessment based on the likely impacts towards parks and open spaces used by the local community	Neutral/No Impact	Deemed neutral due to lack of information on the final choice of sub-station locations.
User Benefits / Quality of Life	Transportation Efficiency	Average Journey Time Saving of Electric Train User (mins per passenger)	2.5	The time savings from Allandale to Union station would save passengers 5 minutes.
		Total Journey Time Saving ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	617	Approximately 79.8 million passenger journeys per year benefit from an average of 2.5 minutes.
		Journey time benefits for highway users ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	135	The reduced journey time of electric locomotives creates a passenger transfer from auto to rail, by 1,770 trips in 2031 am peak period, reducing highway congestion and consequently improving journey time for highway users.
		Reduction in Auto operating costs ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	242	Reduced operating costs due to reduced auto km covered; a reduction of 49 million auto km per annum in 2031.
		Reduction in vehicle collisions ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	35	Reduced collision costs due to reduced auto km covered; a reduction of 49 million auto km per annum in 2031.
	Reliability	Passenger Reliability Benefits ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	6.1	The use of the more reliable electric trains avoids 36 rolling stock failures per annum.
	Transit Network/ System Access	Qualitative assessment based on the improvement of accessibility of transit	Neutral/No Impact	No specific measures are being promoted to improve the system access compared to the Reference Case.
	Comfort and Expandability	Qualitative assessment based on the change in crowding levels on the trains and GO's ability to expand capacity accordingly	Neutral/No Impact	No notable impact on passenger comfort. Electric trains have a greater potential to expand in capacity but there are no significant passenger capacity issues anticipated.
Social Community	Land Use Integration	Qualitative assessment based on how improved transit can help shape communities and link up key activity centres	Slight Positive	Improved journey times between key journey origins and destinations give a slight improvement in integrating the urban environment.
	Social and Community	Qualitative assessment based on the perceived impacts towards the local communities	Slight Negative	Some noise and vibration benefits due to electrification. The visual changes due to overhead catenary systems will concern 63% of the population and 60% of community, institutional and recreation features. Development of a bridge and 17 sub-stations and autotransformer stations

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 15 Electrify Georgetown, Lakeshore, Milton and Barrie*
				will contribute slightly to the visual impact. Construction impacts for reconstruction of 4 bridges.
Economic	Cost-Effectiveness	Transportation Benefit:Cost Ratio (BCR)	0.8 : 1	Costs outweigh the benefits with Present Value Benefits of $939 million and Present Value Costs of $1,204 million, giving a Net Present Value -$265 million (2010 $).
		Cost per New Rider in 2031 ($m Capex/new daily passenger)	0.30	Total capital costs of $2,568 million (PV 2010) and a new user demand in 2031 of 9,200 passengers per day.
		Tonnes of GHG saved (from technology and modal shift) per annum per $10m capital cost	1,060	A measure of how cost effective the option is in delivering GHG reductions and contributing towards Metrolinx's emission reduction targets and addressing climate change. In 2031, 273,600 tonnes of GHG will be saved at the cost of $2,568 million.
		Long Term Economic (GDP+Wages) PV Benefits per $10m capital cost	5.7	GDP and wage benefits of $1471 million over the evaluation period at the cost of $2,568 million (PV 2010 $)
	Land Use and Property Development	Qualitative assessment based on the influence on land use and potential for development	Slight Positive	Anticipated modest journey time improvements and limited noise and air quality improvements produces a significant positive impact on property development.
	Property / Land Take	Qualitative assessment based on the property/land required to implement the option	Slight Negative	The substations will require land take in the open areas adjacent to the rail corridor, however the quantifiable impact will depend on the final choice of locations.
	Wider Economic Impacts During Construction	Incremental GDP and wages due to construction ($m Real 2010 prices)	680 – 1,060	Construction will generate direct impacts of $380 million to $590 million in GDP.
		Number of regional jobs created due to construction (Employment-years)	5,200 – 8,200	The direct GDP can support 2,200 to 3,400 direct (but temporary) jobs associated with construction that will pay $150 million to $230 in aggregate wages.
	Wider Economic Impacts During Operations	Incremental GDP and wages in the long term due to improved transit times ($ per annum in 2031)	87	Industry that experiences part of the direct economic benefit will have a unique response in terms of how much a better functioning public transportation system affects their business outlook. Electrification will generate social benefits that can be compared in monetary terms, including valuing time savings and emission benefits.
		Number of regional jobs in the long term due to improved transit times (Employment-years in 2031)	890	
	Taxes	Effect/increased provincial and federal taxes in 2031 ($m per annum)	25	The key tax impacts analyzed are Harmonized Sales Tax and Personal Income Taxes, which reflect the purchases of goods and services and wages generated.

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 15 Electrify Georgetown, Lakeshore, Milton and Barrie*
Financial	Capital Cost	Incremental Capital Cost ($m 2010 prices, i.e. excluding inflation)	2,568	The Total Incremental Capital Cost comprises of $2,147 million in Infrastructure Capital Costs and $421 million in Rolling Stock Capital Costs (both in 2010 prices) to procure 65 Electric Locomotives and 4 EMUs.
		Incremental Capital Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	1,890	
	Total Life Cycle Cost	Life Cycle Present Value Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	1,200	Taking into account: Infrastructure costs of $1,584.3, Rolling stock costs of $310.4, Operation and Maintenance Costs of -$594.7 and Revenue of -$96.1 (all prices PV 2010 $million)
	Operating Cost	Incremental Operating and Maintenance Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	-590	The cost savings in 2021 and 2031 will be $45 million and $67 million (both real prices) respectively. These are significant cost savings. The majority of the cost savings associated with electrification is due to the difference in costs spent on diesel and electricity.
	Total Revenues	Incremental revenues of the transit network ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	96	Assuming additional ridership can be accommodated, the greater the extent of electrification, the more additional riders and the greater the revenue generated for GO. 3.4 million passengers per year in 2031 are generated.
	Operating Sustainability	Reduction in Operating Subsidy in 2031 ($m Real 2010 prices per annum)	-88	GO can operate more cost-effectively with a reduced net operating cost, leading to a reduction in operating subsidy.
Deliverability	Constructability	Qualitative assessment of the construction constraints, techniques and impacts to transit users	Strong Negative	Taking into account: Space and accessibility, construction activity next to populated areas, infrastructure affected and impacts on existing commuter services.
	Acceptability	Qualitative assessment of public and stakeholder (owner and operator) acceptance of each option	Strong Negative	A strong negative considering that 80% of services are electrified, 52% of track to be electrified is currently owned by GO and there are significant freight movements.

Table 55 Multiple Category Evaluation Scorecard – Option 18: Full Network (Including Hamilton TH+B and St Catharines)

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 18 Electrify the Entire Network (Incl. Hamilton TH+B and St Catharines)*
Environmental and Health	Greenhouse Gas Emissions and Climate Change	Regional Greenhouse Gases Reductions - Qualitative assessment based on the overall impact on climate change	Slight Positive	The GHG emission inventory is a fraction of 1% of the GTHA's overall regional emission inventory from all sources.
		Percentage reduction in GO Rail's total GHG contributions (note: excludes modal shift emission reductions)	94%	Electrification could reduce GHG emissions by 319,300 tonnes per year. Furthermore, due to faster transit times and the reduction in highway journeys by private car, a further 11,100 tonnes of GHG per year can be saved.
	Regional Air Quality	Regional Air Quality - Qualitative assessment based on reduced CACs emitted by GO Rail to the region	Slight Positive	Option 18 produces an emission reduction of 319,292 Tonnes from the reference case, a fraction of 1% of the GTHA's overall regional emission inventory from all sources.
	Local Air Quality	Local Air Quality - Qualitative Assessment based on the impact on reduced CAC and the population who benefit from it	Moderate Positive	Small positive health effects towards a population of 330,000 due to improved air quality. 2,400 additional transit users in the morning peak improving physical fitness.
		Value of Health Benefits due to Air Quality - reduction of GO Rail's contribution to regional smog ($m p.a. 2010 prices)	18	A small proportion (0.19%) of the overall health and environmental cost of air pollution in Ontario.
		Physical Fitness - Qualitative assessment based on the number of additional transit users	Slight Positive	2,400 additional transit users in the morning peak improving physical fitness, a small proportion of the overall population of Greater Toronto.
	Other Health	Electro-Magnetic Fields (EMF) - Qualitative assessment based on guidelines by the Institute of Electrical & Electronics Engineers	Neutral/No Impact	The EMF is expected to be well below the guidelines due to the overhead catenary system
		Qualitative assessment based on the change in safety hazard of the railway network after mitigation measures are in place	Neutral/No Impact	Appropriate measures have been proposed to mitigate any increase in risk to safety therefore, the overall safety assessment of all options is deemed neutral.
	Noise and Vibration	Noise - Qualitative assessment based on the change in noise levels and the population who benefit from it	Slight Positive	Electrification produces slight benefit from just perceptible (i.e. 2-3 dB) overall reductions affecting 182,489 people in 2021 (i.e., 35% less than the reference case)

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 18 Electrify the Entire Network (Incl. Hamilton TH+B and St Catharines)*
		Vibration - Qualitative assessment based on the change in vibration levels and the population who benefit from it	Slight Positive	Electrification produces slight benefit from minor reductions in perceptible vibration (i.e., 2-3 dB) affecting 182,489 people in 2021 (i.e., 35% less than the reference case)
	Terrestrial Ecosystem	Qualitative assessment based on the impacts towards the terrestrial ecosystem's natural heritage	Slight Negative	Bridge replacements required in previously disturbed, urban areas therefore low impact anticipated on terrestrial ecosystem. Additional minor impacts may be caused with the construction of the sub-station(s).
	Aquatic Ecosystem	Qualitative assessment based on the impacts towards the aquatic ecosystem's natural heritage	Slight Negative	Bridge replacements required which do not cross watercourses with the exception of two bridges that cross the Don River in Toronto. Therefore slight impact anticipated on aquatic ecosystem.
	Effect on Parks / Public Open Space	Qualitative assessment based on the likely impacts towards parks and open spaces used by the local community	Neutral/No Impact	Deemed neutral due to lack of information on the final choice of sub-station locations.
User Benefits / Quality of Life	Transportation Efficiency	Average Journey Time Saving of Electric Train User (mins per passenger)	2.4	The time savings from Bloomington to Union station would save passengers 1 minute. The time savings from Lincolnville to Union station would save passengers 2 minutes.
		Total Journey Time Saving ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	692	Approximately 80.2 million passenger journeys per year benefit from an average of 2.4 minutes.
		Journey time benefits for highway users ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	153	The reduced journey time of electric locomotives creates a passenger transfer from auto to rail, by 2,000 trips in 2031 am peak period, reducing highway congestion and consequently improving journey time for highway users.
		Reduction in Auto operating costs ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	275	Reduced operating costs due to reduced auto km covered; a reduction of 55 million auto km per annum in 2031.
		Reduction in vehicle collisions ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	40	Reduced collision costs due to reduced auto km covered; a reduction of 55 million auto km per annum in 2031.
	Reliability	Passenger Reliability Benefits ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	7.2	The use of the more reliable electric trains avoids 44 rolling stock failures per annum.

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 18 Electrify the Entire Network (Incl. Hamilton TH+B and St Catharines)*
	Transit Network/ System Access	Qualitative assessment based on the improvement of accessibility of transit	Neutral/No Impact	No specific measures are being promoted to improve the system access compared to the Reference.
	Comfort and Expandability	Qualitative assessment based on the change in crowding levels on the trains and GO's ability to expand capacity accordingly	Neutral/No Impact	No notable impact on passenger comfort. Electric trains have a greater potential to expand in capacity but there are no significant passenger capacity issues anticipated.
Social Community	Land Use Integration	Qualitative assessment based on how improved transit can help shape communities and link up key activity centres	Slight Positive	Improved journey times between key journey origins and destinations give a slight improvement in integrating the urban environment.
	Social and Community	Qualitative assessment based on the perceived impacts towards the local communities	Moderate Negative	Some noise and vibration benefits due to electrification. The visual changes due to overhead catenary systems will concern 70% of the population and 69% of community, institutional and recreation features. Development of 6 bridges, a major tunnel and 25 sub-stations and autotransformer stations will contribute to the visual impact. Construction impacts for reconstruction of 9 bridges and a tunnel.
Economic	Cost-Effectiveness	Transportation Benefit:Cost Ratio (BCR)	0.5 : 1	Costs outweigh the benefits with Present Value Benefits of $1,058 million and Present Value Costs of $2,106 million, giving a Net Present Value -$1,048 million (2010 $).
		Cost per New Rider in 2031 ($m Capex/new daily passenger)	0.41	Total capital costs of $3,946 million (PV 2010) and a new user demand in 2031 of 10,400 passengers per day.
		Tonnes of GHG saved (from technology and modal shift) per annum per $10m capital cost	840	A measure of how cost effective the option is in delivering GHG reductions and contributing towards Metrolinx's emission reduction targets and addressing climate change. In 2031, 330,400 tonnes of GHG will be saved at the cost of $3,946 million.
		Long Term Economic (GDP+Wages) PV Benefits per $10m capital cost	4.2	GDP and wage benefits of $1,646 million over the evaluation period at the cost of $3,946 million (PV 2010 $)
	Land Use and Property Development	Qualitative assessment based on the influence on land use and potential for development	Slight Positive	Anticipated modest journey time improvements and limited noise and air quality improvements produces a significant positive impact on property development.
	Property / Land Take	Qualitative assessment based on the property/land required to implement the option	Slight Negative	The substations will require land take in the open areas adjacent to the rail corridor, however the quantifiable impact will depend on the final choice of locations.

Category	Sub Category	Measure	Results	Performance – Option 18 Electrify the Entire Network (Incl. Hamilton TH+B and St Catharines)
	Wider Economic Impacts During Construction	Incremental GDP and wages due to construction ($m Real 2010 prices)	1,210 – 1,850	Construction will generate direct impacts of $660 million to $1,000 million in GDP.
		Number of regional jobs created due to construction (Employment-years)	9,700 – 14,800	The direct GDP can support 4,100 to 6,200 direct (but temporary) jobs associated with construction that will pay $270 million to $400 in aggregate wages.
	Wider Economic Impacts During Operations	Incremental GDP and wages in the long term due to improved transit times ($ per annum in 2031)	97	Industry that experiences part of the direct economic benefit will have a unique response in terms of how much a better functioning public transportation system affects their business outlook. Electrification will generate social benefits that can be compared in monetary terms, including valuing time savings and emission benefits.
		Number of regional jobs in the long term due to improved transit times (Employment-years in 2031)	1,000	
	Taxes	Effect/increased provincial and federal taxes in 2031 ($m per annum)	28	The key tax impacts analyzed are Harmonized Sales Tax and Personal Income Taxes, which reflect the purchases of goods and services and wages generated.
Financial	Capital Cost	Incremental Capital Cost ($m 2010 prices, i.e. excluding inflation)	3,946	The Total Incremental Capital Cost comprises of $3,210 million in Infrastructure Capital Costs and $736 million in Rolling Stock Capital Costs (both in 2010 prices) to procure 92 Electric Locomotives and 4 EMUs.
		Incremental Capital Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	2,910	
	Total Life Cycle Cost	Life Cycle Present Value Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	2,110	Taking into account: Infrastructure costs of $2,368.5, Rolling stock costs of $543.3, Operation and Maintenance Costs of -$697.5 and Revenue of -$108.6 (all prices PV 2010 $million)
	Operating Cost	Incremental Operating and Maintenance Cost ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	-700	The cost savings in 2021 and 2031 will be $53 million and $79 million (both real prices) respectively. These are significant cost savings. The majority of the cost savings associated with electrification is due to the difference in costs spent on diesel and electricity.
	Total Revenues	Incremental revenues of the transit network ($m Present Value 2010 prices discounted at 5% p.a. over 30 years)	109	Assuming additional ridership can be accommodated, the greater the extent of electrification, the more additional riders and the greater the revenue generated for GO. 3.8 million passengers per year in 2031 are generated.
	Operating	Reduction in Operating Subsidy in 2031 ($m	-103	GO can operate more cost-effectively with a reduced net operating cost, leading to a reduction in operating subsidy.

Category	*Sub Category*	*Measure*	*Results*	*Performance – Option 18 Electrify the Entire Network (Incl. Hamilton TH+B and St Catharines)*
	Sustainability	Real 2010 prices per annum)		
Deliverability	Constructability	Qualitative assessment of the construction constraints, techniques and impacts to transit users	Strong Negative	Taking into account: Space and accessibility, construction activity next to populated areas, infrastructure affected and impacts on existing commuter services.
	Acceptability	Qualitative assessment of public and stakeholder (owner and operator) acceptance of each option	Strong Negative	A strong negative considering that 100% of services are electrified, 61% of track to be electrified is currently owned by GO and there are significant freight movements.

12. ANALYSIS OF UNCERTAINTIES

12.1. Sensitivity Testing

This section covers the sensitivity and scenario testing which provides insight into how the transportation case of electrifying each option could change depending on a number of key assumptions. These assumptions will be discussed in turn and the outcomes of a potential range of assumptions will be examined in terms of transportation benefit cost ratios.

While this section focuses on the factors potentially affecting the transportation benefit cost ratio, there are other factors in the MCE which influence the overall decision making process. The risk section of the Study considers other issues that may affect the success of the electrification of the GO Rail network.

Sensitivity to Infrastructure Capital Cost Assumptions

Although every effort has been put into estimating the capital costs, there will always be uncertainties over the scope and prices that may not be anticipated. The contingency currently allocated to the capital costs may not be sufficient to cover additional expenditure.

- Test 1 – BCR if the infrastructure capital costs were to decrease by 20%
- Test 2 – BCR if the infrastructure capital costs were to decrease by 10%
- Test 3 – BCR if the infrastructure capital costs were to increase by 10%
- Test 4 – BCR if the infrastructure capital costs were to increase by 20%

Table 56 BCR Sensitivity Tests – Infrastructure Capital Costs

Shortlist Option	**Test 1 Infrastructure Capital Cost -20%**	**Test 2 Infrastructure Capital Cost -10%**	**Central Case**	**Test 3 Infrastructure Capital Cost +10%**	**Test 4 Infrastructure Capital Cost +20%**
Option 1	0.5	0.4	**0.4**	0.3	0.3
Option 2	1.7	1.3	**1.1**	1.0	0.8
Option 3	1.3	1.1	**0.9**	0.8	0.7
Option 11	1.3	1.1	**0.9**	0.8	0.7
Option 15	1.1	0.9	**0.8**	0.7	0.6
Option 18	0.7	0.6	**0.5**	0.5	0.4

The results show that the BCRs are relatively sensitive to the infrastructure capital costs, with the best performing Option 2 varying between 0.8:1 and 1.7:1 with a +/-20% change in capital costs. Options 3 and 11 also result in a BCR above 1:1 with a slight reduction in capital costs.

Sensitivity to Rolling Stock Capital Cost Assumptions

The transportation appraisal assumes that the cost of a diesel and electric locomotive are $8.8m and $12.2m respectively, including contingency. The incremental cost is therefore $3.4m per locomotive. Rolling stock pricing can depend on a number of factors, including the market competition at the time of going to tender, the size of order, bespoke requirements and the opportunity to purchase from an existing production. Furthermore, Tier 4 diesel locomotives are not in commercial production and there will be further uncertainties. Because the incremental rolling stock costs are potentially affected by the diesel and electric locomotive costs working in opposite directions, for example, the diesel locomotive being cheaper than assumed while the electric locomotive being more expensive, compounding the increase in incremental cost. The rolling stock cost sensitivity tests include:

- Test 5 – BCR if the rolling stock capital costs were to decrease by 40% (incremental cost of $2.0m)
- Test 6 – BCR if the rolling stock capital costs were to decrease by 20% (incremental cost of $2.7m)
- Test 7 – BCR if the rolling stock capital costs were to increase by 20% (incremental cost of $4.1m)
- Test 8 – BCR if the rolling stock capital costs were to increase by 40% (incremental cost of $4.8m)

Table 57 BCR Sensitivity Tests – Rolling Stock Capital Costs

Shortlist Option	**Test 5 Incremental Rolling Stock Capital Cost -40%**	**Test 6 Incremental Rolling Stock Capital Cost -20%**	**Central Case**	**Test 7 Incremental Rolling Stock Capital Cost +20%**	**Test 8 Incremental Rolling Stock Capital Cost +40%**
Option 1	0.4	0.4	**0.4**	0.4	0.3
Option 2	1.2	1.2	**1.1**	1.1	1.0
Option 3	1.0	1.0	**0.9**	0.9	0.9
Option 11	1.0	1.0	**0.9**	0.9	0.9
Option 15	0.9	0.8	**0.8**	0.7	0.7
Option 18	0.5	0.5	**0.5**	0.5	0.5

The results show that, although the range of rolling stock costs might be relatively broad given the uncertainties of Tier 4 diesel locomotive costs and the market conditions, the BCRs are not particularly sensitive to the incremental rolling stock capital costs. This is because it is a relatively small proportion of the overall cost which is dominated by the infrastructure capital cost. It should be noted that the cost of converting the ARL to EMUs, at $19m in total, is a small proportion of the overall costs of Option 1 and is not expected to be a key driver in the uncertainty of determining the cost effectiveness of each option.

Sensitivity to Operating and Maintenance Cost Assumptions

The O&M cost estimates undertaken in the Study employ industry knowledge on system costs with different technologies. O&M costs are traditionally easier to estimate using benchmark costs, but they are also affected by local O&M practices and, in particular, when two different maintenance regimes are required, meaning that economies of scale have been reduced. O&M costs could also be affected by different fuel cost escalation assumptions which are tested separately.

Because the incremental rolling stock costs are potentially affected by the diesel and electric locomotive costs working in opposite directions, for example, the diesel locomotive being cheaper to operate than assumed while the electric locomotive being more expensive than assumed, compounding the increase in incremental cost, the operating and maintenance cost sensitivity tests include:

- Test 9 – BCR if the incremental O&M cost savings were to increase by 40%
- Test 10 – BCR if the incremental O&M cost savings were to increase by 20%
- Test 11 – BCR if the incremental O&M costs savings were to decrease by 20%
- Test 12 – BCR if the incremental O&M costs savings were to decrease by 40%

Table 58 BCR Sensitivity Tests – O&M Costs

Shortlist Option	Test 9 O&M Cost Savings +40%	Test 10 O&M Cost Savings +20%	Central Case	Test 11 O&M Cost Savings -20%	Test 12 O&M Cost Savings -40%
Option 1	0.4	0.4	**0.4**	0.4	0.3
Option 2	1.6	1.3	**1.1**	1.0	0.9
Option 3	1.2	1.1	**0.9**	0.9	0.8
Option 11	1.2	1.1	**0.9**	0.9	0.8
Option 15	1.0	0.9	**0.8**	0.7	0.7
Option 18	0.6	0.5	**0.5**	0.5	0.4

The results show that the BCRs are relatively sensitive to the incremental O&M cost saving estimates. The effect is particularly pronounced because it is a cost saving and can significantly change the net present value costs, and as a result the upside tests (9 and 10) deviate from the Central Case more than the downside tests (11 and 12). While the O&M cost savings are primarily driven by the relative energy costs, there are other uncertainties around the incremental rolling stock and wayside O&M costs which could result in a deviation from the Central Case estimates.

Sensitivity to Energy Cost Inflation Assumptions

The O&M cost estimates undertaken in the Study have assumed that the cost of diesel will increase by 5% per annum in nominal terms (i.e. including background inflation, or 3.1% in real terms, excluding inflation), while the cost of electricity is assumed to increase by 2.5% per annum in nominal terms (0.6% in real terms), giving a difference of 2.5% per annum.

The cost of energy is highly speculative and volatile. It is difficult to provide a solid estimate over the Study's evaluation period and given the likelihood that diesel, as a non-renewable source of energy, is likely to increase above the background rate of inflation due to increased global demand in developing countries and the concept of peak oil, the point where the extraction of petroleum has reached a maximum. The cost of electricity is also expected to increase above inflation, albeit at a slower rate compared to diesel because Canada is a major producer of hydroelectricity, while in Ontario, nuclear reactors also produce significant electricity.

The US Energy Information Administration provides short and long term energy price trends in the US. Those forecasts suggest that, in real terms, transportation diesel prices will go up on average by 2.0% (3.9% nominal) from 2010 to 2030, while electricity remains constant (or 1.9% nominal), meaning that the differential in inflation between electricity and diesel is 2.0% per annum. According to International Energy Agency's World Energy Outlook, Ontario has no stockpiled oil - every OECD member except Canada maintains substantial stockpiles of oil to protect against interruptions in supply, therefore we have assumed for the Electrification Study that the differential in inflation is slightly higher at 2.5%.

Given the uncertainty of energy costs, sensitivity tests have been carried out to illustrate how the transportation case for electrification would change if the cost inflation assumptions were to vary. Because the incremental O&M costs are potentially affected by diesel and electric inflation working in opposite directions, for example, the diesel inflation being lower than assumed while the electricity inflation being higher than assumed, compounding the difference, the energy cost sensitivity tests include:

- Test 13 – BCR if the diesel cost inflation was 7% nominal and electricity was 2.5% nominal per annum (4.5% difference) until 2031 and constant in real terms thereafter
- Test 14 – BCR if the diesel cost inflation was 6% nominal and electricity was 2.5% nominal per annum (3.5% difference) until 2031 and constant in real terms thereafter
- Test 15 – BCR if the diesel cost inflation was 4% nominal and electricity was 2.5% nominal per annum (2% difference) until 2031 and constant in real terms thereafter
- Test 16 – BCR if the diesel cost inflation was 2.5% nominal and electricity was 2.5% nominal per annum (0% difference) until 2031 and constant in real terms thereafter

Table 59   BCR Sensitivity Tests – Energy Cost Inflation

Shortlist Option	Test 13 Diesel 7% Electricity 2.5%	Test 14 Diesel 6% Electricity 2.5%	Central Case	Test 15 Diesel 4% Electricity 2.5%	Test 16 Diesel 2.5% Electricity 2.5%
Option 1	0.4	0.4	**0.4**	0.4	0.3
Option 2	1.9	1.4	**1.1**	1.0	0.8
Option 3	1.4	1.1	**0.9**	0.8	0.7
Option 11	1.4	1.1	**0.9**	0.8	0.7
Option 15	1.1	0.9	**0.8**	0.7	0.6
Option 18	0.6	0.6	**0.5**	0.5	0.4

The results show that the BCRs are relatively sensitive to the energy cost inflation assumptions, with the BCR of Option 2 ranging from 0.8:1 to 1.9:1. The impacts also appear greater than the high level O&M +/-40% tests previously carried out. This will be one of the areas with the most uncertainty as there is no consensus on long term energy costs.

Sensitivity to Ridership Assumptions

The case to electrify the network is dependent on the level of ridership on the corridor considered for electrification. This is because electric trains offer journey time reductions which passengers benefit from, so the more passengers on the trains the more transit benefits are achieved.

As part of the work subsequent to the publication of the RTP, Metrolinx undertook sensitivity tests of ridership and auto operating costs using the GGH model. It was determined that the elasticity of ridership with respect to auto operating costs was 0.12, so for every 1% increase in auto operating costs there is a 0.12% increase in ridership. This is a fairly inelastic relationship, but it should be noted that the modeling assumptions for the Reference Case assumed a modest 50% increase in vehicle operating costs in real terms, while the RTP assumed a 200% increase by 2031, reflecting potential sources of auto cost changes such as fuel prices, parking and highway tolls. Employing the RTP assumptions would result in an additional 4.5% riders by 2021 and 8.7% by 2031.

Other factors could affect ridership forecasts, for example the perceived improvement in service levels as forecast by the GGH model may be higher or lower than reality due to other constraints such as park and ride capacity or Transit Oriented Development meaning that growth in each district could be more intense adjacent to GO stations.

- Test 17 – BCR if demand levels were 20% lower than forecast by 2031
- Test 18 – BCR if demand levels were 10% lower than forecast by 2031
- Test 19 – BCR if demand levels were 10% higher than forecast by 2031
- Test 20 – BCR if demand levels were 20% higher than forecast by 2031

Table 60 BCR Sensitivity Tests – Demand Forecasts

Shortlist Option	Test 17 Demand -20% by 2031	Test 18 Demand -10% by 2031	Central Case	Test 19 Demand +10% by 2031	Test 20 Demand +20% by 2031
Option 1	0.3	0.3	**0.4**	0.4	0.4
Option 2	0.9	1.0	**1.1**	1.2	1.3
Option 3	0.8	0.9	**0.9**	1.0	1.1
Option 11	0.8	0.9	**0.9**	1.0	1.1
Option 15	0.7	0.7	**0.8**	0.8	0.9
Option 18	0.4	0.5	**0.5**	0.5	0.6

The results show that the BCRs are moderately sensitive to the demand forecasts, with the BCR of Option 2 ranging from 0.9:1 to 1.3:1. Options 3 and 11 would have a BCR of 1:1 if demand levels were 10% higher by 2031 due to higher growth rates.

Appraisal Assumptions

The benefit cost ratio can be affected by a number of appraisal assumptions. Three further sensitivity tests are undertaken to examine the BCR under different assumptions:

- Test 21 – BCR if the discount rate is assumed to be 3% over 60 years (as opposed to 5% over 30 years), representing the view that electrification requires decisions made to meet longer term visions. A longer evaluation period is typically accompanied by a lower discount rate because it reflects the willingness to reap the benefits of long-term investments with a corresponding timeframe;
- Test 22 – BCR assuming the exclusion of auto related benefits, reflecting the fact that these benefits are more difficult to forecast accurately and are not a key part of Metrolinx's objectives; and
- Test 23 – BCR assuming that passenger ridership will continue to grow beyond 2031 to 2049 at the extrapolated rate between 2021 and 2031 (as opposed to be static).

Table 61   BCR Sensitivity Tests – Appraisal Assumptions

Shortlist Option	Test 21 60 year appraisal with 3% discount rate	Test 22 No Auto Decongestion Benefits	Test 23 Demand Growth Continues beyond 2031	Central Case
Option 1	1.0	0.3	0.4	**0.4**
Option 2	10.3	1.0	1.2	**1.1**
Option 3	5.6	0.8	1.0	**0.9**
Option 11	5.6	0.8	1.0	**0.9**
Option 15	3.7	0.7	0.8	**0.8**
Option 18	1.7	0.4	0.5	**0.5**

The results for Test 21 show that if a lower discount rate and evaluation period was used, all options would have a BCR of 1:1 or higher. The results are dramatically different primarily because future benefits are discounted at a lower rate, and since the O&M cost savings increase considerably over time, the cost savings are able to offset a considerable portion of the capital costs. However, this test does not fully consider the incremental life-cycle renewal of infrastructure or rolling stock which has reached the end of its design life.

The results for Test 22 show that if no auto-related decongestion time savings were realized due to induced traffic, the BCRs are only marginally affected because the proportion of decongestion benefits is relatively small part of the overall time saving benefits.

Test 23 shows that if demand levels were to continue to grow for the entire 30 year period, the BCR only increases marginally and this is primarily because benefits incurred a the latter part of the evaluation period is heavily discounted so the impact would be limited.

12.2. Scenario Testing

Alternative Service Level Scenarios

The Electrification Study has been based on service levels defined in the Reference Case. The Reference Case represents a realistic but aspirational view of the future service but there are uncertainties over the timescales for delivering the significant improvements. These may include the delay of implementing proposed extensions and/or additional services on particular corridors. It may also be possible to run more services than specified in the Reference Case, particularly in the latter part of the evaluation period when ridership growth may warrant an increase in capacity provided.

A reduction in service levels throughout the corridor would reduce the rolling stock capital costs and O&M cost savings, as well as the number of passengers who benefit from the journey time improvement. If we assume that the level of ridership was not affected by the change of service levels, we can determine, at a high level, how the cost changes associated with a change in service level affects the BCR. The tests carried out include:

- Test 24 – BCR if the incremental rolling stock and O&M cost savings were to decrease by 20%

- Test 25 – BCR if the incremental rolling stock and O&M cost savings were to decrease by 10%
- Test 26 – BCR if the incremental rolling stock and O&M cost savings were to increase by 10%
- Test 27 – BCR if the incremental rolling stock and O&M cost savings were to increase by 20%

Table 62 BCR Scenario Tests – Service Levels

Shortlist Option	Test 24 Service Levels +20%	Test 25 Service Levels +10%	Central Case	Test 26 Service Levels -10%	Test 27 Service Levels -20%
Option 1	0.4	0.4	**0.4**	0.4	0.4
Option 2	1.2	1.2	**1.1**	1.1	1.0
Option 3	1.0	1.0	**0.9**	0.9	0.9
Option 11	1.0	1.0	**0.9**	0.9	0.9
Option 15	0.8	0.8	**0.8**	0.8	0.7
Option 18	0.5	0.5	**0.5**	0.5	0.5

In the high level evaluation, it was concluded that in most cases (except for Lakeshore West), it is more worthwhile to electrify the entire corridor rather than parts of a corridor. This is because in most cases the infrastructure required in the inner sections of the corridor were significantly more costly to construct than the outer sections, and the marginal costs of electrifying the outer sections would mean that the longer but less frequent services would give more journey time savings per passenger and O&M cost savings.

If the Reference Case service levels into Union station were maintained but the number of trains which run to the end of the line was to increase, the overall case for electrification would also improve and passengers would also gain a benefit associated with a more frequent service – although that could be achieved regardless of electrification. Conversely, if the service levels along the outer sections were to be lower than assumed in the Reference Case, the BCR is likely to decrease for electrifying the entire line, but it would increase the case for partially electrifying the corridor to the point where the majority of trains terminate.

It is possible to trade off and optimize the benefits of electrification against the service levels offered to passengers, particularly at the outer sections of GO Rail corridors. We have not considered alternative service scenarios in the context of this Study but such alternatives could be considered in the future.

Optimized Use of Rolling Stock Scenario

The deployment of the faster electric locomotive trains could potentially reduce the overall rolling stock requirement by a train set for the Lakeshore East and West lines. Given that a 10 coach diesel locomotive hauled train costs in the region of $39.2m, options which involve the electrification of the Lakeshore corridor could offer rolling stock capital cost savings.

However, without detailed consideration of a new timetable, it would be not possible to verify if this can be achieved, as such it is being treated as a potential upside to options which involve electrifying the Lakeshore corridor.

Table 63 BCR Scenario Tests – Optimized Use of Rolling Stock

Shortlist Option	Test 28 One Trainset Saved on the Lakeshore Corridor	Central Case
Option 1	0.4	**0.4**
Option 2	1.2	**1.1**
Option 3	1.0	**0.9**
Option 11	1.0	**0.9**
Option 15	0.8	**0.8**
Option 18	0.5	**0.5**

12.3. Sensitivity and Scenario Testing - Conclusions

The previous two sections covered a wide range of independent sensitivity and scenario tests illustrating how the BCR could change based on each assumption. In order to illustrate what the potential range of results this gives, we have taken the maximum and minimum of each set of test results and combined the impacts to produce upside and downside results. The BCR is therefore presented as a range, noting that the larger the deviation away from the Central Case would be, the lower the probability of that outcome would be because it would involve more individual upsides or downsides working in tandem.

A final set of sensitivity tests were undertaken to determine a likely envelope of BCRs – upside and downside – based on the combined effects of a number of previous sensitivity tests. These two tests are defined as:

- Upside Scenario – The combination of tests 2, 6, 14, 19, 23, 28
- Downside Scenario – The combination of tests 3, 7, 15, 18, 22

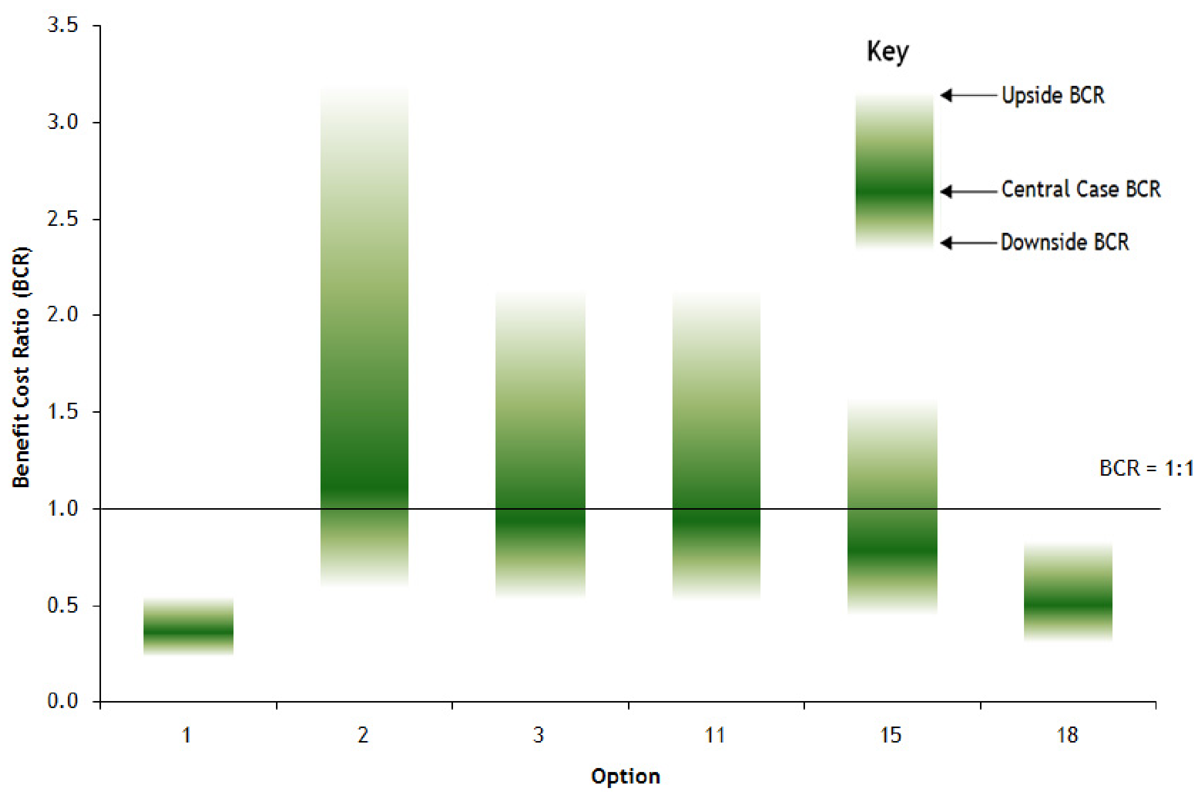
Table 64 presents the upside and downside BCR envelopes for each option, while Figure 28 summarizes the range of BCRs given the plausible outcomes of the factors affecting the assessment. It shows that when all the upsides and downsides are considered together as defined above, the potential range of BCRs can be quite significant.

As a proxy for the likelihood of the BCR being in a particular range, the darker green shades represent the zone where there is a higher confidence level of the BCR being in the range. It shows that Option 2 overall is likely to have a BCR above 1:1 with the possibility of being significantly higher, while Options 3 and 11 both perform similarly and have a fair chance of delivering a BCR higher than 1:1. Options 1 and 18 are not expected to yield a BCR greater than unity under the current evaluation framework with the range of scenarios tested.

Table 64 BCR Scenario Tests – Upsides and Downsides

Shortlist Option	Test 29 Downside Envelope	Central Case	Test 30 Upside Envelope
Option 1	0.2	**0.4**	0.5
Option 2	0.6	**1.1**	3.2
Option 3	0.5	**0.9**	2.1
Option 11	0.5	**0.9**	2.1
Option 15	0.5	**0.8**	1.6
Option 18	0.3	**0.5**	0.8

Figure 27 – Sensitivity and Scenario Tests – Range of BCRs



12.4. Capital Cost Updates

As a project continues to be developed and assumptions are continuously reviewed, cost estimates are refined. The transportation appraisal and evaluation of each option in this report was undertaken using the draft final cost estimates. Subsequently the infrastructure capital costs were refined, reflecting ongoing discussions with Metrolinx and the verification of contingency levels assumed on the capital costs, and the overall capital costs increased between 6% and 10% on each option. Without repeating the transportation appraisal in full detail, the revised BCRs reflecting the updated capital costs are set out below.

Table 65 Indicative 30 Year Life-Cycle Transportation Appraisal of Electric Locomotive Trains with Updated Capital Costs (All Figures in $m and Discounted at 5% p.a. to 2010 Present Values)

Electric Locomotives: Transportation Appraisal Impacts (All figures in $m and Discounted at 5% p.a. to 2010 Present Values)	**Option 1**	**Option 2**	**Option 3**	**Option 11**	**Option 15**	**Option 18**
	Georgetown + ARL	**Lakeshore:** Hamilton James to Bowmanville	**Option 1+2**	**Option 3 plus Milton**	**Option 11 plus Barrie**	**Full Network**
BENEFIT COST RATIO (BCR)	**0.3**	**1.0**	**0.8**	**0.9**	**0.7**	**0.5**

As expected, the BCRs decrease marginally as the capital costs increases, with Option 2 remaining the most cost effective option in terms of delivering transportation benefits. Option 11 becomes marginally better than Option 3 (although the difference appears greater due to rounding). Overall, these changes are well within the ranges of uncertainties explored in this chapter.

The Monte-Carlo simulation undertaken on risks and contingencies identified that the level of contingency to achieve a 90% confidence level was around 35% for the overall cost, while the maximum confidence level was 55%. The central case estimates, based on a range of contingencies by cost element, averaged at around 50% overall. The table also sets out the range of BCRs which correspond to the range of infrastructure capital cost estimated in the Study.

Electric Locomotives: Transportation Appraisal Impacts (All figures in $m and Discounted at 5% p.a. to 2010 Present Values)	**Option 1**	**Option 2**	**Option 3**	**Option 11**	**Option 15**	**Option 18**
	Georgetown + ARL	**Lakeshore:** Hamilton James to Bowmanville	**Option 1+2**	**Option 3 plus Milton**	**Option 11 plus Barrie**	**Full Network**
35% Overall Contingency	0.4	1.1	1.0	1.0	0.8	0.5
Central Case Estimate	0.3	1.0	0.8	0.9	0.7	0.5
55% Overall Contingency	0.3	0.9	0.8	0.8	0.7	0.5

If the lower contingency level was assumed, the BCR of Options 3 and 11 both reach 1.0:1, meaning the transportation benefits repay the costs over the project life-cycle.

12.5. Review of Electric Multiple Units

During the high level evaluation, electric locomotive trains and EMUs were considered together in the technology evaluation. At the time it was concluded that while EMUs deliver higher levels of total user benefits, they were significantly more costly to procure and operate and they are substantially less cost effective in delivering transportation and environmental benefits. Electric locomotives are more affordable, they present less implementation and operational risk than EMUs. When all categories were considered in the round, Electric Locomotives were taken forward as the preferred technology in the detailed evaluation stage.

Although electric locomotives were taken forward for detailed evaluation, it should be noted that EMUs would be able to take the GO Rail system closer to the RTP aspirations given the significant journey time savings, and they were not excluded as a potential technology.

Now that we have accumulated more information on the capital costs and the environmental benefits of electrification, the high level evaluation conclusions were reviewed. It has been possible to update the high level evaluation to include:

- Latest infrastructure capital cost estimates which now expanded to include professional services and contingency;
- Rolling stock capital costs with revised fleet sizes and taking into account the current diesel locomotives and passenger coaches that would have to be replaced by EMUs for Options 11, 15 and 18;
- O&M cost savings with refined assumptions on train kilometres operated by technology; and
- High level passenger benefit estimates to include new elements previously not captured.

The transportation appraisal results are set out in Table 66.

Table 66 Indicative 30 Year Life-Cycle Transportation Appraisal of Bi-Level EMUs (All Figures in $m and Discounted at 5% p.a. to 2010 Present Values)

Bi-Level EMUs: Transportation Appraisal Impacts (All figures in $m and Discounted at 5% p.a. to 2010 Present Values)	**Option 1**	**Option 2**	**Option 3**	**Option 11**	**Option 15**	**Option 18**
	Georgetown + ARL	**Lakeshore:** Hamilton James to Bowmanville	**Option 1+2**	**Option 3 plus Milton**	**Option 11 plus Barrie**	**Full Network**
Infrastructure Capital Costs	521	764	1,089	1,251	1,584	2,369
Rolling Stock Capital Costs	252	479	668	954	1,290	2,078
Operations & Maintenance Costs	30	216	242	299	379	492
Incremental Revenues	-41	-137	-178	-208	-235	-274
TOTAL PRESENT VALUE COSTS	**762**	**1,322**	**1,821**	**2,296**	**3,018**	**4,664**
Journey Time Saving Benefits	281	1,074	1,355	1,585	1,837	2,141
Reliability Benefits	1	3	4	5	6	7
Auto Cost Savings	53	285	339	396	471	551
TOTAL PRESENT VALUE BENEFITS	**335**	**1,362**	**1,697**	**1,986**	**2,314**	**2,699**
Net Present Value	**-427**	**40**	**-124**	**-310**	**-704**	**-1,965**
BENEFIT COST RATIO (BCR)	**0.4 :1**	**1.0 :1**	**0.9 :1**	**0.9 :1**	**0.8 :1**	**0.6 :1**

It shows that the estimated high level BCRs for EMUs are now higher than those for the electric locomotive trains, with Option 2 having a BCR of 1.0:1, while Options 3 and 11 are around 0.9:1. This means that in terms of delivering transportation benefits, EMUs offer similar transportation BCRs compared to the diesel locomotive. This conclusion however does not take into account other aspects of the MCE, particularly on affordability and implementation issues.

The EMUs now perform closer to diesel locomotives because between the high level evaluation and the detailed evaluation the infrastructure capital cost estimates have been revised to reflect the detailed bridge rework estimates but also expanded to include the inclusion of additional elements such as grounding of the network infrastructure, professional services and contingency. As a result, the infrastructure capital cost is a much larger component of the total costs, meaning that the BCRs for EMUs, which are more expensive to operate but deliver more benefits, are more resilient to these changes.

It should also be noted that EMU's lower environmental cost effectiveness was also taken into consideration at the high level evaluation but the detailed assessment concluded that environmental benefits associated with electrification are relatively modest.

Although EMUs have always been a potential technology to be considered alongside electric locomotives, EMUs remain significantly more expensive to purchase (The overall infrastructure and rolling stock costs are around 40% more expensive with EMUs) and operate on a day-to-day basis (a net O&M cost/subsidy increase, compared to significant savings with Electric Locomotives), while delivering similar environmental benefits. EMUs also present greater risks in terms of implementation because all coaches would need to be tested extensively prior to service deployment while Electric Locomotives would haul the standard passenger coach cars currently in operation.

The Future Considerations section of the Final Report also discusses other aspects which could potentially improve the case for EMUs, particularly if the service offered by GO Rail could be optimized with EMUs in mind.