1.0 Introduction

GO Transit is known as the Greater Toronto and Hamilton Area's interregional public transportation service. Today, approximately 180,000 passengers commute into the City of Toronto by rail each weekday, most of them living within 20 to 50 km of the city. With the population increasing, jobs increasing, and the push to go green, GO Transit has been presented with the challenge of upgrading their existing system by expanding the current lines to provide additional trains, both during the peak commuting times and off peak. On November 28, 2008 Metrolinx adopted a Regional Traffic Plan (RTP) named "The Big Move". The Big Move forecasts that by 2031 the train traffic level on the Union Station Rail Corridor will quadruple. It also states that 75% of the people will be living within 2 km of rapid transit. GO Transit followed this work with their GO 2020 strategic plan which sets out how GO Transit would meet the RTP plan. In an effort to determine what infrastructure will be required to accommodate this level of traffic, GO Transit retained AECOM to study the capacity of the current Union Station Rail Corridor ("USRC") and Union Station as well as the capacity once planned improvements have been completed. Finally if the proposed infrastructure was not sufficient, make recommendations for additional improvements to provide sufficient capacity for the proposed level of service.

Determining capacity becomes complex because it is not a static system, it is a physical and dynamic system that depends on the different types of trains and how they operate within USRC network. There are two predominant methods in determining rail capacity. The first is by mathematically determining theoretical capacity, which is a static representation that determines the number of trains that could run on a specific route during a specific time in a predetermined environment with an ideal headway. This number is then de-rated to establish a practical capacity. This method is not practical with the complexity of the USRC which contains many switches and parallel routes. The second method involves the use of rail network modelling software. Many simulation packages are commercially available and AECOM selected Berkeley Software's RTC package. This application allows the construction of an entire network including switches and signals and is widely accepted as the present standard in North America with a licence being owned by all of the North American Class One railways.

The goal of a capacity analysis is to determine the maximum number of trains that could operate on a given railway infrastructure with specific operational conditions. Using RTC, a model of the USRC was created including up to the first stations on the seven routes over which GO Transit currently operates. There were three major traffic levels which were modelled with supporting infrastructure to show the different milestones and all the benefits. Bottlenecks were identified and supporting infrastructure was recommended and modelled to demonstrate how the network would operate with the different levels of changes.

2.0 Basis of Analysis

Berkeley's RTC software was used to model the system. This software package allows construction of an entire rail network including signals. The software will then attempt to dispatch the trains as efficiently as possible and provide as output, animations, time distance graphs, average train velocity, track occupation, and average train delay by type. This information is indispensible in determining if trains are maintaining an acceptable level of performance.

Our modeling was performed in metric with all imperial inputs being converted to equivalent metric values. We used the Davis Basic resistance formula as this has been shown to accurately represent high horsepower to tonnage ratio (HPT) trains which includes the majority of the trains operated in the USRC.

Davis Basic Resistance Formula

$R = 1.3 + 29/W + 0.045 \text{ X } V + 0.0005 \text{ X } AV^2/Wn$

R = Resistance in lbs/ton on level tangent track

W = weight per axle in tons

n = number of axles per car

A = cross section of car in square feet

V = speed in miles per second

Grade Based Curve Resistance was utilized where a one degree curve provides the same resistance as a 0.04% grade.

2.1 Study Area

Our area of study was defined by the limits of the USRC as illustrated in drawing UC50-C-SG10009, included as Appendix A. To obtain a more accurate representation of how the trains will operate in the USRC, we modelled additional track out to the first station stop in each direction. Due to the quantity of equipment moves from Willowbrook and the VIA TMC we further extended the model on the Oakville Subdivision to the connections to these facilities at Mimico as illustrated in the following diagram (Figure 1).

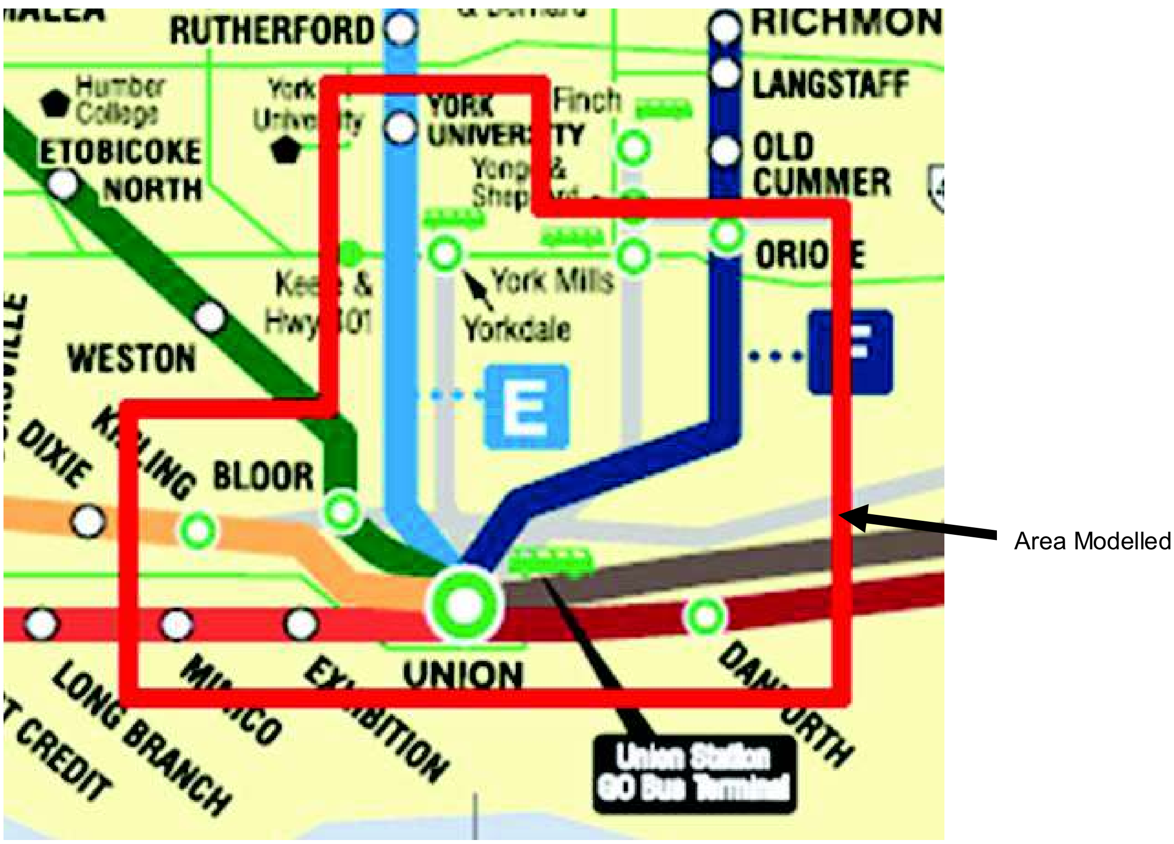

Figure 1: Area Modelled

2.2 Equipment

Passenger service train loading is typically referred to as AW loading and the various levels of loading are defined in the following table.

Table 1 – AW Loading Defined

Loading	Description	Definition
AW0	ready to run	The mass of vehicle ready to run with all mounted components including full operating reserves of windshield fluid, sand, etc., and the mass of the train operator but without any passenger load.
AW1	fully seated	AW0 plus full-seated passenger load and the train operator on board.
AW2	system load	AW1 plus 4 passengers per m^2 (3.3 passengers per yd^2) in standing areas, and train operator on board
AW3	crush load	AW1 plus 6 passengers per m^2 (5 passengers per yd^2) in standing areas, and train operator on board
AW4	structural load	AW1 plus 8 passengers per m^2 (6.7 passengers per yd^2) in standing areas, and train operator on board

2.2.1 GO Transit

The motive power modelled for all GO Transit trains consisted of one MP40. Tractive effort and dynamic braking curves were provided by GO Transit and are shown in Figure 2.

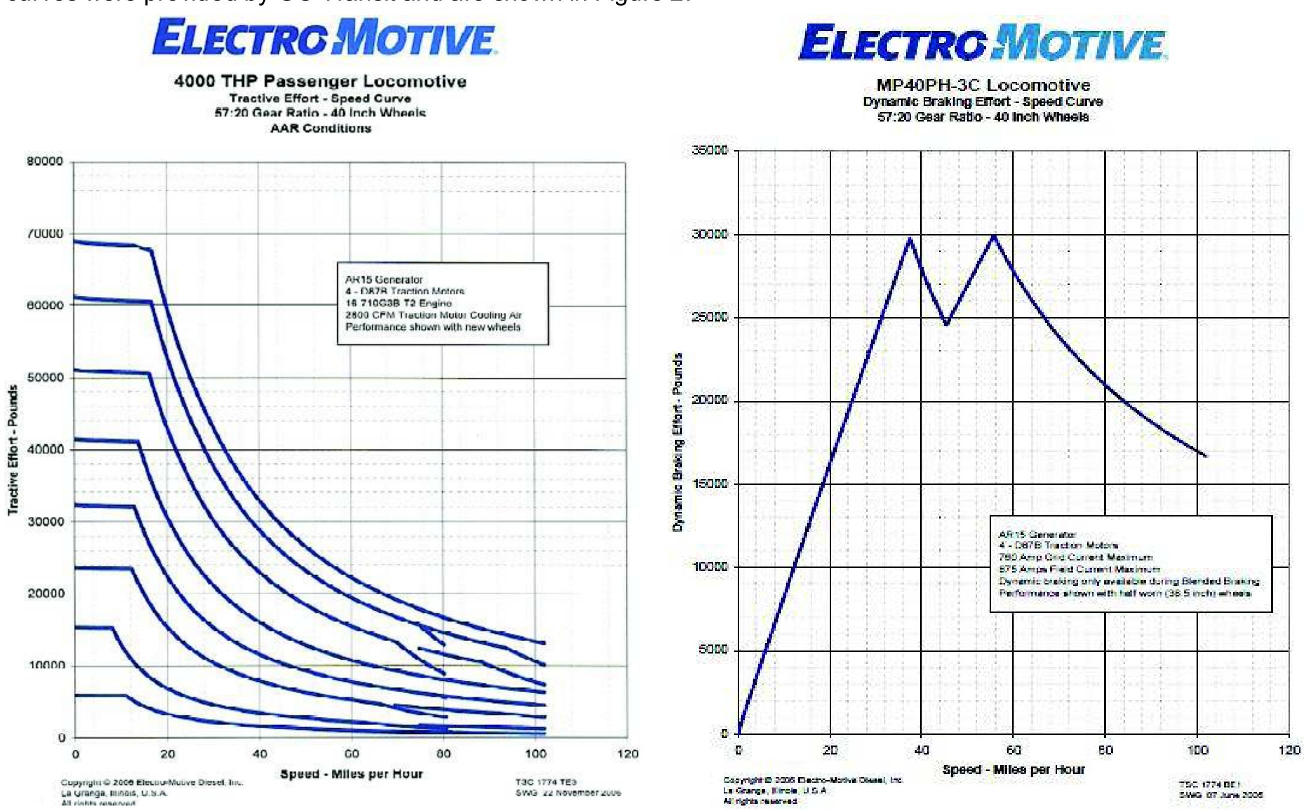

Figure 2: Tractive Effort and Dynamic Braking Curves

The passenger equipment used was 12 Bombardier bi-level coaches. To provide conservative results AW4 loading was used with all trains.

2.2.2 Airport Rail Link (ARL)

The ARL is a future service for which equipment has not been procured. We modelled a three Budd Car RDC-1 consist with a loaded train weight of 211 tonnes. The tractive effort and braking curves are illustrated in the following figure.

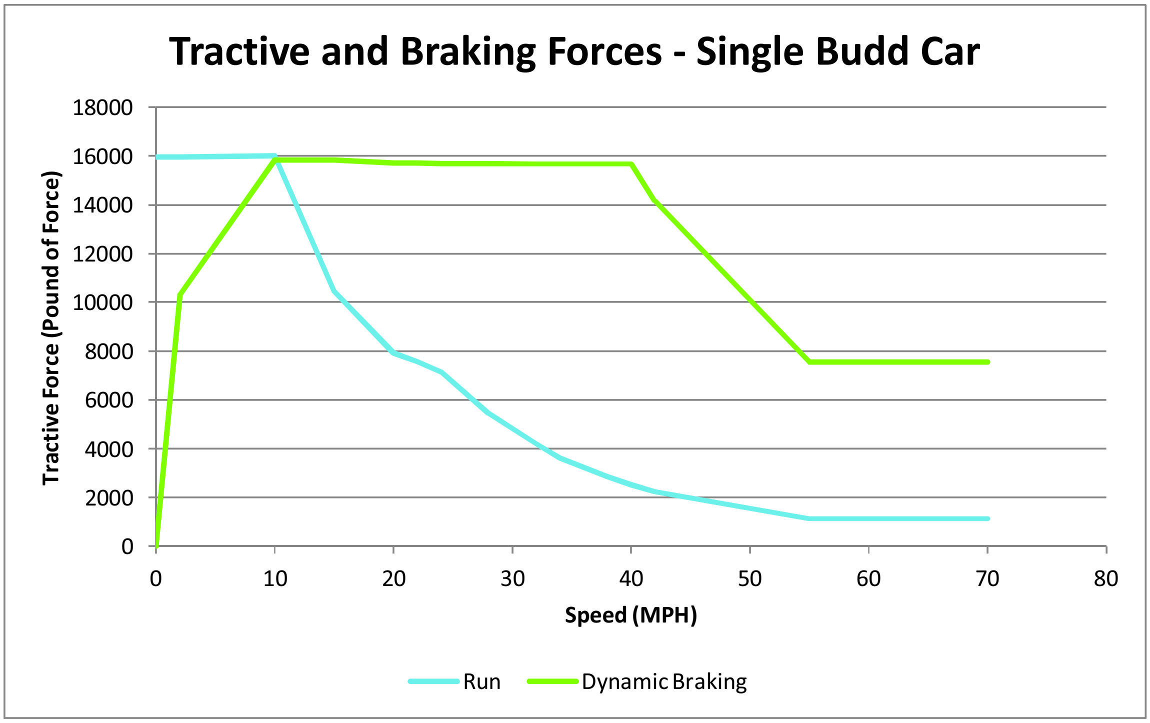

Figure 3: ARL Tractive and Braking Forces

2.2.3 VIA Rail

We modelled two basic types of trains for VIA's operations.

The Windsor-Montreal corridor trains consisted of one P42DC locomotive plus seven Renaissance coaches with AW1 loading. This provides a train gross weight of 521 tonnes.

The Canadian, or super-continental train, consisted of one F40PH-2 operating, one F40PH-2 electrical power generation/deadhead plus 15 passenger coaches with AW1 loading. This configuration has a gross weight of 1226 tonnes.

One exception to the default consists was #40+52 which departs Union Station as one train. This train is made up of two trains coupled with a total consist of two locomotives and 12 cars and a gross weight of 932 tonnes.

2.2.4 Ontario Northland

For Ontario Northland trains, a typical train consisting of one FP7A plus four passenger coaches with AW1 loading was used. This provides a gross train weight of 547 tonnes.

2.2.5 CN

CN currently has a freight train, A43531, which operates daily from the Bala Subdivision, through the USRC to the Oakville Subdivision. We modelled a 120 car train with two SD80MAC locomotives for a total weight of 7955 tonnes and 2777 metres in length. This information was received from CN and in addition to this scheduled through train, CN also operates way freights through Union Station. These way freights typically run off peak with relatively low priority, and as a result of this, these trains will have a negligible effect on the capacity of the USRC and were not modelled.

2.3 Operating Characteristics

Operating rules were obtained from the CN and USRC Operating Manuals.

We used Simulated On Time Performance ("SOTP") as our primary measure for system performance and capacity. GO Transit has a standard for OTP that considers any train which is less than five minutes late as being on time with a 95% on-time goal. It is our understanding that GO service is currently operating at 94% OTP.

2.4 Methodology

Our assignment included several different track configurations and train schedules as well as determining the advantage or disadvantage of different operating practices included the following:

- **Base Case –** with existing track configuration and train schedule. The purpose of this model is two-fold. First to calibrate the model and develop measures to which subsequent models can be compared. We developed a Simulated On Time Performance (SOTP), similar to GO Transit's On Time Performance (OTP) measure. Secondly we determined if additional capacity exists by adding trains to the existing track and schedule.
- **2015 Case –** with current ongoing track improvements proposed by GO Transit completed. The GO train schedule remains unchanged but the ARL service is added plus additional VIA trains. Again we added trains beyond the scheduled trains to determine if there would be additional capacity available.
- **ERC_1** – We modelled the proposed infrastructure with GO Transit's projected train levels. The Electrification Study Team provided this initial train service plan developed based on the GO 2020 strategy which was titled the "Electrification Reference Case" (ERC) schedule. GO Transit also has numerous track and signal upgrades proposed within the USRC. We modelled the ERC schedule as well as the ARL and the future VIA services on the proposed infrastructure.
- **ERC_2** – Our next model modified the ERC schedule by shifting the arrival time of trains within the USRC to avoid conflicts on tracks within the USRC. In addition we modified the equipment storage locations, while maintaining the same number of train sets stored at each location, to better compliment the USRC track layout. Finally, infrastructure, such as crossovers, was added to improve connections within the USRC and the adjacent subdivision's tracks were increased to the number proposed by GO Transit.
- **ERC_3** – The Electrification Reference Case was revisited to determine if there was any advantage to relocating the ARL service from Track One as was previously required.

- **Beyond ERC** –
    - We reviewed the run time and performance differences which may be available through electrification of the train service.
    - Next we reviewed operating changes to determine their impact on train shed capacity. These included turning trains in the station versus operating them straight through and removing tracks to provide wider platforms for improved passenger throughput.
    - We then reviewed the advantages or disadvantages of turning trains on the capacity of the USRC itself. It should be noted that operating changes affect the capacity of the USRC and Union Station in different ways.
    - Finally we explored what the potential train throughput within the USRC and Union Station could be with two options. The first with a new underground station and tracks below the current USRC, and the second with a satellite stub ended station in the area of Bathurst Yard.

3.0 Establishment of Baseline Train Service Model

A baseline train service model was completed running all the current GO, VIA, and freight traffic. This was done in order to calibrate the RTC model to ensure all future simulations accurately reflect real world performance and that they can be compared to the current level of traffic operating within the USRC.

3.1 Track Layout

The current track layout including the locations of all the switches for existing conditions was modelled in RTC. The information was extracted from drawing TSL-1 dated August 10, 2009.

3.2 Signals

Signal route and aspect information for the existing USRC operation were provided by GO Transit in the files listed below:

- Bathurst St. RA-E-1 Dated July 7. 1987
- Bathurst St. RA-W-2 Dated July 7, 1987
- Bathurst St. RA-E-W-3 Dated July 7, 1987
- Cherry Street Route and Aspects Drawing No. SEQ23_24_25-09E1 Revision P1 Dated Oct. 29, 2009
- Cherry Street Route and Aspects Drawing No. SEQ23_24_25-09E2 Revision P1 Dated Oct. 29, 2009
- Cherry Street Route and Aspects Drawing No. SEQ23_24_25-09E3 Revision P1 Dated Oct. 29, 2009
- Cherry Street Route and Aspects Drawing No. SEQ23_24_25-09W1 Revision P1 Dated Oct. 29, 2009
- Cherry Street Route and Aspects Drawing No. SEQ23_24_25-09W2 Revision P1 Dated Oct. 29, 2009
- John Street Route and Aspects Drawing No John-RA-E1 Revision P0 Dated Nov. 25, 2009
- John Street Route and Aspects Drawing No John-RA-W1 Revision P0 Dated Nov. 25, 2009
- Scott Street Route and Aspects Drawing No Scott-RA-E1 Revision P0 Dated Nov. 25, 2009
- Scott Street Route and Aspects Drawing No Scott-RA-W1 Revision P0 Dated Nov. 25, 2009
- Scott Street Route and Aspects Drawing No Scott-RA-W2 Revision P0 Dated Nov. 25, 2009
- Scott Street Route and Aspects Drawing No Scott-RA-W3 Revision P0 Dated Nov. 25, 2009

3.3 Operating Plan

In order to model the USRC network, operating plans and schedules were required for GO, VIA and CN's current traffic. GO's operating plan was obtained from Form 660 dated Apr 3/10 and Weekday Track Allotment spreadsheet dated January 11 2010. In addition, VIA's and ONR's operating plans were obtained from their current published schedules and CN's Passenger Grid spreadsheet dated May 1, 2010. CN's operating plan for their freight movement was obtained directly from CN. We were not provided with specific train routing within the USRC so we utilized RTC's logic to optimize the routing.

The quantity of trains modelled in the Base Case is illustrated in the following table. Revenue moves are trains which are carrying passengers while the daily trains represent the number of trains which are operating in and out of Union Station and include both the revenue and equipment moves.

Table 2 – Base Case Trains

Train Type	Daily Revenue Moves	Total Daily Trains (Equipment and Revenue)
GO	180	300 *
VIA	48	82 *
CN	1	1
ONR	2	4 *

**Includes all moves in or out of Union Station*

3.4 Results

The existing Track and Schedule was modelled and the results indicated a 100% SOTP. Randomization was induced in the train schedule to determine the robustness of the system and to obtain results similar to the current operating performance. Train departure time was randomized to depart 0 minutes early to an incremental number of minutes late. We then analysed the results to determine the SOTP. Figure 4 demonstrates all of the runs performed with increasing randomization. It shows the change in SOTP as the randomization of the departure time is increased in minutes. The 4 minute randomization factor provides a modelled SOTP which is similar to the OTP GO is currently experiencing on their system and we use this value throughout our modelling as a comparison base. It is recognized that the 94% OTP currently achieved by GO is for their entire system, but as this randomization will include late starts at the first station out of Union Station it will take into account delays on the system. The negligible increase in the SOTP when the randomization was increased from 2 to 3 minutes can be attributed to the fact that the delays are randomly generated.

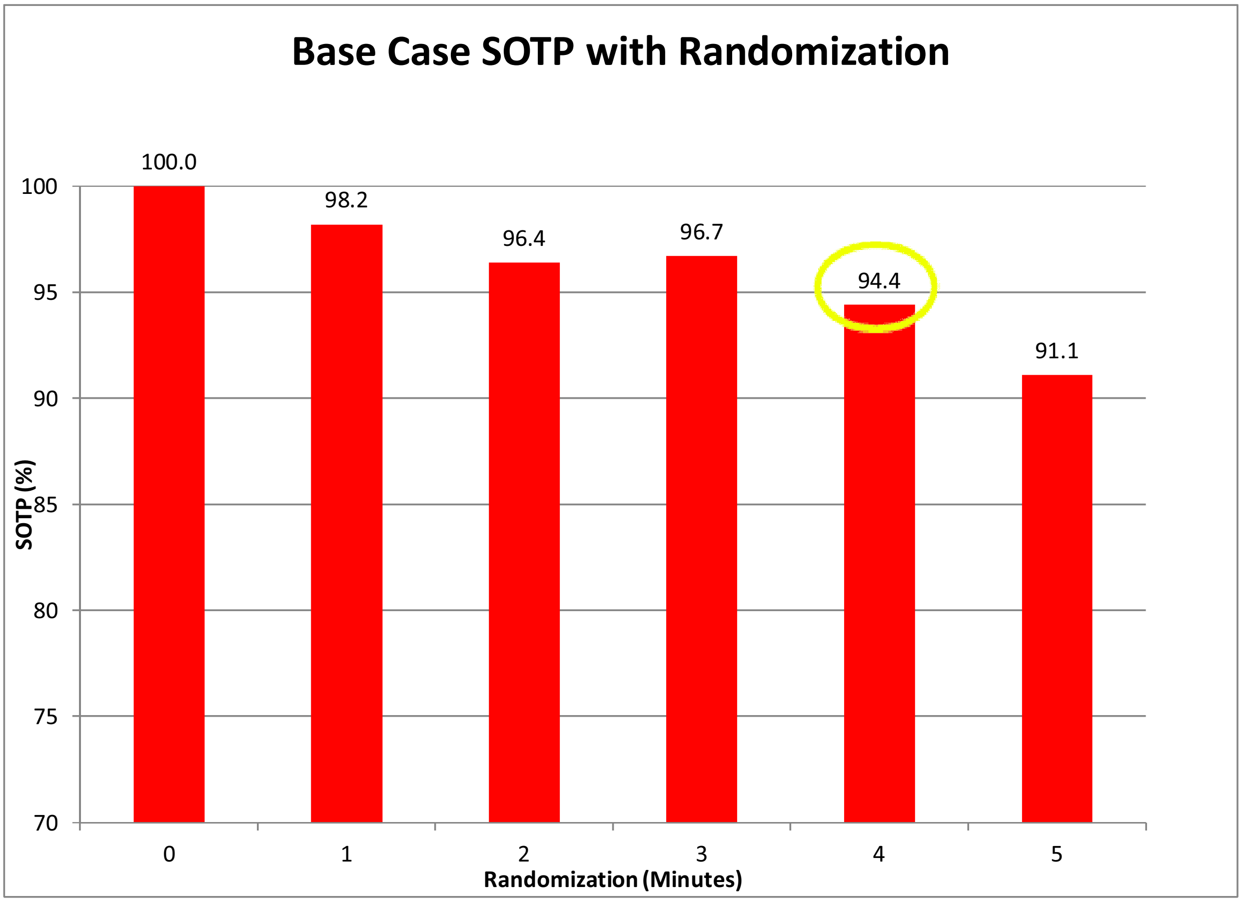

Figure 4: Base Case SOTP

3.5 Maximum Network Capacity Analysis

The limiting factor to the USRC capacity is not the number of trains per day but more accurately the number of trains per defined period during the peak service period. The graphs in Appendix B demonstrate the number of trains per 10 minute period arriving in the train shed. In the base case we see peaks of eight trains per 10 minute period. The same principle can be applied to the station capacity as they are two different issues. The graphs in Appendix C illustrate both the total station usage by hour and individual track usage by day. These values include both the additional time required to enter and depart the platform as well as a buffer or separation time between trains. In addition Appendix D provides a graphic representation of track occupancy and allocation.

To quantify maximum network capacity in this case we need to determine how many trains can be run on the simulated network while still operating at an acceptable performance level. To do this we added additional trains to the existing service. As these are theoretical trains for which an operating plan or schedule does not exist we used the following standards:

- 5 minutes dwell for through trains
- 10 minute dwell for turnaround trains
- One train added per hour during the peak period 06:30 – 09:30 and 15:30 – 19:30

- Tracks 11 and 12 were reinstated as they were modelled out of service in the Base Case due to train shed roof repairs

We initially chose to add one additional train per hour to each of the seven services during the peak period. This equates to 7 trains per service or 49 trains per day in total. The results of this Alternate (Base Case 'A') provided a SOTP of 47.6%. This value falls well below GO Transit's OTP target of 95% and it can be concluded that the capacity of the existing infrastructure with GO and VIA's current operating methods was exceeded. To further explore whether any additional capacity exists we ran additional alternates (B – E) with trains added to only specific services. Our next Alternate (Base Case 'B') had additional trains added to the Milton, Lakeshore East, and Lakeshore West services. Our results indicated a SOTP of 87.1%. While this is an improvement over Base Case 'A', the performance level still does not meet GO Transit's minimum requirement of 95%.

To allow a direct comparison between the results of the various cases and alternates we have included, in Table 3 below, the number of train scheduled to arrive in Union Station between 07:30 and 08:30, which we will refer to as the 'Peak Hour'. To clarify, if we examine Table 3, the Barrie service currently has two trains arriving in Union Station between 07:30 and 08:30. In case 'A' we added one train per peak hour for a total of three trains. This was reduced to the existing two trains in cases 'B', 'C', and 'D'. In case 'E' we again added a train for a total of three during the peak hour.

The Simulated On Time Performance (SOTP) is indicated in the bottom row for each alternate.

Table 3 – Base Case Trains per Peak Hour by Alternate

Case	Base (Existing)	A	B	C	D	E
Barrie	2	**3**	2	2	2	**3**
Georgetown	3	**4**	3	3	**4**	**4**
Milton	3	**4**	**4**	3	**4**	**4**
Stouffville	2	**3**	2	2	2	2
Richmond Hill	2	**3**	2	2	2	2
Lakeshore East	6	**7**	**7**	**7**	**7**	**7**
Lakeshore West	6	**7**	**7**	**7**	**7**	**7**
Total per Peak Hour	24	**31**	**27**	**26**	**28**	**29**
SOTP (%)	**94.4**	**47.6**	**87.1**	**88.7**	**76.7**	**68.3**

The best performance with trains above what GO Transit is currently running was found in alternate 'C' when we added one additional train per peak hour to both Lakeshore services. This provided a SOTP of 88.7% which does not meet GO's minimum requirement.

These results indicate that with the current dwell times and schedule the USRC and Union Station is at capacity. By examining the delay locations and animations we determined the limiting factor is in the vicinity of the John Street Ladder.

4.0 2015 Model

We next modelled the proposed 2015 level of traffic using the proposed track and signal configuration. This model included current GO trains, VIA's projected service, the Airport Rail Link ("ARL") trains and current freight traffic.

4.1 Track Layout

Track layout used to model the 2015 traffic level was the proposed, post construction configuration of the USRC. The track layout was obtained from the UC50-C-SG10009 drawing, dated February 29, 2008 (Appendix A). The proposed "New B Track" was modelled but was left out of service as it was indicated that this track will not be functioning by the 2015 milestone. In addition, GO has recently purchased both the North and South CN connecting tracks through the USRC. To allow use of the additional tracks GO proposes to remove one of the connecting tracks through the train shed area in order to install a passenger platform on the remaining track. For the purpose of modelling it is irrelevant as to which track is removed. We modelled with Track 16 removed and a platform added to Track 15.

4.2 Signals

The UCS90-T-SG-10-CW-400 drawing dated March 17, 2010, was used to locate all the signals and all the signal route and aspects were obtained from drawing UCS-90-T-I-401 dated April 9, 2010. The track layout drawing included the Cherry Ladder between tracks E1 and E3 in the vicinity of Parliament Street, however, the proposed signal drawings did not provide infrastructure for these routes. The Cherry Ladder was included in the 2015 model and the signal drawings were modified to provide routing for those switches. We modelled a maximum allowable speed limit of 45 mph for trains diverging on these switches. Train performance will change should this speed change.

4.3 Operating Plan

4.3.1 GO Transit

GO's operating plan was obtained from Form 660 dated Apr 3/10. We modified the track allocation as indicated in the following table to provide sufficient platform capacity for the additional traffic.

Table 4 – 2015 Proposed Platform Allocation

Track	Service
1	Airport Rail Link
2	Richmond Hill (Bala)
3	Milton (Galt)
4	Barrie (Newmarket)
5	Georgetown (Weston)
6	Lakeshore Westbound (Kingston to Oakville)
7	Lakeshore Westbound (Kingston to Oakville)
8	Stouffville (Uxbridge)
9	Lakeshore Eastbound (Oakville to Kingston)
10	Lakeshore Eastbound (Oakville to Kingston)
11	Overflow
12	VIA
13	VIA
14	VIA

Track	Service
15	VIA and Freight
16	Removed

4.3.2 VIA Rail

VIA provided us with their proposed Phase One and Two schedules which can be found in the following table. VIA indicated they propose to implement the Phase One schedule by 2012 but could not provide a date for the Phase Two schedule. Our modeling beyond the base case will include both VIA's Phases One and Two trains. We were provided with arrival or departure times only and did not receive proposed equipment routing. In developing the VIA schedule we allowed for the minimum dwells that VIA is currently using, 10 minutes to unload and 40 minutes to load. In addition, where practical, we connected trains to reduce the number of equipment moves to and from VIA's TMC which is located on the south side of the Oakville Subdivision at Mimico.

This operating plan was not presented to VIA and should be further reviewed to determine its feasibility.

Table 5 – Proposed VIA Schedule

Ottawa – Toronto			Toronto - Ottawa		
Departure Times			Departure Times		
Current	**Phase 1**	**Phase 2**	**Current**	**Phase 1**	**Phase 2**
5:45	5:30/5:45	5:30/5:45	6:55	6:55	6:55
	7:00	7:00	9:30	8:15	8:00
8:35	9:00	9:00			9:00
12:25	11:35	11:35	12:10	12:00	12:00
17:00	15:15	13:00*			13:00
		15:15	15:30	15:30	15:30
		16:15		16:30	16:30
	16:15	17:00	17:30	17:30	17:30
18:15	18:00	19:00*		18:35/19:00	18:35/19:00

* Alternates to be reviewed

Montreal - Toronto			Toronto - Montreal		
Departure Times			Departure Times		
Current	**Phase 1**	**Phase 2**	**Current**	**Phase 1**	**Phase 2**
6:35	6:35	6:00	6:55	6:55	6:00
	7:45	7:00	9:30	7:45	7:45
9:40	9:40	8:00		9:30	9:30
		9:40	11:35	12:00	12:00
11:45	11:00/12:00	11:00/12:00			14:00
15:40	15:00	15:00/14:00	15:10	15:00	15:00
	16:00	16:00		16:00	16:00
17:00	17:00	17:00	17:00	17:00	17:00
18:05	18:00	18:00	18:35	18:35	18:35
		19:00			19:00

4.3.3 Airport Rail Link

The Airport Rail Link ("ARL") service was added using 15 minute headways. In addition there was a requirement for the ARL service to load and unload in Track 1. As this is a new service we were unable to use the same calibration technique used for the GO service in the Base Case. Given the short headways and the relative isolation of the ARL service from other trains outside of the USRC, we selected a randomization of 0 minutes early to 1 minute late for this service. When we initiated our modelling the ARL trains were not under GO Transit's responsibility and are not included in the GO SOTP results.

4.3.4 Other Trains

Both ONR and CN's operations remained the same as in the base case. The quantity of trains modelled is illustrated in the following table.

Table 6 – 2015 Case Trains

Train Type	Daily Revenue Moves	Total Daily Trains (Equipment and Revenue)
GO	180	300 *
VIA	66	100 *
ARL	150	158 *
CN	1	1
ONR	2	4 *

** Includes all moves in or out of Union Station*

4.4 Results

Using GO Transit's standard for OTP we obtained the results indicated in the following table. The top cell indicates daily trains by service while the lower cell represents the SOTP.

Table 7 – 2015 SOTP by Service

Randomization	Revenue Trains by Service							
1 min ARL and 4 min GO	**BA**	**MI**	**GT**	**SV**	**RH**	**LE**	**LW**	**Totals**
2015 Daily Trains	*8*	*14*	*13*	*10*	*9*	*63*	*63*	***180***
SOTP	87.5%	89.2%	100.0%	97.8%	94.3%	97.1%	98.5%	**96.5%**

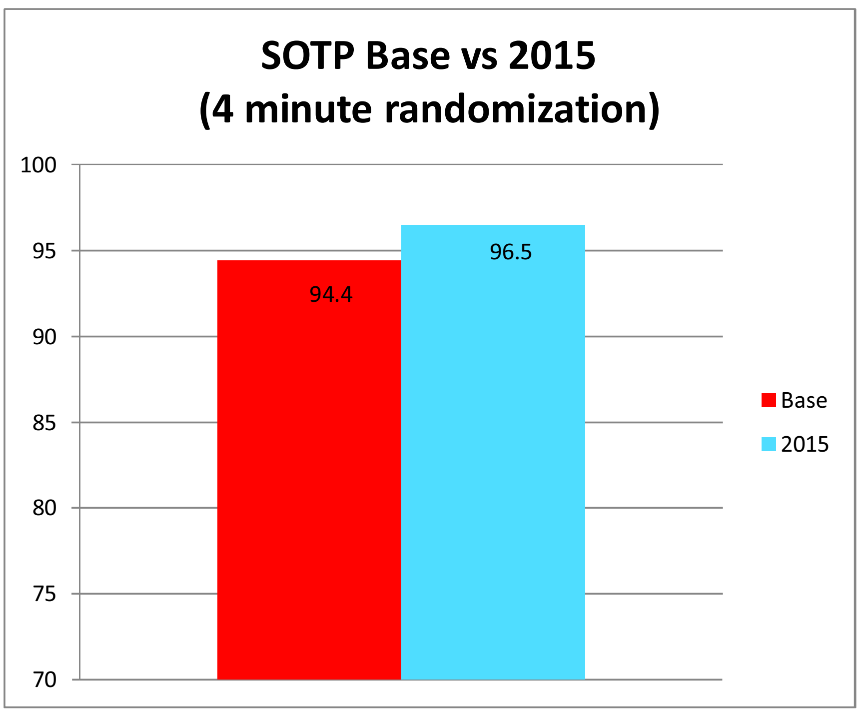

Figure 5: Base vs 2015 SOTP

We see an improvement over the base case and the performance of the network exceeds GO's minimum requirement. While our focus was on obtaining an acceptable network SOTP it should be noted that the SOTP for the Barrie, Milton, and Richmond Hill services does not meet GO's minimum requirement. This is related to the randomized starts that were implemented in the model to reflect real world performance. When the randomization was decreased we found the SOTP of all lines exceeded 95%.

4.5 Maximum Network Capacity Analysis

The number of trains arriving in the train shed per 10 minute period can be found in Appendix B. We see that the peak is 9 trains per 10 minute period which is an increase from 8 which was observed in the Base Case.

Again station occupancy and track allocation can be found in Appendices C and D. In addition the preferred train routing can be found in Appendix E.

As with the Base Case, to quantify the amount of additional train capacity available we added GO trains during the peak hours, 06:30 – 09:30 and 15:30 – 19:30. These additional trains were modelled with a minimum dwell of 5 minutes for through trains and 10 minutes for turnaround trains. Initially we added one train an hour to each of the services during the peak hours for a total of 49 additional daily trains. These trains were subsequently reduced as the initial results did not provide an acceptable SOTP. The following table provides train by service per peak hour and the SOTP for each alternate. In all alternates with additional GO trains, an acceptable SOTP was not obtained and it can be determined that with GO Transit's existing schedule and dwells, Union Station and the USRC will be at capacity in 2015 with the additional VIA trains and the ARL.

Table 8 – 2015 Trains per Peak Hour by Alternate

Case	2015	A	B	C
Barrie	2	**3**	2	2
Georgetown	3	**4**	3	3
Milton	3	**4**	3	3
Stouffville	2	**3**	**3**	2
Richmond Hill	2	**3**	2	2
Lakeshore East	6	**7**	**7**	**7**
Lakeshore West	6	**7**	**7**	**7**
Total per Peak Hour	24	31	27	26
SOTP (%)	96.5	85.7	91.3	92.4

While the base case was at capacity, this model, 2015, was able to attain an acceptable level of performance with the addition of the ARL service and an increase in VIA's trains. This can be attributed to two factors. The proposed track and signal improvements increased the speeds through the USRC which results in decreased occupation of the tracks in the vicinity of the station and VIA's schedule was modified to decrease the duration of their station stops thus reducing the number of tracks dedicated to VIA.

5.0 Electrification Reference Case One (ERC_1)

The Electrification Study Group provided us with a schedule designed to accommodate the level of service required for the electrification of the rail corridors. Track and signal layout remained the same as what was modelled in the 2015 case.

5.1 Operating Plan

VIA and ARL service levels remained the same as what was modelled in the 2015 case.

GO service increased substantially to 483 revenue moves in or out of Union Station daily. The schedule provided included equipment storage locations and allowed for a 5 minute dwell in Union Station for through movements and a 10 minute dwell for turnaround moves. Passenger flows in Union Station were not examined to determine whether the reduced dwells are practical. A summary of the ERC_1 operating plan can be found in Appendix F.

Table 9 – $ERC_{1,2,3}$ Case Trains

Train Type	Daily Revenue Moves	Total Daily Trains (Equipment and Revenue) *
GO	483	666 *
VIA	66	100 *
ARL	150	158 *
CN	1	1
ONR	2	4 *

** Includes all moves in or out of Union Station*

We further modified the platform allocation as indicated in the following table.

Table 10 – ERC_1 Platform Allocation

Track	Service
1	Airport Rail Link
2	Barrie (Newmarket)
3	Richmond Hill (Bala) / Georgetown (Weston)
4	Georgetown (Weston) / Richmond Hill (Bala)
5	Double Berthing Milton (Galt) west / Stouffville (Uxbridge) east
6	Overflow
7	Lakeshore Westbound (Kingston to Oakville)
8	Lakeshore Westbound/Eastbound
9	Lakeshore Eastbound (Oakville to Kingston)
10	Overflow
11	Overflow
12	Overflow
13	VIA
14	VIA
15	VIA and Freight
16	Removed

5.2 Results

We modelled the proposed schedule using a revised USRC based on proposed works but did not alter the rail corridors abutting the USRC. The model was unable to find an acceptable resolution to the many conflicts which the increased train counts presented. In examining the conflict locations and animations it became apparent that the restrictions preventing the model from solving existed on the adjacent subdivisions. To overcome this restriction we modelled the USRC bounded by Strachan Ave and the Don River only. It should be noted that this case was the only one where this modification to the model was required to enable a solution. As a result of the differences between this model and the others the outcome of this model cannot be directly compared with our previous or following results.

Our simulations provided the results as listed in the following table. The top cell indicates daily trains by service while the lower cell represents the SOTP.

Table 11 – ERC_1 SOTP by Service

Randomization	Revenue Trains by Service							
1 min ARL and 4 min GO	**BA**	**MI**	**GT**	**SV**	**RH**	**LE**	**LW**	**Totals**
ERC Daily Trains	*53*	*62*	*61*	*53*	*52*	*98*	*104*	***483***
SOTP	89.1%	77.2%	88.1%	86.3%	100.0%	85.7%	72.4%	**84.40%**

The above table indicates that a SOTP of 95% was only met on one corridor, Richmond Hill, with the busiest corridor, Lakeshore West (Oakville sub) only having 72.4% SOTP. This provided an unacceptable average SOTP of 84.4%.

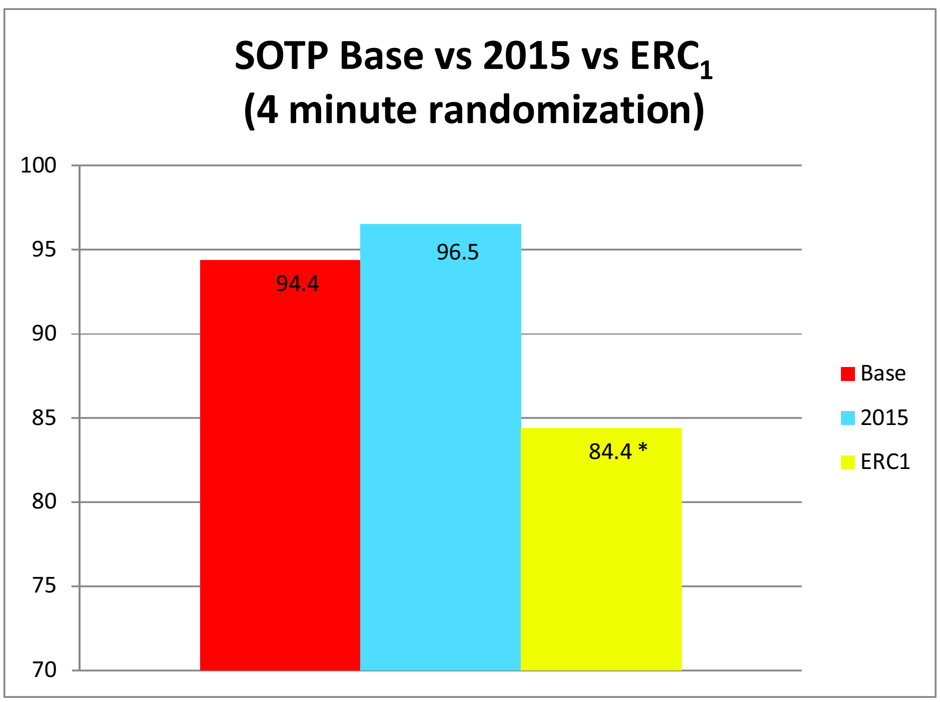

Figure 6: Base vs 2015 vs ERC_1 OTP

**The ERC_1 results cannot be directly compared with previous results and are shown as information only*

5.3 Maximum Network Capacity Analysis

Given the poor results of this model, the ERC schedule as presented cannot be accommodated with the proposed infrastructure and signal improvements. Further trains were not added.

There were several issues noted with this model. First, the proposed equipment moves did not compliment the layout of the USRC. For example, Newmarket trains were scheduled to layover in the Don Yard which required equipment to cross over the entire USRC. Secondly, the schedule appears to be optimized for the trains on the various subdivisions which results in multiple trains appearing in the USRC simultaneously. The number of trains arriving in the train shed per 10 minute period can be found in Appendix B. We see that the peak is 12 trains per 10 minute period. Finally and most importantly there was insufficient capacity abutting the USRC to allow the quantity of proposed trains to arrive and depart the limits of the USRC. This was most apparent on the west side of the station where there are four separate GO services, Lakeshore West, Milton, Georgetown, and Barrie, as well as the ARL and VIA trains. This is further congested by both VIA's and GO's equipment moves to and from Willowbrook. Fifteen tracks were modelled in the train shed, which reduced to 10 tracks at John Street and ultimately to 8 tracks at Strachan Ave.

Again station occupancy, track allocation, and train routing can be found in Appendices C, D, and E.

6.0 Electrification Reference Case Two (ERC_2)

In an effort to accommodate the Electrification Reference Case level of traffic we modified the ERC schedule slightly to stagger the arrival time of trains. Modifications included adjustments to equipment mid-day layover locations and station arrival times. The same frequency of service was maintained.

In addition the track layout was modified within the USRC to include additional crossovers. Finally tracks were added on each of the subdivisions adjoining the USRC to eliminate the restrictions noted with the ERC_1 model.

6.1 Track Layout

The subdivisions adjacent to the USRC were modified to include the number of tracks proposed by GO Transit as indicated in the following table.

Table 12 – ERC_2 Number of Approach Tracks

Subdivision	Existing Tracks	Proposed Tracks
Oakville	4	5
Galt	2	2
ARL	0	2
Weston	2	2
Newmarket	1 (0 connecting to USRC)	2
Bala	1	2
Kingston	3	4

In addition, to minimize the impact of bottlenecks, we added crossovers and connections in several locations. Notably to free up a portion of the North Ladder 1 at John Street a crossover was added between B1 and A1. This permits the ARL traffic to access the B track and Track One while only traversing one double slip switch on the North Ladder 1. Also in examining the results of the ERC_1 model a bottleneck was noted at the west end of the train shed on tracks 11 through 15. Improved connections at the west end of the train shed were modelled in this area to allow multiple paths. Crossovers were also added west of the USRC on the Oakville Subdivision near Fort York to allow parallel moves to the North and South Connecting tracks. A track diagram showing all proposed track modifications can be found in Appendix G. It should be noted that conceptual design or review of the modelled track changes was not completed. The locations must be reviewed to determine the constructability of the modifications as well as any impacts on safe braking distances or signal locations.

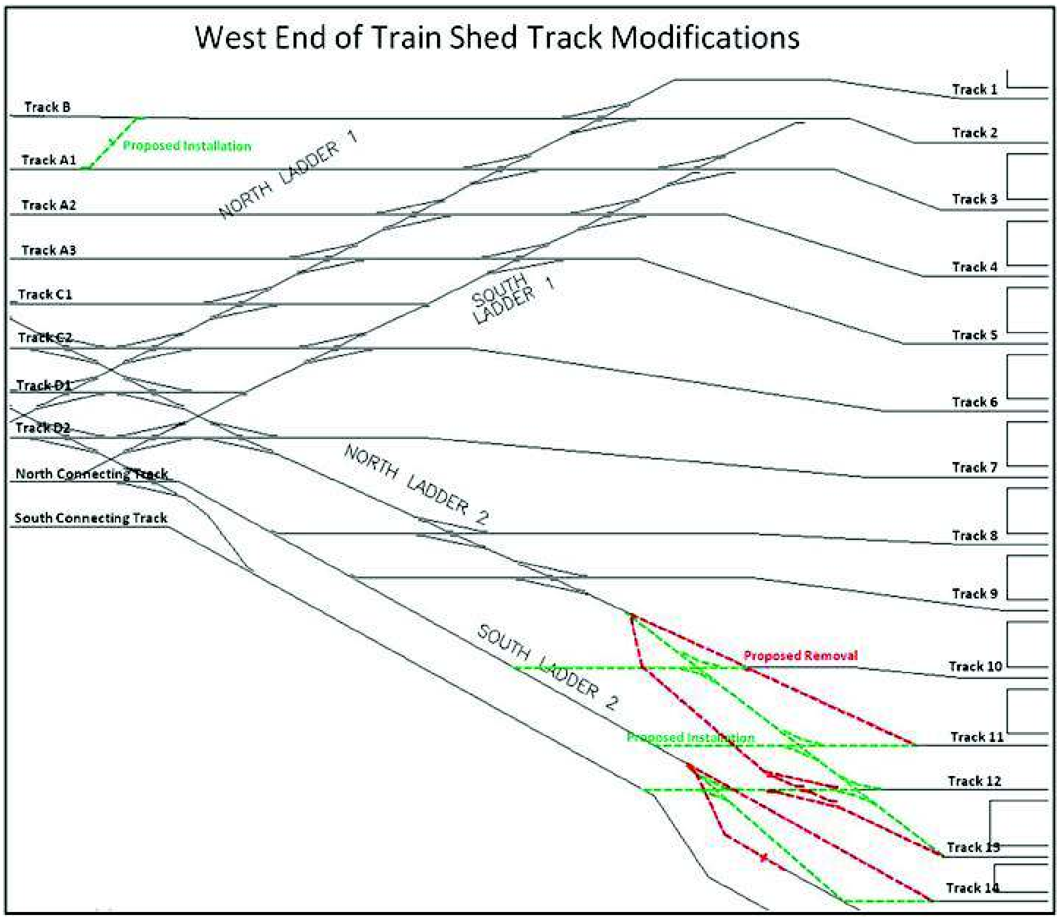

Figure 7: West End of Train Shed Proposed Track Modifications

6.2 Operating Plan

The number of trains modelled was identical to the Electrification Reference Case One.

The Electrification Reference Case schedule was modified slightly to stagger the arrival times of trains, in particular to avoid trains arriving at the same time from the same service or subdivision. Equipment storage was modified to better suit the layout of the USRC and the tracks selected for each type of service. We maintained the same number of trains at each location as was represented in the Electrification Reference Case schedule. These quantities can be found in the table below. An operating plan for the ERC_2 can be found in Appendix F.

Table 13 – $ERC_{1,2,3}$ Midday Storage Locations

Layover Facility	Number of Midday Trains Stored
Bathurst	7
Willowbrook	22
Don	19
East Rail Maintenance Facility	9
Bradford	1
Milton	9

We further modified the platform allocation as indicated in the following table.

Table 14 – ERC_2 Platform Allocation

Track	Service
1	Airport Rail Link
2	Milton (Galt)
3	Richmond Hill (Bala)
4	Double Berthing Milton (Galt) west / VIA to Georgetown (Weston) east
5	Double Berthing Barrie (Newmarket) west / Stouffville (Uxbridge) east
6	Georgetown (Weston)
7	Georgetown (Weston)
8	Lakeshore Westbound (Kingston to Oakville)
9	Lakeshore Westbound (Kingston to Oakville)
10	Lakeshore Eastbound (Oakville to Kingston)
11	Lakeshore Eastbound (Oakville to Kingston)
12	VIA
13	VIA
14	VIA
15	VIA and Freight
16	Removed

6.3 Results

Our model provided us with an SOTP of 97.5% based on GO's criteria. With the addition of tracks on the surrounding subdivisions we were able to model the same area as both the base and 2015 cases. While the ERC_1 case cannot be directly compared with the first two cases that is not the case with these results.

Our simulations provided the results as listed in the following table.

Table 15 – ERC_2 SOTP by Service

Randomization	Revenue Trains by Service							
1 min ARL and 4 min GO	BA	MI	GT	SV	RH	LE	LW	Totals
ERC Daily Trains	*53*	*62*	*61*	*53*	*52*	*98*	*104*	***483***
SOTP	98.3%	98.6%	96.9%	99.5%	100.0%	98.0%	93.3%	**97.5%**

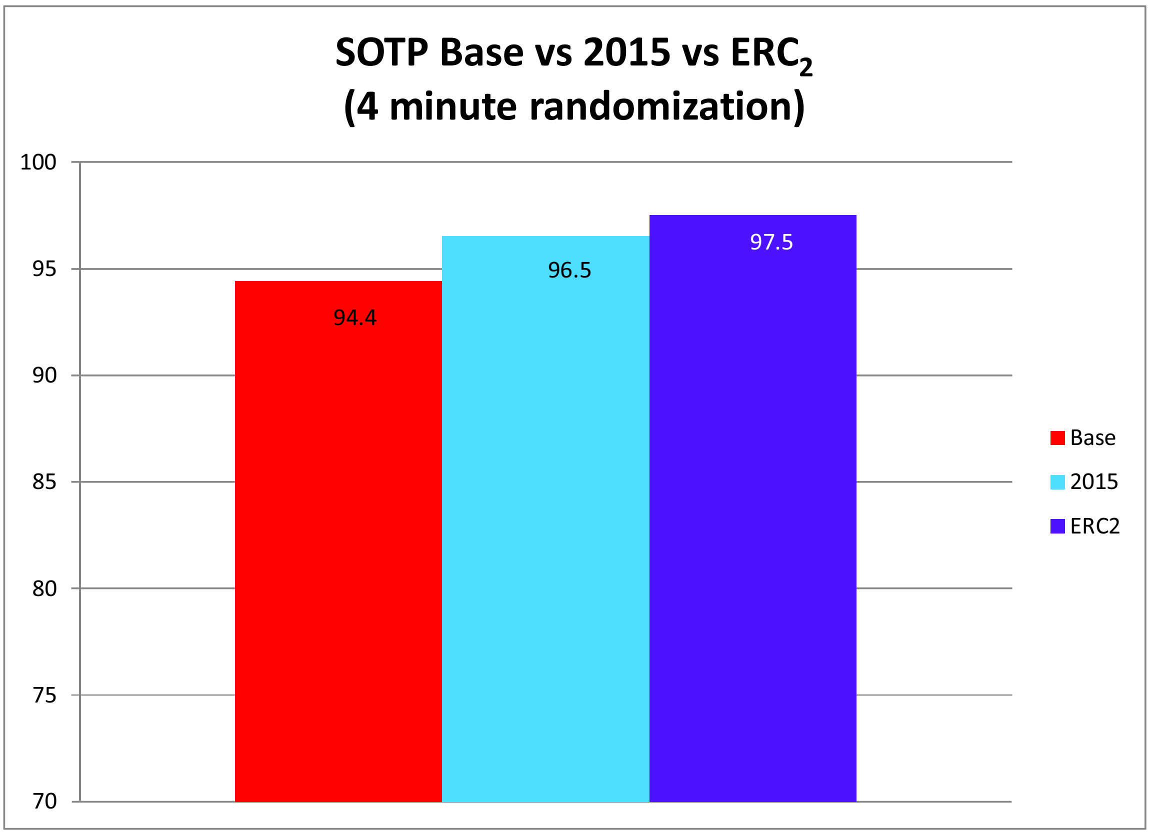

Figure 8: Base vs 2015 vs ERC_2 SOTP

6.4 Maximum Network Capacity Analysis

The number of trains arriving in the train shed per 10 minute period can be found in Appendix B. We see that the peak is 10 inbound trains per 10 minute period which is the same as the 2015 Case. Again station occupancy, track allocation and train routing can be found in Appendices C, D, and E. As with previous cases, to quantify the amount of additional capacity available we added GO trains during the peak hours, 06:30 – 09:30 and 15:30 – 19:30. These additional trains were modelled with a minimum dwell of 5 minutes for through trains and 10 minutes for turnaround trains. Initially we added one train an hour to each of the services during the peak hours for a total of 49 additional daily trains. These trains were subsequently reduced as indicated in the following table as the initial results did not provide an acceptable SOTP.

Table 16 – ERC_2 Trains per Peak Hour by Alternate

Case	ERC_2	A	B
Barrie	4	**5**	4
Georgetown	6	**7**	6
Milton	5	**6**	5
Stouffville	4	**5**	4
Richmond Hill	3	**4**	**4**
Lakeshore East	8	**9**	**9**
Lakeshore West	11	**12**	**12**
Total per Peak Hour	41	48	44
SOTP (%)	97.5	79.1	95.5

In this case an additional train per hour was successfully added to the Lakeshore and Richmond Hill services only. Double berthing (the practice of dwelling two trains at a time in the train shed in the same track) in Track One was needed to accommodate the additional Richmond Hill trains which will require track modifications to provide sufficient track length. Double berthing is accomplished by bringing the ARL trains into the west end of Track One from the west, and after completing their station stop, returning to the west. At the same time Richmond Hill trains will be entering Track One from the east, and after completing a station stop east of a stopped ARL train, depart to the east. While both services will be utilizing the same track, possibly at the same time, they will not occupy the same portion of Track One.

7.0 Electrification Reference Case Three (ERC_3)

We were asked to explore the potential benefit of routing the ARL service to a track other than Track One which was a requirement in the previous cases. The potential advantage to this is improved routing for the Newmarket and Weston Subdivisions which enter the USRC north of the ARL service. It also allows unimpeded access to Bathurst Yard from Tracks One and Two. The same schedule, track layout, and signal layout as the ERC_2 were used.

7.1 Operating Plan

The platform allocation modelled can be found in the following table. In addition a summary of the operating plan can be found in Appendix F.

Table 17 – ERC_3 Platform Allocation

Track	Service
1	Barrie (Newmarket)
2	Richmond Hill (Bala)
3	ARL
4	Double Berthing Milton (Galt) west / Via to Georgetown (Weston) east
5	Double Berthing Barrie (Newmarket) west / Stouffville (Uxbridge) east
6	Double-Berthing Georgetown (Weston) west / Stouffville (Uxbridge) east
7	Georgetown (Weston)

Track	Service
8	Lakeshore Westbound (Kingston to Oakville)
9	Lakeshore Westbound (Kingston to Oakville)
10	Lakeshore Eastbound (Oakville to Kingston)
11	Lakeshore Eastbound (Oakville to Kingston)
12	VIA
13	VIA
14	VIA
15	VIA and Freight
16	Removed

7.2 Results

Our model provided us with an improvement over the ERC_2 model with an SOTP of 97.9%. Our simulations provided the results as listed in the following table.

Table 18 – ERC_3 SOTP by Service

Randomization	**Revenue Trains by Service**							
1 min ARL and 4 min GO	**BA**	**MI**	**GT**	**SV**	**RH**	**LE**	**LW**	**Totals**
ERC Daily Trains	*53*	*62*	*61*	*53*	*52*	*98*	*104*	***483***
SOTP	100.0%	99.1%	100.0%	99.0%	99.4%	97.0%	93.9%	**97.9%**

7.3 Maximum Network Capacity Analysis

The number of trains arriving in the train shed per 10 minute period can be found in Appendix B.

Again station occupancy, track allocation, and train routing can be found in Appendices C, D, and E.

As with previous cases to quantify the amount of additional capacity available we added trains during the peak hours, 06:30 – 09:30 and 15:30 – 19:30. These additional trains were modelled with a minimum dwell of 5 minutes for through trains and 10 minutes for turnaround trains. Initially we added one train an hour to each of the services during the peak hours for a total of 49 additional daily trains. These trains were subsequently reduced as indicated in the following table as the initial results did not provide an acceptable SOTP.

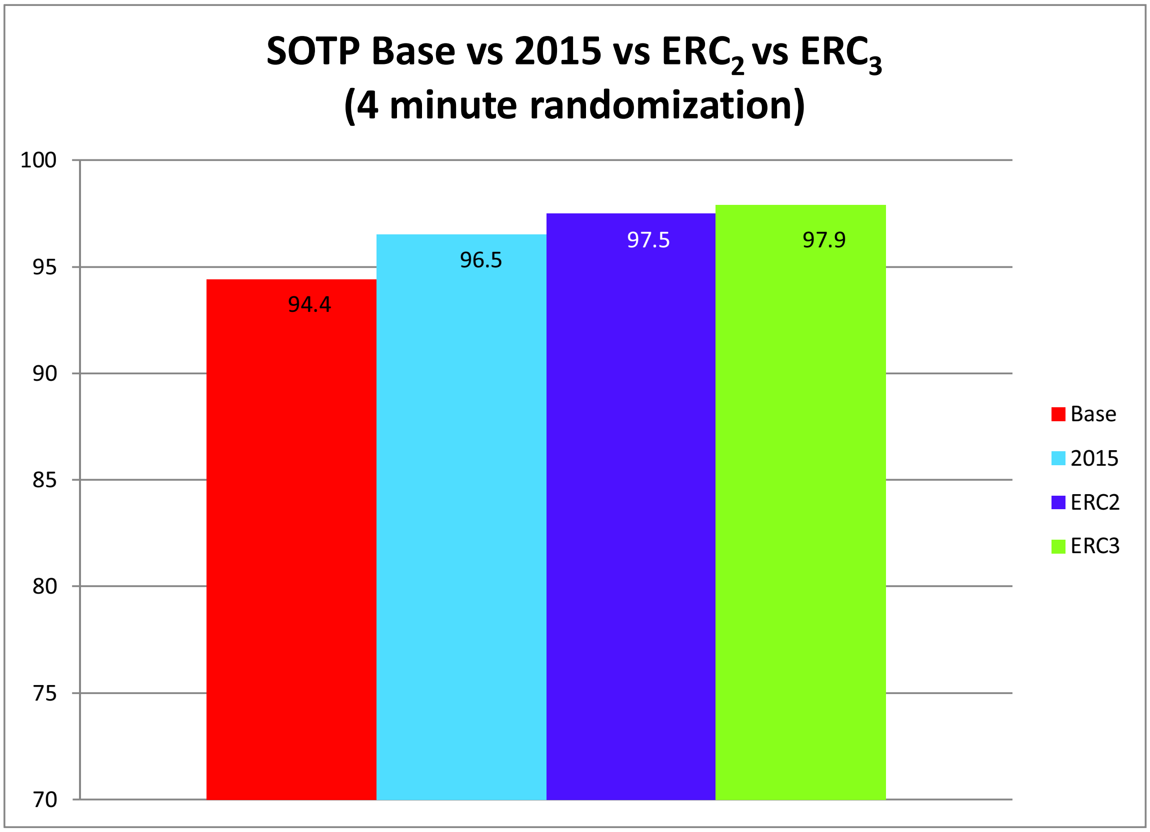

Figure 9: Base vs 2015 vs ERC_2 vs ERC_3 SOTP

Table 19 – ERC_3 Trains per Peak Hour by Alternate

Case	ERC_3	A	B
Barrie	4	**5**	4
Georgetown	6	**7**	**7**
Milton	5	**6**	5
Stouffville	4	**5**	4
Richmond Hill	3	**4**	**4**
Lakeshore East	8	**9**	**9**
Lakeshore West	11	**12**	**12**
Total per Peak Hour	41	**48**	**44**
SOTP (%)	97.9	84.1	95.8

In this case with an additional train per hour added to the Lakeshore, Richmond Hill, and Georgetown services we achieved an acceptable SOTP. These additional trains did not require double berthing in Track One.

8.0 Impact of Electrification

In several of the previous cases we modelled trains with electric locomotives replacing the diesel locomotive to determine the potential improvement associated with the increased tractive effort of the electric locomotives. The graph below compares the tractive effort available in pound of forces versus the speed of the locomotive in mph.

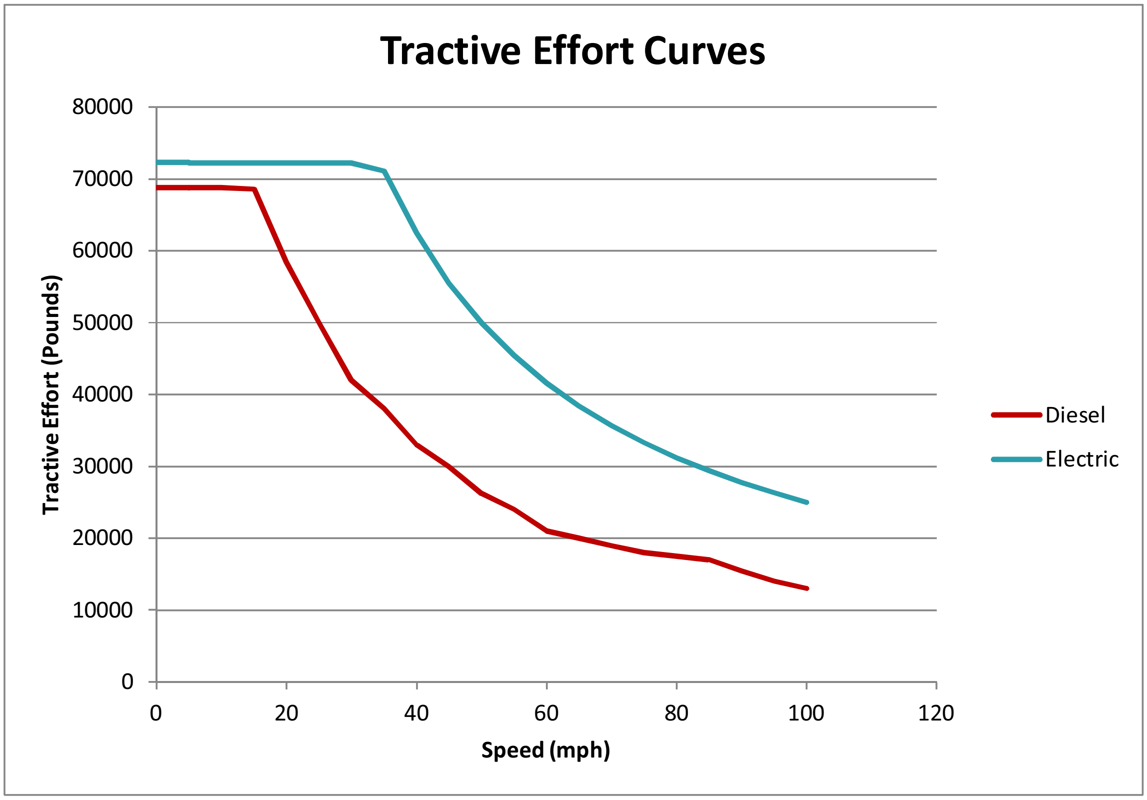

Figure 10: Tractive Effort Curves

The diesel locomotive used was an MP40 while the electric locomotive tractive effort was provided by the Electrification Study Team and can be found in Appendix H. We compared the runtime through the USRC and the SOTP with two consists which were identical other than with the substitution of electric locomotives in lieu of diesel. We found that the run decreased by approximately 16 seconds for a 7 minute and 23 second run time with the electric locomotive for a train operating from the Oakville Subdivision to the Kingston Subdivision with a station stop in the train shed.

The following graph illustrates the distance travelled by both a diesel and electric train versus time. It should be noted that the trains operate similarly on the left side which is entering the USRC or the deceleration portion of the run. The advantage of the electric locomotives can be found in the acceleration from the station stop.

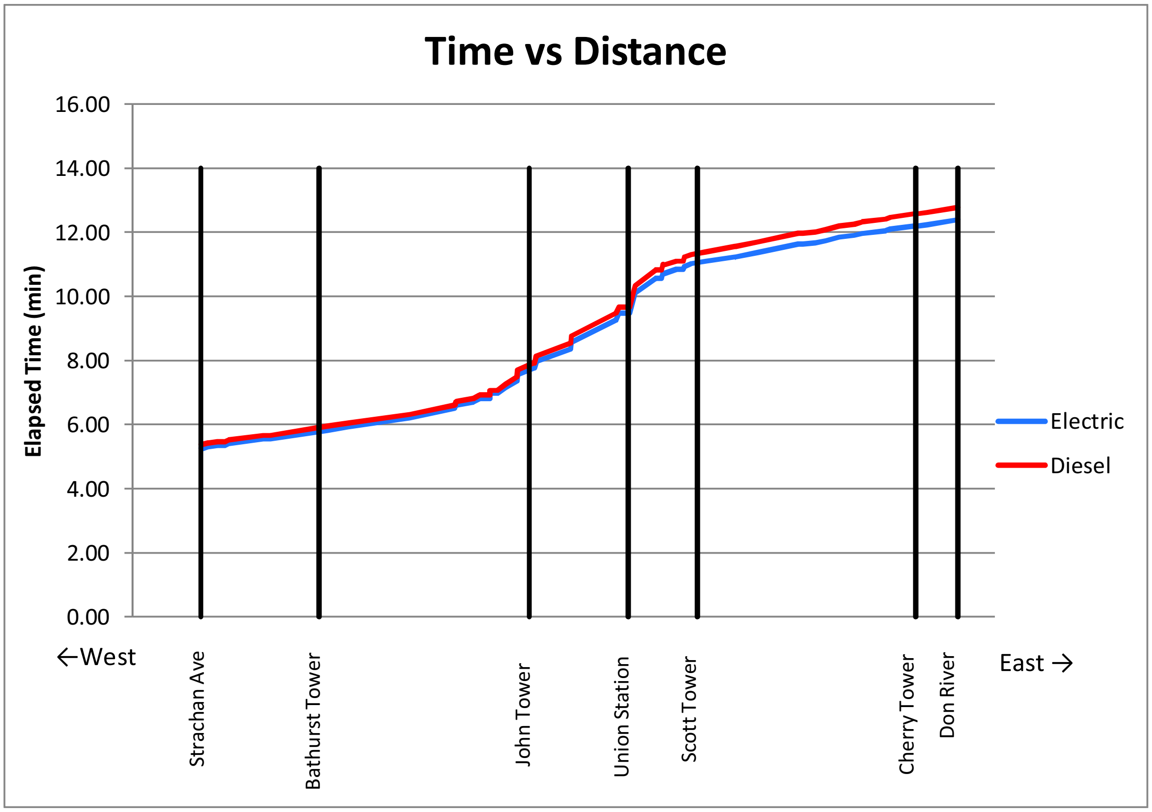

Figure 11: Time Distance Graph

The next graph illustrates the speed versus distance for both a diesel and electric locomotive equipped train. Again it should be noted that the deceleration portion of the graph is almost identical for both trains. In examining the acceleration of the trains, the electric locomotive reaches the maximum track speed much quicker than the diesel equipped train, but due to speed restrictions within the USRC, must delay further acceleration until clear of the slower track.

Figure 12: Speed Distance Graph

We reviewed the SOTP of several of the scenarios modelled to determine the impact on train performance with diesel versus electric locomotives. The results can be found in the following graph.

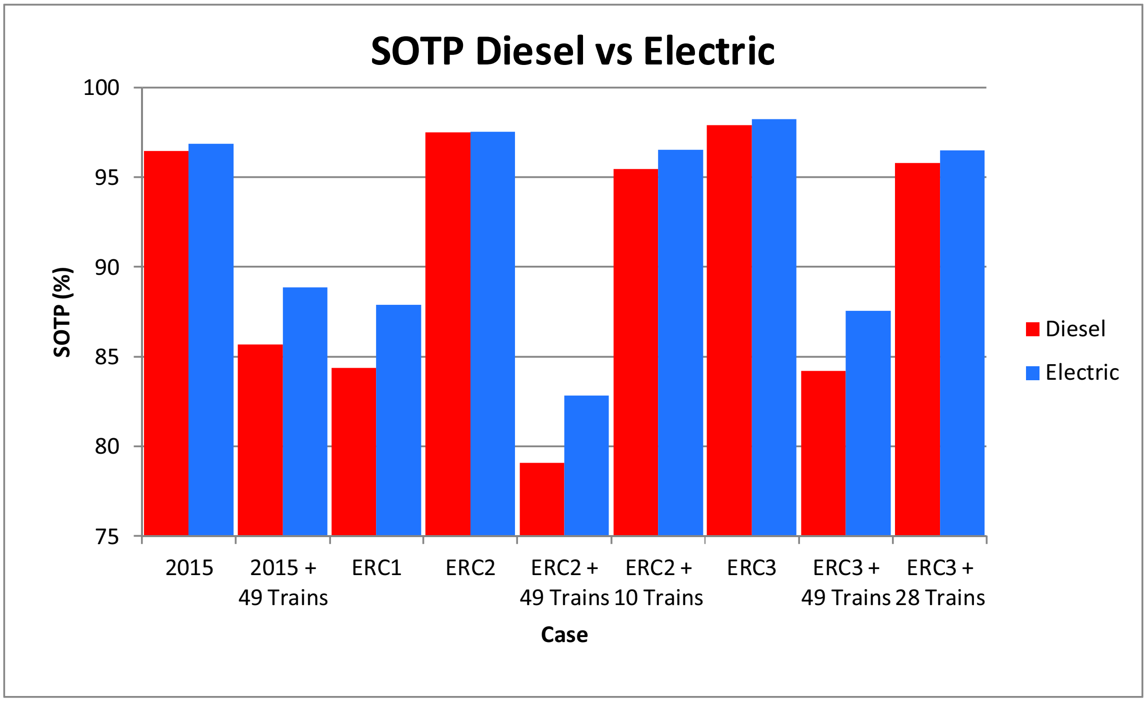

Figure 13: SOTP Diesel vs Electric

The advantage of the increased tractive effort of the electric locomotives is more pronounced when the USRC is operating above capacity. This can be attributed to unscheduled stops and re-starts as a result of the desired route being unavailable for a train. When the original model with diesel locomotives provided a SOTP above 95% the gain in using electric locomotives is approximately 1%. When the original SOTP was below 95% the gain is closer to 3.5%.

9.0 Operating Changes and the Effect on Capacity

Part of our assignment included review of different operating practices on train throughput within the Train Shed and USRC. Two items of interest were the advantage or disadvantage of turning trains in the station when compared to operating trains through the station after completing a station stop and improving passenger throughput on the platforms by providing wider platforms through track removals.

9.1 Train Shed Capacity Turning Trains vs. Operating Through

We performed a theoretical exercise to determine the impact on train shed capacity when trains are turned during their station stop, returning in the same direction they arrived, versus trains continuing through the station after completing their station stop. Similar to our previous modelling we used a minimum station dwell of 5 minutes for a through train and 10 minutes for a train which is turning. We reviewed the total occupation of the station track which commences when the leading end first occupies the track circuit until the dwell was completed and the trailing end of the train clears the track circuit.

The results can be found in the following graph. There are three bars associated with each track as well as the average. The first bar (blue) represents the amount of time a train, entering from the west, dwelling 10 minutes, and returning to the west would occupy the station track. The second bar (green) represents the amount of time a train will occupy the station track if it enters from the west, dwells for 5 minutes, and departs the station to the east. These numbers are similar to what we would expect for a train traveling in the opposite direction. Finally the third bar (orange) represents the station track occupation for a train entering from the east, dwelling 10 minutes, and departing the station to the east.

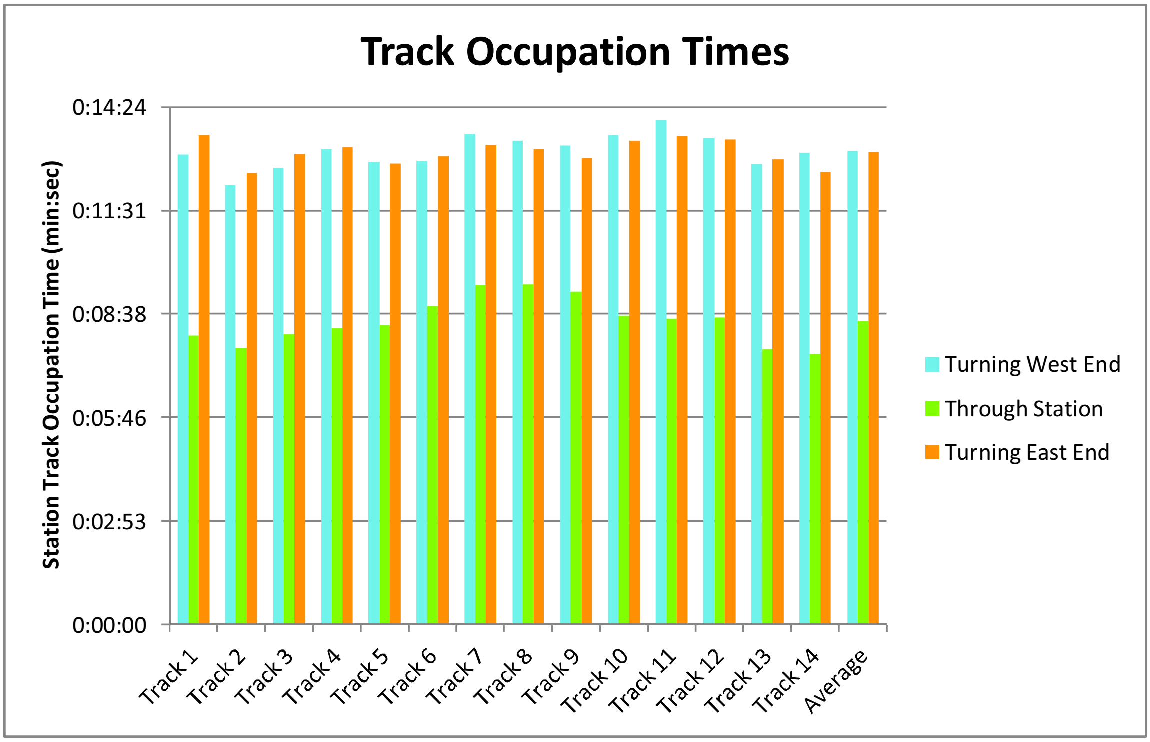

Figure 14: Station Track Occupation Times

The track occupation times vary by track due to the different track lengths. The average station occupation time for a through train is 8 minutes and 26 seconds while a turning train's average is 13 minutes and 10 seconds.

There is an obvious advantage for through trains over turning trains if only one train at a time can occupy the track within the train shed. Turning trains may provide an advantage when two trains can occupy the train shed in a single track through double berthing, bringing two trains half-way into the station from opposite directions and turning the trains.

9.1.1 Turning Trains with Double Berthing

Where the track has sufficient length to allow two trains to occupy the train shed within the ladders, the average station track occupation time is 13 minutes and 10 seconds including a 10 minute dwell. It would not be practical to schedule trains at this interval as a permissive signal would not be displayed when a train was approaching and any variation in schedule would affect subsequent trains. To provide a more robust operating plan a buffer or time separation should be allowed between trains using the same track. If we allow a one minute and 50 second buffer we could accommodate a train every 15 minutes. Using double berthing this would allow 8 trains per hour to unload and depart the station. This could be accomplished on longer tracks by having trains enter the track from opposite directions and stopping prior to reaching the centre of the train shed. After the passengers have disembarked and loaded, and the train crew has configured the train for its new departure direction, the train could depart in the direction from which it had originated.

9.1.2 Through Moves

Through trains will occupy the station track for an average of 8 minutes and 26 seconds including a 5 minute dwell. The term "Through Train" should not be confused with "Express Train". All revenue trains operating through Union Station will stop to embark and disembark passengers. Again to ensure a robust schedule we must allow a buffer time between trains. As the trains departing the station are following moves, as opposed to the facing moves that turning trains would have between subsequent trains, a slightly shorter buffer would be acceptable. If we allow a buffer of 1 minute and 34 seconds we could accommodate a train every 10 minutes. Since only one train will occupy the track in this scenario this would allow 6 trains per hour.

9.1.3 Conclusion

All other factors aside, if a track can accommodate double berthing, turning a train is more efficient within the train shed than operating through trains and will allow approximately one third more trains per hour in the train shed as indicated in the following graph.

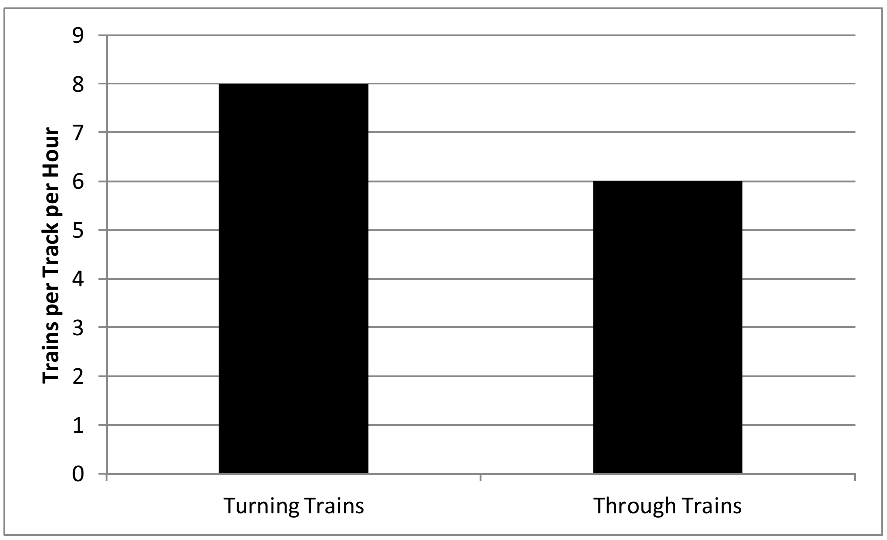

Figure 15: Train Shed - Turning vs Through Trains

9.2 Wider Platforms Resulting from Track Removals

Part of our mandate was to review the potential of increased train throughput with wider platforms. The platform improvements would necessitate track removals. Wider platforms would allow passengers to embark and disembark faster, resulting in decreased dwell times, and may ultimately increase the number of trains through the platform. To quantify the advantage or disadvantage of this proposal we determined the dwell time for each train while maintaining the same level of service but with fewer tracks.

9.2.1 Through Moves

Using the 5 minute minimum dwell for through trains, trains can be operated through the station on a single track with 10 minute headways. This includes a 5 minute dwell, 3 minute and 30 second arrive depart time, and a 1 minute and 30 second buffer.

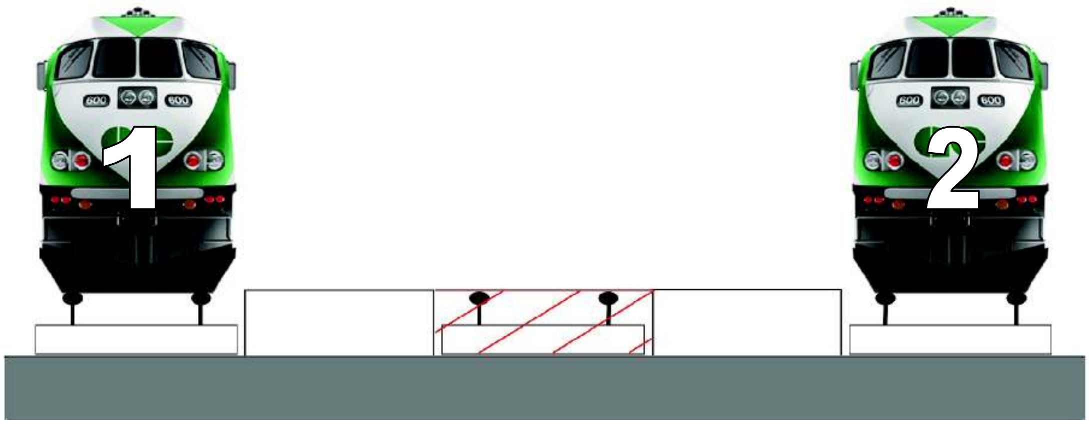

Figure 16: Wider Platform Created by Track Removals

If we remove a track and an improvement to passenger throughput is obtained on a single track only, the headway must be reduced to 5 minutes on this track to accommodate the same number of trains (2) on a single track which was previously accommodated on two tracks. This would include no dwell, 3 minute and 30 second arrive depart time, and a 1 minute and 30 second buffer. To clarify if the track between train one and train two in Figure 16 is removed and replaced with a platform and only track one benefited from the wider platform the dwell would have to be reduced to zero seconds, to accommodate the same number of trains per hour. If the track removal provides improved passenger throughput on two tracks we would need to accommodate three trains on two tracks during the same 10 minute period. This would require a headway of 6 minutes and 40 seconds (10 X 2 ÷ 3) to provide the same level of service. This would include a 1 minute and 40 seconds dwell, 3 minute and 30 second arrive/depart time, and a 1 minute and 30 second buffer.

9.2.2 Turning Trains

Using the 10 minute minimum dwell for turning trains, trains can be operated in and out of the station on a single track at 15 minute headways. This includes a 10 minute dwell, 3 minute and 30 second arrive/depart time, and a 1 minute and 30 second buffer.

If we remove a track and an improvement in passenger throughput is obtained on a single track only, the headway must be reduced to 7 minutes and 30 seconds. This would include a 2 minute and 30 second dwell, 3 minute and 30 second arrive/depart time, and a 1 minute and 30 second buffer.

If the track removal provides for improved passenger throughput on two tracks, we would need to accommodate three trains on two tracks during the same 15 minute period. This would require a headway of 10 minutes (15 X 2 ÷ 3) to provide the same level of service. This would include a 5 minute dwell, 3 minute and 30 second arrive/depart time and a 1 minute and 30 second buffer.

With turning trains these values and impacts would remain the same with both single and double berthing.

9.2.3 Conclusion

A significant reduction in dwell time must be realized on the remaining tracks to maintain the same level of service if tracks are removed to improve passenger flows. With through moves, if the advantage of wider platforms can be realized on a single track only, no dwell time would be available if the same level of service is required. The maximum permissible dwell required to maintain the same level of service for each scenario is indicated in the following table.

Table 20 – Maximum Dwell with Track Removals

Move Type	Tracks Improved	Maximum Dwell	Arrive/Depart	Buffer	Headway	Equivalent Headway
Through	1	**0:00**	3:30	1:30	5:00	10:00
Through	2	**1:40**	3:30	1:30	7:40	10:00
Turnaround	1	**2:30**	3:30	1:30	7:30	15:00
Turnaround	2	**5:00**	3:30	1:30	10:00	15:00

9.3 USRC Capacity (Minimum Reliable Headway)

We next looked at the minimum reliable headway available for the various services using the routing modelled in the Electrification Reference Case 2.

9.3.1 Single Station Track Turnaround Operations

For turnaround operations using a single platform per service the minimum reliable headway supported by the USRC exceeds the minimum theoretical station turnaround times presented previously in this section. This is as a result of shortfalls in the capacity of the tracks within the USRC approaching the train shed. With the majority of the turnaround services, the inbound and outbound trains are required to operate on a single track from the train shed to the limits of the USRC, particularly on the west end of the station where 13 tracks on the adjacent subdivisions will be connected to only 10 tracks in the USRC.

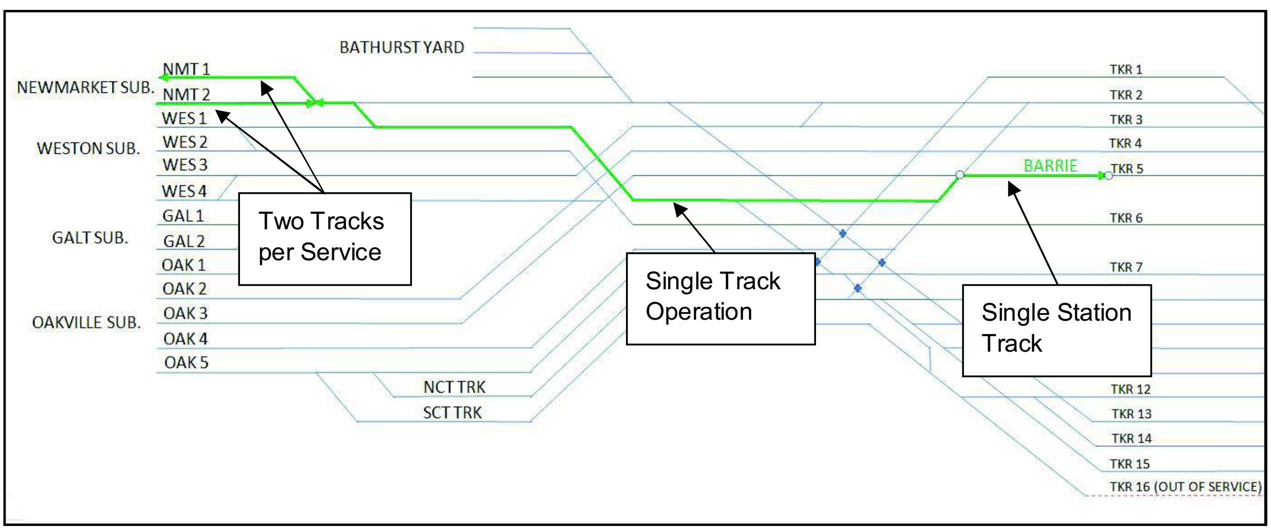

Figure 17: Single Station Track Turnaround Operations

The following table illustrates the minimum reliable headways available for turnaround operations with both 10 and 5 minutes dwells. We have included the 5 minute dwell headways to show the benefit of operational changes to allow 5 minute turnaround operations.

Table 21 – Minimum Reliable Headway with Single Station Track Turnaround Operations

Service	Single Track Operation Time	Total with 10 Minute Dwell	Total with 5 Minute Dwell	Buffer Time between Trains	Minimum Reliable Headway with 10 Minute Dwell	Minimum Reliable Headway with 5 Minute Dwell
Barrie	5:34	**15:34**	10:34	1:26	17:00	12:00
Milton	5:10	**15:10**	10:10	1:20	16:30	11:30
Georgetown	7:05	**17:05**	12:05	1:25	18:30	13:30
Richmond Hill	5:49	**15:49**	10:49	1:41	17:30	12:30
Stouffville	7:49	**17:49**	12:49	1:41	19:30	14:30

It should be noted that the Georgetown and Stouffville services have longer single track operation areas which results in a longer minimum reliable headway.

9.3.2 Two Station Track Turnaround Operations

Single station track turnaround operations require opposing trains to meet outside of the train shed and in some cases outside of the USRC. An alternative is to provide two platforms in the station with trains meeting in the station and alternating between two station tracks.

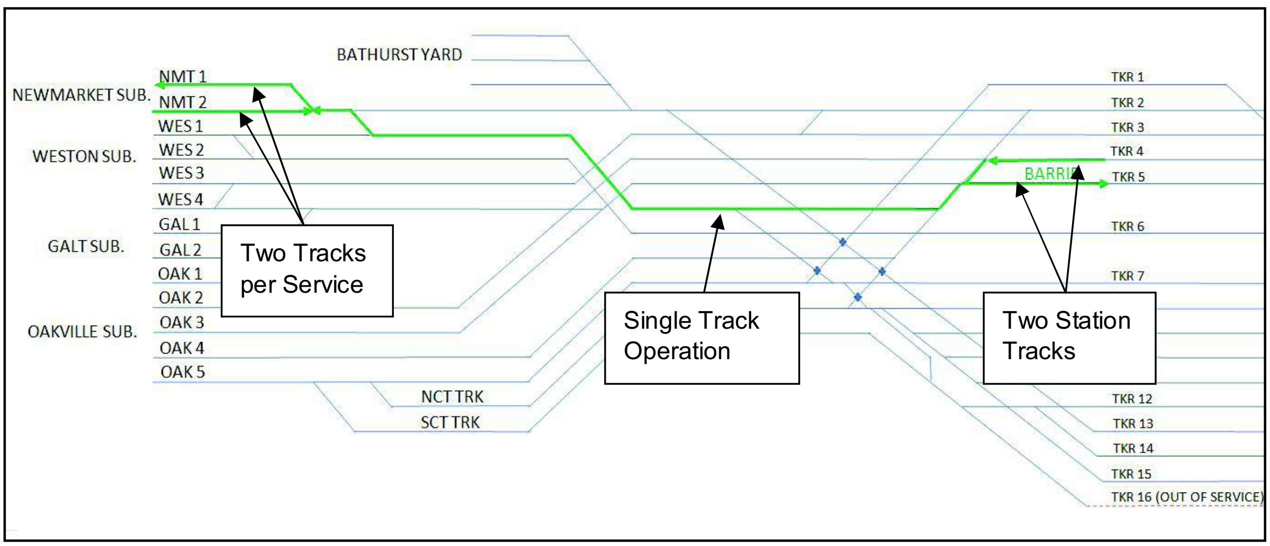

Figure 18: Two Station Track Turnaround Operations

The following table provides the minimum reliable headways available with a two station track operation. It should be noted that a 5 minute dwell is not feasible with this type of operation as the dwell must exceed the headway to avoid conflicts in the single track area and to permit trains to meet in the station.

Table 22 – Minimum Reliable Headway with Two Station Track Turnaround Operations

Service	Single Track Operation Time	Total with 10 Minute Dwell	Minimum Reliable Headway with 10 minute Dwell
Barrie	5:34	**15:34**	8:00
Milton	5:10	**15:10**	8:00
Georgetown	7:05	**17:05**	8:00
Richmond Hill	5:49	**15:49**	8:00
Stouffville	7:49	**17:49**	8:00

The benefit of this type of operation can be seen in the reduced minimum headway requirements.

9.3.3 Through Train Operations

With through train operations the minimum dwell into a single platform is 10 minutes. The signal spacing and USRC infrastructure will support a headway significantly less than this for following moves. If we alternate our trains between two station tracks we can cut the headway in half to 5 minutes.

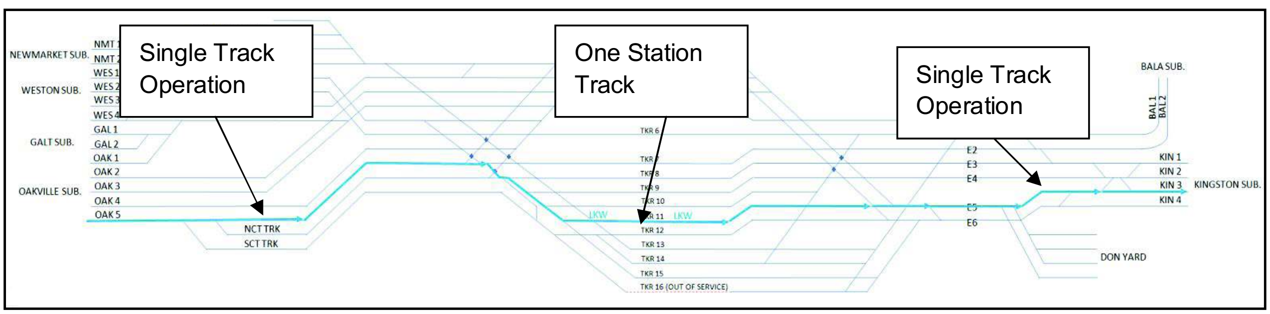

Figure 19: Through Operation One Station Track per Direction

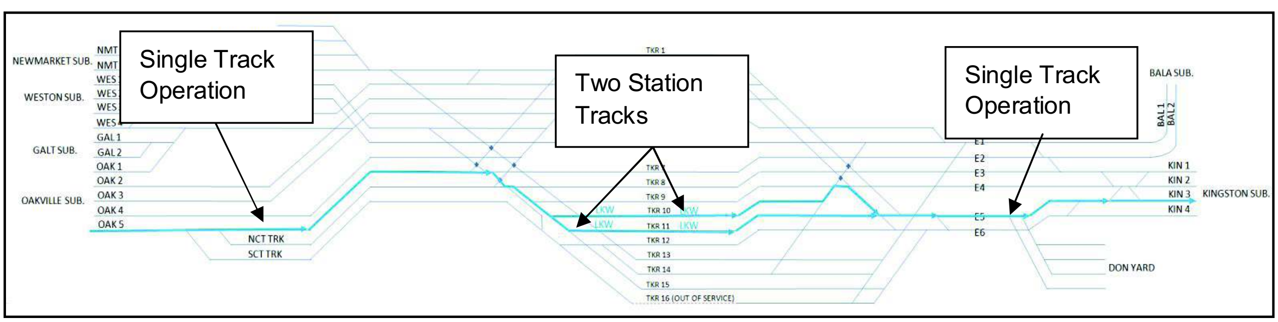

Figure 20: Through Operation Two Station Tracks per Direction

9.4 VIA Service Platform

We were asked to explore the possibilities of providing VIA with a servicing platform out of the train shed. This platform could be used to stock the VIA trains while freeing up train shed space for other trains. With the decreased dwells modelled, 10 minutes to unload and 40 minutes to load, this modification was not required. If the VIA services cannot function with the reduced dwells especially during the peak periods this would be a viable option. The servicing platform should be located on the east end of the train shed on the southernmost track.

10.0 Beyond the ERC (Maximum Capacity)

With a few infrastructure improvements beyond what GO is currently proposing, the ERC level of service can be accommodated. To move beyond this density of trains, significant operating changes or capital investments will be required. We explored two possibilities which are as follows.

10.1 Relocation of the Lakeshore Service to a New Underground Station

Appendix I, demonstrates an artist's concept of new underground tracks linking the Oakville and Kingston Subdivisions. These four tracks will accommodate a linked Lakeshore East and West service and thus free-up tracks in both the USRC and train shed to allow expansion of the other services.

This should allow the level of service represented in the following table.

Table 23 – Service Level with Underground Tracks

Track	Service	Potential Headway	Trains per Hour
1	Airport Rail Link		
2	Milton (Galt)	8:00	**7 ***
3			
4	Barrie (Newmarket)/Richmond Hill (Bala) Westbound	5:00	**12**
5			
6	Barrie (Newmarket)/Richmond Hill (Bala) Eastbound	5:00	**12**
7			
8	VIA Primarily destined to Georgetown		
9	Georgetown (Weston)/Stouffville (Uxbridge) Westbound	5:00	**12**
10			
11	Georgetown (Weston)/Stouffville (Uxbridge) Eastbound	5:00	**12**
12			
13	VIA		
14			
15	VIA and Freight		
17	Lakeshore Westbound (underground)	5:00	**12**
18			
19	Lakeshore Eastbound (underground)	5:00	**12**
20			

**Milton (Galt) potential is actually 15 trains per two hour period*

This configuration will allow for 79 GO trains per hour in addition to the ARL traffic and VIA's proposed traffic levels. Track configuration and routing for both of these options can be found in Appendix E.

10.2 Relocated Barrie and Georgetown Service

We also looked at the potential increase of service that would be available if some of the traffic from the Weston corridor was moved out of the station. These trains could be moved to a satellite station at the Bathurst North Yard location or to four stubbed underground tracks. The potential trains per hour can be found in the following table.

Table 24 – Service Level with Remote Station

Track	Service	Potential Headway	Trains per Hour
1	Airport Rail Link		
2	Milton (Galt)/Richmond Hill (Bala) Westbound	5:00	**12**
3			
4	Milton (Galt)/Richmond Hill (Bala) Eastbound	5:00	**12**
5			
6	VIA Primarily destined to Georgetown		
7	Stouffville (Uxbridge)	8:00	**7 ***
8			
9	Lakeshore Westbound	5:00	**12**
10			
11	Lakeshore Eastbound	5:00	**12**
12			
13	VIA		
14			
15	VIA and Freight		
17	Barrie (Newmarket) (relocated)	8:00	**7 ***
18			
19	Georgetown (Weston (relocated)	8:00	**7 ***
20			

**Stouffville, Barrie, and Georgetown potential is actually 15 trains per two hour period*

This configuration will allow for 69 GO trains per hour in addition to the ARL traffic and VIA's proposed traffic levels with a potentially lower investment cost than four underground tracks extending for the length of the USRC.

11.0 Phasing of Growth

Currently GO Transit has a number of initiatives underway within the USRC and Union Station which will modify the track configurations and modernize the signal system. These initiatives include upgrade and adjustment to the main lead tracks east and west of the station and the associated upgrading of the signal system over the whole USRC. Separately there are building and platform changes underway which will enable patron movement more freely between the platform level and the concourse. This study is based on these modifications being in place in 2015. The phasing of growth to the infrastructure and associated train service go hand in hand.

11.1 2015 Train Service Plan

2015 is the initial level of growth expected as GO Transit strives to meet their GO 2020 plan. A significant part of this plan will be adding the Airport Rail Link (ARL) train service operating between Pearson International Airport and Union Station. This ARL train service will add 158 daily trains to an expanded Georgetown rail corridor. Within the USRC this train service will operate over the west end segment on Track A1, through the fly-under rail/rail grade separation at Bathurst Street to enable this train service to access the chosen station track at the west end of Track One just outside of the train shed.

This phase of expansion will require the relocation of the VIA train service to tracks 13-15 in the Station. VIA train service is planned to grow to 100 trains per day and they will need to minimize their station track occupancy to the time required for loading and unloading passengers. GO Transit will need to work with the intercity passenger services to streamline the train servicing at the station tracks.

11.2 ERC Level of Growth

In our analysis, our first level of modification to the track and signals will be what is required to accommodate the Electrification Reference Case. Within the USRC we have proposed an additional crossover between B1 and A1 tracks near John Street. This will enable the ARL train service to move in and out of their station track on Track One and allow parallel train movements with trains moving between Track A2 and Track Two in the train shed (see Appendix E). Without this, only one of these two train routes can move at any one time which will create delays for either of these services (see Appendix F, ERC_2). Separately the connection between Track 14 & 15 and the west lead tracks is a bottleneck for train traffic destined for these tracks. Similarly four crossovers are also required where the southern two tracks in the USRC western corridor join with the Oakville Subdivision near Fort York. This modification will provide for direct train routings without interference from other train moves in this area and allow the Lakeshore West, VIA, and GO train service to move quickly and freely from the corridor to the train shed. Lastly, changes to the equipment movements into and out of service at the station were revised to be routed during the peak periods so they would not interfere with other train movements.

The result of these changes to the USRC plant enabled further growth in traffic in the USRC and Union Station to the level of the ERC case. But this was not all that would be required to enable the ERC level of traffic to flow. Given what we had learned as we studied various alternatives for this level of train service, we better understood that train meets in the western segment of the USRC must be kept to a minimum. The long range plan for line corridor train service calls for a total of 13 tracks approaching the USRC from the west and going into a 10 track limitation in the USRC near John Street then opening up to 15 tracks at the station. The study team looked at streamlining train services from each rail corridor in an effort to reduce the cross plant movements, blend the adjacent line corridor train traffic onto single tracks as necessary, and overall adjust the train schedules to allow all train services to enter from the west to the station through the 10 track restriction without delay. The by-product of this analysis showed that a number of train meets would need to occur outside of the USRC and this would require rail corridor capacity to handle these changes to train schedules. Corridor capacity must be provided along with a schedule designed to enable maximum use of the USRC's limited tracks.

GO Transit will want to make certain, as they determine the frequency of each corridor's train service, that the capacity of the USRC trackage is clearly developed at each stage. In the short term, the USRC and Union Station tracks can be used to their best effect, but as train service grows closer to the maximum capacity, GO Transit must look at streamlining their train service to achieve the conditions required to get the maximum usage out of the USRC. This will require corridor train service to be scheduled on a simple direct routing over the USRC and into the required station tracks.

Each line corridor train service must be designed to operate through the USRC on the same track which will lead directly into the appropriate station track. In this way there is little or no interference between train corridor services and the track speed can remain at its best and not be impacted by divergent routings. This will keep the impact of train service disruption to a single corridor and not affect adjacent corridors which will be routed on adjacent tracks through the USRC.

11.3 Through Trains versus Double Berthing Implications

The theory of Through Trains versus Double Berthing of trains within the Station Train Shed was discussed in Section 9. Two distinct types of station train stops were looked at to find out if either of these would improve train capacity in the USRC and Union Station. One method of station stop is a train that is destined to go through the station from one corridor to another with a stop at Union Station. The second method is a train arriving from one direction, then departing back to that same direction from one half of the platform while this same type of movement is operating off of the second half of the platform at the same time. In this way they would require the platform for a little more time than the previous stop type but in this case two trains could use one platform back to back at the same time, increasing the number of passengers handled on that station track.

The results of this assessment indicates that through train movements will make the best use of station track capacity but will create a level of passenger handling which will need to be efficient for it to be managed in the current station set up. On the other hand double berthing will allow more trains at the platform and possibly more time for passenger handling but will create more passengers to be handled due to the increased number of trains in any given period. This will also reduce the train management capability in the approach tracks to the station. This creates the need for a trade-off between these two possibilities.

Better customer handling time in the station versus maximizing track capacity in the USRC is the trade-off. This may provide a solution which could use double berthing of trains as train service grows and then as it reaches full train service capacity, change to through train movement when most trains will need to be put through the station to maximize track capacity and meet the train service plan for the approaching rail corridors. Double berthing of trains on one track at present can only be offered between tracks 6 to 9 at Union Station.

11.4 VIA Train Service Revisions

One of the major issues to train shed capacity is the amount of track and platform capacity allocated to VIA Rail Canada. At present VIA occupies tracks 8 to 10 for most of the day. This allows VIA arrivals and departures from east and west/northwest. In addition VIA provides various services to their trains at the station platforms such as food supply, cleaning services, and other amenities. As part of the capacity analysis the study team was directed to determine what might be a better way to use the station track capacity in an effort to determine the maximum train service possible within the USRC and Union Station.

The analysis revised VIA's station track occupancy to 10 minutes for unloading trains and 40 minutes for loading trains which was found to be what is required on a number of VIA trains at present. In addition the study looked at which tracks would be the best for VIA to occupy to ensure that train capacity and flow would be maximized. In most cases this indicated that VIA would be best located on tracks 12 to 14 with overflow onto 15 or 16 where they would be mixed with any freight activity through the train shed area. GO Transit indicated they plan for a new station platform to be set up at the existing track 15 and this would service tracks 14 and 16. Lastly the study team made every effort to flow VIA trains from service off of the eastern corridors to train service in the western corridors and vice versa. In this way it was expected this would service the VIA equipment utilization and would reduce the need for equipment movements over the Western corridor to their Toronto Maintenance Centre (TMC) in Mimico. For those VIA train sets which could not be linked to other train service on other corridors they were allowed 40 minutes within the train shed to enter into train service on another corridor or they were run to the TMC for storage or servicing. In most cases this worked well within the simulations. If these dwells are not acceptable to VIA an alternative may be to move trains off the station tracks to a cleaning and supply track just to the south-east of the train shed with associated track modifications to facilitate this movement of these trains off line until next required.

11.5 Long Range Train Service Additional Capacity

Once the current USRC and Union Station capacity was fully utilized, it was recognized that any new growth would need its own additional capacity. The study team looked at the rail corridors, the USRC, and Union Station, and determined one option was to establish a new station under the current Union Station but offset to the east between Bay Street and Yonge Street. Portals for the tunnel access to this station could be located in the vicinity of Bathurst Street in the west and Cherry Street in the east. This would provide for a two track tunnel under the current Union Station and establishing a four tracks/two platform station at this level between Bay & Yonge Streets. This would enable the Lakeshore East and West rail traffic to be removed from the current station therefore freeing up capacity for the remaining corridors. This addition of station capacity could have the ability to increase the commuter train traffic in the order of 30%. On the other hand this may pose issues for the handling of the travelling commuters who would use this system as they move from the train system into and out of the Central Business District of Toronto (CBD).

The second alternative would be to terminate the Barrie and Georgetown train services in the current Bathurst North Yard area and develop a pedestrian linkage between this location and the CBD. The proposed satellite terminus station would be made up of two island platforms and four stub end station tracks, linked to the Georgetown Corridor track network. The station would consist of a concourse above the trains and connected to Front Street. It has the possibility of having further development above the station and linkages to the south side of the rail corridor and possible links to a revised TTC Downtown Relief Line that could pass under this site and continue on to The Exhibition grounds. This proposal would be much less expensive than the first tunnel option. The obvious issue with this alternative is, it does not bring the people to the CBD but instead offers a train commuting service for the north and northwest commuter to the edge of the CBD with a walk to their work place or to link up with the Path System, or a connection to a future subway. If the City develops additional subway capacity which may service this location, then this would provide a very acceptable train service for these commuters. In addition such a station would draw the development of office space in this vicinity and enhance the opportunity for the Subway Relief line to be aligned with this station. From a train traffic point, this would remove approximately 20% of the commuter train traffic from the current station and allow the traffic from the other corridors to grow. A variation of this could be to tunnel these trains into the Union Station area and stub end these services there.

11.6 Phasing of Train Service Changes

Phasing in of new train service will depend on available funding, demand, and dovetailing with the needed linkages between the Commuter Rail System and the other mass transit systems which serve the increased number of commuters expected to use this system.

GO Transit will need to work with other agencies to determine which expansion corridors must be undertaken in which order. This study will benefit GO Transit in understanding the design of the ultimate train service plan to fully utilize the limited capacity of the USRC and Union Station.

Capacity within the approaching rail corridors will need to be added in association with additional train service to and from Union Station depending on which additional train service is added. ARL may be the first train service addition to the USRC. When train service approaches the ERC levels, corridor improvements will be required as well as the need for the crossover addition between Tracks B1 & A1 just west of the lead track on the west side of the station. This train service will not to interfere with other trains on the west end ladder tracks. The four crossovers on the Oakville Subdivision near Fort York and the revisions to the entrance tracks into track 10 to 15 at the west end of the station will reduce the conflicts between VIA and GO train movements in this area.

Once train capacity demands exceed what the USRC and Union Station can handle, GO Transit can examine the two proposed solutions: adding a tunnel under the current Union Station to increase the number of tracks managed at this location; or, develop a satellite station in Bathurst North Yard to limit the impact of increased commuter traffic to and from the City of Toronto, and if combined with a new subway line could broaden the downtown area and enhance the number of commuters handled by this system.

11.7 Probable Cost for Physical Changes

The probable order of magnitude cost for the proposed track and signal changes associated with train service improvements within the USRC are as follows:

1) Crossover between B2 to A1, west of west end ladder at approx. $500K
2) Station track connection revisions to track 10 &15 at the west end requires 4 double slip switches at approx. $6M and 3 conventional switches at approx. $1.5M
3) Four crossovers at Fort York to lead train service to the connection tracks at Approx. $2M

Future Expansion

1) 2 track tunnel from Bathurst to Cherry St. plus a 4 track station at Approx. $1.3 Billion
2) Bathurst North Yard Satellite station of 4 Stub tracks & overhead Station at Approx. $75 Million *(may vary considerably depending on type and size of station development, Subway features and PATH connections not estimated)*

These probable costs provide a measure of magnitude only. Should any of these items be worthwhile pursuing, we recommend a further engineering and feasibility study be undertaken to narrow the understanding of what will be required to implement the changes. Property availability for widening the rail corridor to accommodate the tunnel entrance and exit points may be a major obstacle.

12.0 Summary

The project analysis is summarized in Table 25 below. As growing levels of train service were assessed, this table shows us the number of trains entering Union Station at Peak Hour, 07:30 – 08:30. These numbers represent the capacity of the USRC and Union Station and include any additional trains that were added to the proposed service while still providing an acceptable level of performance. The table also demonstrates the potential maximum trains per hour with significant modifications to the USRC in the form of tunnelling or a satellite station.

Table 25 – Trains per Peak Hour by Case

	Base	2015	ERC_1	ERC_2	ERC_3	Potential with Underground Station	Potential with Satellite Station
Barrie	2	2	4	4	4	12	7
Georgetown	3	3	6	6	6	12	7
Milton	3	3	5	5	5	7	12
Stouffville	2	2	4	4	4	12	7
Richmond Hill	2	2	3	3	3	12	12
Lakeshore East	6	6	8	8	8	12	12
Lakeshore West	6	6	11	11	11	12	12
Total GO Service	**24**	**24**	**41**	**41**	**41**	**79**	**70**
ARL	-	4	4	4	4	4	4
VIA	5	7	7	7	7	7	7
USRC Total	**29**	**35**	**52**	**52**	**52**	**90**	**81**
SOTP (%)	94.4	96.5	84.4	97.5	97.9	-	-

12.1 Present Service Level

Our modelling indicated that the present configuration is at capacity during the peak hour using the station dwells found in the current schedule. We were unable to obtain an acceptable SOTP with the addition of any traffic during the peak period. There is potential to add trains off-peak during the shoulder periods or by reducing the dwells. It should be kept in mind that today's station tracks are reduced by two tracks due to shed maintenance and construction needs.

12.2 2015 Service Level

Our modelling confirmed that the proposed 2015 level of service is obtainable with the proposed modifications to the USRC. This was accomplished by reducing VIA's occupation of the Train Shed. VIA provided a proposed schedule but did not include equipment cycling nor station dwell times. We modelled VIA's trains using the minimum dwell they currently employ, 10 minutes to unload and 40 minutes to load, and linked trains whenever practical. This resulted in an increase in revenue moves by 18 per day while only increasing the number of daily trains by nine. This also allowed a significant reduction in VIA's occupancy of the train shed to a level where they could operate their traffic levels using three dedicated tracks and a track shared with freight movements. VIA's agreement within Union Station must be reviewed to determine if this is feasible. Again there is little room for expansion of service during peak hours with this configuration. We did add 29 additional trains during the peak period but obtained an SOTP of only 94% which does not meet GO's minimum requirement.

12.3 Electrification Reference Case One, Service Level

The Electrification Reference Case schedule as provided by the Electrification Study Team did not produce results with an acceptable level of reliability. To obtain a functioning model we were required to reduce the modelled area to the USRC only which does not allow a direct comparison between these results and the results of the other models. This is an indication that the current tracks connecting to the USRC are not sufficient to support the level of service required. Our results provided an SOTP of only 84.4% and it is anticipated that, were we able to model the same area as in the other cases, the results would have been slightly worse.

Two factors were noted which contributed to the unacceptable SOTP.

First the equipment cycling and daytime storage locations did not compliment the entrance points of the various services to the USRC and the track layout in the vicinity of the station. One example is, a train entering from the Newmarket subdivision, the north-west end of the USRC, and is destined for daytime storage in the Don Yard, located in the south-east end of the train shed, has to negotiate its way to the south end of the USRC tying up numerous tracks and a ladder.

The second significant factor was the timing of the trains entering the USRC. In several instances multiple trains from the same corridor enter the USRC within minutes of each other. This complicates the track allocation within the train shed requiring trains to overflow into other tracks. This in turn requires trains take switches onto adjacent tracks which demands capacity from two or three tracks instead of only one route.

12.4 Electrification Reference Case Two, Service Level

In an effort to accommodate the Electrification Reference Case level of traffic we modified the model. This included building out the adjacent subdivisions to GO's proposed number of tracks. Other infrastructure was added within the USRC to provide improved connections on the west end of the USRC. These included a crossover from B1 to A1, several crossovers south-west of the train shed and crossovers at the entrance to the USRC by the Oakville subdivision.

In addition to these infrastructure changes the schedule was modified slightly while maintaining the same level of service. These modifications included changes to the daytime equipment storage locations and spacing the arrival times of the trains at the gateways to the USRC.

Our results provided an acceptable SOTP of 97.5%. To determine what additional capacity might be available we attempted to add an additional train to each service, each hour during the peak period. This did not provide acceptable results with an SOTP of only 79.1%, however, trains could be added to the Richmond Hill, Lakeshore East, and Lakeshore West services with an SOTP of 95.5%.

12.5 Electrification Reference Case Three, Service Level

We were asked to review the advantages of relocating the ARL service to another track in the centre of the Train Shed. The potential advantage of this would be improved routing or trains entering the USRC at Strachan Avenue.

The results did improve slightly with an SOTP of 97.9%. In addition, while we could add a train per hour to each service we found that an acceptable SOTP of 95.8% could be obtained when trains were added to the Georgetown service in addition to the previously added Richmond Hill, Lakeshore East, and Lakeshore West services.

12.6 USRC and Union Station Maximum Capacity, Service Level

Determining capacity becomes complex because it is not a static system; it is a physical and dynamic system that depends on the different types of trains running and how they operate within the USRC network. The goal of a capacity analysis is to determine the maximum number of trains that could operate on a given railway infrastructure with specific operational conditions. Given the variations that this study looked at, the most consistent maximum capacity developed would be the level of train service provided for in the ERC 2 or 3 case analyses. These cases indicate that using the conditions set out, the Union Station and Union Station Rail Corridor will reach maximum capacity during the peak hours at this level of train service.

It is well recognized that this is a theoretically determined level of train service and that, over time and depending on how train service is added and operated, the actual maximum may differ. This maximum value will provide a target for developing the train service plans to achieve the maximum capacity. These targets consist of the conditions and volumes set out. Train service planners can use this guidance to work on future infrastructure development and start the planning which meets GO Transit's needs beyond the capacity the USRC and Union Station can provide. As commuter train service expansion starts to approach this volume, GO Transit will understand that their next capacity expansion will need to be developed if they want to enable growth up to and beyond this volume.

12.7 Impact of Electrification

This study looked at the impact which electrification might have on train capacity within the USRC. We found that electrified trains would have quicker starts and stops for each train but given the 6 km length of the USRC and the one planned stop within these limits, the electrification of commuter trains would have approximately a 3.5% improvement in run times or 16 seconds in a 7minute 23 second run time over the USRC. Under a disruption of train service, which would cause greater stops and starts within the USRC, electrification would enable quicker response and movement of slow speed trains. Other items to factor in would be the track configurations and the speeds this allows. Within the train shed, the track geometry and the safety of passengers on the platform will not allow train speeds greater than 10 mph until the train has completely left the train shed. Should a train need to go through a switch or ladder track it must not proceed at a speed greater than between 15 – 45 mph depending on the switch or ladder type. A close look at the track geometry and safety issues would have to be undertaken to determine what improvements, if any, could be undertaken to gain improvements on some of these speeds. Given some of the other operational issues and the short length of the USRC, it was felt that although electrification was much better in starts and stops, the small territory did not enable significant increases in performance in the USRC.

12.8 Train Shed Capacity

We found that with decreased dwells, 5 minutes for through GO trains and 10 minutes for turnaround GO trains, as well as reducing the number of VIA allocated tracks, that the Train Shed's capacity exceeds that of the USRC.

Our results indicated a maximum peak station utilization of 73% was reached with the ERC level of service. This track occupancy includes arrival and departure time and a buffer between trains. Theoretically trains could be added to bring this number closer to 100%.

We looked at two possibilities for improving operations within the station. We determined that with double berthing, turnaround operations will allow more trains per hour into the station when compared to through operations. Again this is based on a 5 minute dwell for through trains and a 10 minute dwell for turning trains. We also looked at the impact of track removal within the train shed to provide for better pedestrian throughput on wider platforms. We determined that a significant reduction in station dwells would be required to obtain the same level of service on fewer tracks. If the same level of service must be maintained this does not appear to be a viable option.

12.9 Union Station Rail Corridor Capacity

We looked at the minimum reliable headway available for the various services with a track layout similar to what will exist once the proposed USRC upgrades are completed. The headway is limited by the number of tracks between the train shed and the connecting subdivisions which necessitates single track operation for turnaround operations. This provides an advantage to operating through trains over turnaround operations. To increase service beyond the level modelled in the ERC, additional tracks would be required. The addition of a satellite station, whether it be located underground or off site in conjunction with four tracks supporting the station, could see train volumes of 70 to 80 GO trains per hour in addition to the proposed ARL and VIA services.

Train routing should be planned such that trains have a dedicated route from the entrance to the USRC to the appropriate track within the Train Shed. Dedicated routes will provide a two-fold advantage to train operations. First this will isolate the various services which will reduce the impact of schedule anomalies or service disruptions. With services sharing a route, a schedule variation on one service may affect the availability of that route for an adjacent service. Also minimizing reverse or turnout moves on switches will allow a greater average velocity through the USRC. The benefits of this will be more pronounced with electric locomotives.

The location of storage yards within the USRC has a detrimental effect on the capacity of the USRC. This requires that equipment moves traverse portions of the ladders to access yards on the northern or southern extremity of the USRC. It is more efficient to have equipment return to its origin, or, in the case of through moves, continue through the station and onto a storage yard located on the adjacent subdivision. At first glance this may appear to sacrifice capacity on the adjoining subdivisions but further examination reveals that these equipment moves are reverse peak moves on multiple track corridors allowing these equipment moves to dovetail between reduced reverse peak revenue moves. Ideally yards would be located on the Oakville (Mimico), Kingston (Danforth), and Weston (West Toronto Diamond) subdivisions. This will negate the requirement for planned equipment moves to cross over and occupy multiple tracks and thus reduce the footprint or impact of each train.

12.10 Long Range Capacity

With the expected growth in the GTHA as set out in the RTP plan, the GO 2020 plan may well expand beyond the capabilities of the USRC and Union Station. The study team was asked to look beyond the maximum capacity of the USRC and Union Station and developed two conceptual ideas for adding train service and station capacity which may increase the commuter train capacity handled in downtown Toronto.

12.10.1 Expanded Station in Tunnel below Union Station

One possible solution would be to develop a tunnel below the current USRC and Union Station with a four track station below ground and just to the east of the present Union Station. The portals for the two approach tracks to the station could be located in the approximate areas west of Spadina Avenue and west of Cherry Street within the USRC corridor. This tunnel would be developed to carry the Lakeshore East and West train service and any other train service which could be designed to connect with this tunnel. The station would be set up to have four station tracks with two island platforms and passenger links to the city and existing Union Station. The operation of this station would be to have two tracks in the approach tunnels operating with one track for eastbound rail traffic and one for westbound traffic. These train services would meet at the station by providing two station tracks for the eastbound and two for the westbound train traffic. In this way it would be possible to keep the approach tracks down to a minimum of two. This new subterranean station would be developed to the east of the current Union Station and link it with the subway, Front Street, Queens Quay LRT, and the PATH system. The level of train service removed from the current train shed at Union Station would be approximately two out of the seven corridors operated or approximately 30%. The probable total peak hour train service could be increased to approximately 90 trains when this option is included with the maximum train service managed by the existing USRC. The project team has determined the probable cost for this proposed tunnel and station to be approximately $1.3 billion.

12.10.2 Satellite Station, Bathurst North Yard

Bathurst North Yard (BNY) provides a site for a Satellite Commuter Rail Station which could provide additional commuter train services into downtown Toronto. This site provides the possibility of terminating GO train service from the Barrie and Georgetown corridors. This site also has the very real possibility of integrating with the TTC Downtown Relief Line (DRL) plan. A variation to this subway plan would be to revise the route for the DRL to pass under this site on its way from the Queen Street and University Avenue area and on to the Exhibition grounds. As a stand-alone GO terminus, this site would become an exit point for commuters from the Barrie and Georgetown corridors. These commuters would then move into the Central Business District (CBD) of Toronto via the expanded PATH system or at street level. With time, it should be very possible that this terminus would become a stimulus for the CBD to spread out towards this location and office space development to grow in this area. This in turn would encourage the long planned DRL to be aligned with this station and further on to the Exhibition grounds where it would also be able to pick up GO commuters off of the Lakeshore West corridor who are heading for the CBD. The level of train service removed from the current train shed at Union Station would be approximately two out of the seven corridors operated or approximately 20%. The probable total peak hour train service could be increased to approximately 80 trains when this option is included with the maximum train service managed by the existing USRC. The project team has determined the probable cost for this proposed satellite terminus station to be approximately $75 million for a basic station. Grander stations included in larger development of this land may also be possible.

Neither of these two possible expansions has undergone any level of engineering assessment or traffic simulation. The suggestions provided are the most probable solutions to develop more train capacity for commuter train service into the CBD. These probable costs provide a measure of magnitude only. Should any of these items be worthwhile pursuing, we recommend a further engineering and feasibility study be undertaken to narrow the understanding of what will be required to implement the changes.

13.0 Conclusions

Through the development of the many and varied simulations on this project, the study team has learned a number of valuable operating features which they have applied in their effort to define the capability of the USRC and Union Station to manage the ERC train service levels, and what is the maximum traffic that these facilities can manage.

1) Increased train service in USRC must be matched with Increased approach corridor capacity, driven by train service design
2) Train routing between approaching corridors and the station must be routed to reduce or eliminate train conflicts
3) Train meets in the peak periods between trains from the same corridor should be reduced or eliminated within USRC.
4) Equipment train movements into and out of service at the station during peak periods should be routed to reduce or eliminate train conflicts.
5) Eliminate trains crossing over in front of other trains in the USRC during peak periods.
6) Station track dwell times during the peak periods must be reduced for all passenger services
7) With the increase in commuter train service, more equipment movements will be converted into Revenue trains.
8) With the increase in commuter train service, equipment movements in the peak periods will need to follow the flow of trains onto the approaching corridor and travel to a storage location adjacent to that corridor.
9) Train storage at Bathurst North Yard and Don Yard can only handle train movements in and out in off peak periods.

GO Transit will need to work with VIA and ONR to reduce their dwell times at the platform tracks during peak periods for unloading and loading of intercity passengers. One of the significant time issues will be time required at the station tracks to services these intercity trains during the peak periods and where else this work can be done other than at the station tracks.

As a result of applying the above noted lessons the Study team learned that the current track configuration within the USRC can handle approximately three times its current train load but only within these certain specific conditions. It was determined that the fly-under rail/rail grade separation in the western USRC corridor may be underutilized and slip ladders should be reduced to a minimum number required at key locations for emergency and off peak use. Should the elimination of the inner slip ladders make sense, more of the station tracks could be developed into double berthing tracks. With the reconfiguration of the switches and ladder tracks as possible, track speed in the USRC should be increased which would improve the throughput of trains. The use of double berthing with reverse movements could generate as much as 33% more train service on each station track but at the expense of capacity within the USRC corridors.

With maximum capacity for the USRC and Union Station being reached at the ERC level of train service, the study looked at the train service capacity needed beyond this and how might it be provided. The study provides comment on the option of tunnelling under the current station and how this could remove all of the Lakeshore train service. This would enable all other rail corridor traffic to increase and use the existing above ground train shed. This new tunnel station could provide for the possible increase in commuter train traffic in the order of 30% at an approximate cost of $1.2 Billion. In addition the study looked at the alternate stub end satellite train station operation in the Bathurst North Yard area which could service some of the rail commuter traffic from the Georgetown/Milton/Barrie corridors. This has some merits but does not bring the commuters close to the Central Business District of Toronto or its subway system. Should the City or TTC develop a new subway/LRT system to service this area, this idea may prove beneficial. This option station could provide for the possible increase in commuter train traffic in the order of 20% at an approximate cost of $75 Million for a basic station site.

Electrification will play a major role in commuter train service in the future. With this in mind this study commented that within the USRC and Union Station at today's level of train service the impact of electrification may be slight due to the short section of rail corridor, limited number of stops, and the controlled speed within this corridor. The study did project that as rail traffic grows and speed restrictions are removed, then electrified trains will show an increasing benefit in support of a very scheduled and tightly run operation where every second of improved starts and stops will assist in train service performance.

14.0 Definitions

- ARL – Airport Rail Link
- Buffer or Separation Time – Time between trains to ensure trains receive a permissive signal and to allow for schedule variations
- CBD – Central Business District of downtown Toronto
- CN – Canadian National Railway
- Consist – A train made up of a combination of cars and/or locomotives
- Double Berthing – The practice of having two trains dwell in the station on the same track at the same time
- Dwell – The length of time a train waits in the station for loading/unloading passengers, or other operational tasks
- Dynamic Braking – Braking forces applied to the train by the locomotive using the drive motors
- Equipment Move – Trains not currently in service coming to or from storage
- HPT – Horsepower to Tonnage Ratio. A railway measure to gauge the potential performance of a train
- OTP – On Time Performance. A measure used by GO Transit to evaluate their compliance with their schedule. GO considers a train to be on time if it is less than 5 minutes late arriving at its destination station
- Peak Hour – 07:30 – 08:30
- Revenue Moves – Trains carrying passengers
- RTC – A software package developed by Berkeley Simulation Software. This package is widely accepted as the railway capacity modelling standard for North America
- Signal – An appliance (light) located aside the track which governs the movement of trains
- SOTP – Simulated On Time Performance. A measure used to compare the results of the simulations. Developed using the same criteria as GO's OTP
- Through Train – A train which operates through the train shed in one direction
- TMC – VIA's Train Maintenance Centre located on the south side of the Oakville Subdivision at Mimico
- Tractive Effort – The potential force a locomotive can apply to a train
- Train Shed – The tracks within the Union Station canopy
- Turnaround Service – A train which changes direction after completing its dwell
- USRC – Union Station Rail Corridor. The tracks surrounding Union Station bounded approximately by Strachan Avenue to the west and the Don River to the east
- Way Freight – A local train, typically less than 20 cars providing service to local industries