Subway Fleet and Route Planning
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Summary

Plans for additional equipment on the Toronto subway network do not provide for the level of service claimed in public statements regarding various subway projects. Although a 40% improvement is proposed, the available and planned fleets cannot deliver that service. Moreover, Bloor-Yonge Station (and possibly others) cannot accommodate the additional passenger traffic brought on by such a large increase in line capacity.

This causes the ten-year capital budget to understate future costs for increased capacity that would be enabled by the ATC[1] conversion and required by the Langstaff extension.

Collectively, the following factors have not been addressed:

- Additional trains are required for the VCC and Langstaff extensions.[2]
- Additional trains are required for shorter headways on Yonge-University-Spadina.
- Yard space is needed for the additional equipment.
- ATC equipment is needed for T-1 cars that will operate on YUS and Sheppard.
- Congestion problems at Bloor-Yonge and St. George must be relieved. A third platform at Bloor Station has been proposed, but both its cost and construction complexity must be thoroughly reviewed.
- Limitations on terminal operations at Kipling and Kennedy will constrain the ability to add capacity to the Bloor-Danforth line.
- Alternative north-south corridors in the Metrolinx Draft Regional Transportation Plan are projected to reduce future demand on the central subway network to below 2008 levels.

Provision of 40% greater capacity on the Yonge line plus reasonable allowance for growth on BD and Sheppard will require at least 28 additional TR trainsets beyond what are now on order[3]. This has a capital value of roughly $500-million just for the vehicles.

Any evaluation of alternative proposals to relieve demand on the YUS must be measured against the cost of additional trains, yard space, station construction and congestion on the existing system.

[1] Automatic Train Control. Although ATC provides the theoretical ability to operate trains at 90 second headways, in practice the minimum likely to be achieved on the YUS is 110 seconds.
[2] Possibly they are buried in the project budgets for these extensions, but insufficient provision has been made for total requirements including service improvements.
[3] As discussed later in this paper, 34 more trainsets are required for service and spares, less a possible 6 T-1 trainsets surplus to requirements on other lines.

Alternatives such as the Downtown Relief Line (DRL) and the Richmond Hill GO Express service will provide travel options and alternatives within the network that are not available if all we do is to expand within the existing system. This has a value in attracting new riders and keeping the existing network at acceptable levels of congestion.

A consolidated study of all options is urgently needed so that we can understand the contribution and importance of each element to the network, and can make financial plans on a fully-informed basis. (See further details in the Appendix to this paper.)

Introduction

Current TTC subway fleet planning will result in consolidation to two car types by the middle of the next decade. These will be the existing T-1 class cars and the new "Toronto Rockets" or "TR" cars. However, the quantity of TR cars now on order is only sufficient to replace the existing fleet with a very modest provision for expanded service.

Recent discussions of subway extensions north of Steeles Avenue have included claims of substantially increased capacity on the Yonge line through a combination of new signalling and station reconstruction, but there has been no mention of the need for a larger fleet to provide more frequent service.

There has been no discussion of the impact on Bloor-Danforth capacity from the increased arrival rates of transfer passengers at Bloor-Yonge and St. George Stations. The signal system on the BD line will be 50 years old by the time the YUS extensions begin operation, and provision for its replacement should appear within the 10-year window.

At a minimum, these considerations bear on the 10-year capital plan. Moreover, looking at the Metrolinx proposals for a Downtown Relief Line and frequent regional service via GO to Richmond Hill, there is a larger context for discussion.

- How much more capacity, if any, do we need on Yonge in the larger network?
- What capacity and capability for growth, if any, do we need and have on Bloor-Danforth?
- If a DRL is built, should it end at Danforth or continue north to Eglinton?
- What is the comparison between concentrating all demand on the Yonge line and spreading this demand onto other new lines both from a financial view and for expansion of travel options in the transit network as a whole?

For decades, TTC plans have assumed that the subway would have to carry the brunt of regional expansion because GO Transit service would be inadequate to the task. Politically, the DRL, once the second priority for new construction (after the Sheppard line from Yonge to Victoria Park), was pushed aside both to concentrate funding in the suburbs and in the mistaken belief that growth of the office core could actually be throttled by not building the DRL.

What has actually happened is that very little has happened in the suburbs, and downtown growth has been supported by improvements to GO Transit.

Toronto now faces the need to accommodate new demand from extensions into the 905. TTC planning, however, is rooted in a model where its own network must absorb most new demand. Rather than at least study those alternatives, the TTC continues to advance projects that would concentrate demand on Yonge.

This stance is not just misguided, but misleading because the TTC financial projections are incomplete. Improvements on the Yonge line appear less expensive than they might be because some costs are missing, and this skews debate about alternatives.

The projected new demand from the northern extensions is now within the 10-year capital planning window, a period already overwhelmed with other transit spending. If funding partners are suddenly faced with "surprise" projects that should have been foreseen, they could well demand offsetting cuts elsewhere.

Conversely, if this demand will be handled by other routes in the proposed Metrolinx network, the TTC could undertake large-scale capacity improvements on the Yonge line only to see the expected demand diverted elsewhere.

After years of planning for individual projects, the GTA is now looking at building a network. The last thing we need is to concentrate ever more demand and funding on one link in that network. At a minimum, the TTC owes everyone a fair, complete discussion of the alternatives.

Current Fleet and Planned Replacements

The current and planned fleets are set out below. Note that the TR cars are intended to completely replace the H series cars with some provision for growth in service.

	Trains	**Cars**	
H-4 cars	7	44	
H-5 cars	22	136	
H-6 cars	21	126	
Total H series	50		*306*
T-1 cars	62		*372*
Total fleet (2008)			***678***
TR cars (1st order)	39	234	
TR cars (2nd order)	21	136	
Total TR cars	60		*360*
Total fleet (TR cars replace H cars)			***732***
Service Requirements (Fall 2008)			
Bloor-Danforth	42		252
Sheppard (4 car trains)	4		16
Yonge-University	48		288
Change-Off Trains	3		16
Total			***572***

Spare Vehicle Requirements

In addition to the service requirement, one spare train is required on each line to replace trains failing in service. This provision is included in the subway fleet plan although it is not shown in the scheduled service summary. Beyond this, spare cars are needed for maintenance. Over the years, the allowance for spares has grown on the TTC to the point where a 16% spare factor is used. If this is applied to current service requirements, this translates to an extra 92 cars for a total of 664. The actual fleet is 678, and the actual spare factor is 18.2%.

The TTC has operated for decades with a larger fleet than its target spare factor would suggest because they are always in the process of replacing one set of cars with another. Old, almost retired cars make a handy source of spares, and we do not really know whether the TTC can achieve a lower spare factor in day-to-day operations.[4] A minimum number of spares is needed just to provide a pool for routine inspection and maintenance, let alone repairs, and the size of this pool grows as the fleet ages.

When the T-1 fleet was ordered, these cars were claimed to be substantially more reliable than the H cars, similar to claims for the TR fleet. The TTC has not published an updated spare factor for the fleet once the last of the H cars are retired.

However, the target spare factor can be implied from the anticipated saving cited by the subway fleet plan for the post-H-car environment. The fleet plan shows that the spare requirement will fall by 32 cars once the entire H-car fleet has been replaced with TR cars (see table 2, page 4).

The table below shows the spare factor one gets by deducting these 32 cars from the 2008 target fleet configuration (a 16% spare factor) and from the 2008 actual configuration where the fleet is slightly bigger than needed for the target value.

	2008 Actual	2008 Target
Service requirement	572	572
Spare factor with H fleet	18.2%	16%
Spares	104	92
TR savings (from subway fleet plan)	-32	-32
Net spares with TR fleet	72	60
Spare factor with TR fleet	12.6%	10.5%

Modern cars are more complex, and to this we must add the fact that entire TR trainsets will be out of service if any of their cars has failed. Previously, only two of six cars would be lost to maintenance requirements.

[4] Contrast this with the streetcar fleet where reliability has fallen and the spare factor has been able to rise thanks to service cuts and construction projects. Now the TTC faces a shortage of equipment.

In this paper, I use a spare factor of 12% which lies between the two values above.[5] This gives about 68 cars based on current service requirements for a total fleet of 640.

The combined T-1 and TR fleet of 732 cars will be 92 more than needed for this service level, assuming 12% spares. This provides some headroom for improvements on the current network.

[5] In my calculations, I have built the spare fleet up from the service requirement rather than starting with the current fleet and assuming various levels of savings. I believe that this method is superior to the one used by the TTC because it is straightforward and begins with the fundamental value – the number of cars needed for service – rather than the fleet size that happens to exist at the moment.

Automatic Train Control

A project is now underway to resignal the Yonge-University-Spadina line with Automatic Train Control. This is considered an essential pre-requisite to the Langstaff extension because closer headways will be needed than the existing system can support. (Signal equipment on the original Yonge line is also obsolete and needs replacement, but this is not the controlling factor in a move to ATC for the line as a whole.)

A speed control system is being installed (and may by now be active) on the Sheppard line, but this is not full ATC. It is also unclear how the T-1 cars used on Sheppard will be able to operate over the Yonge line once it fully converts to ATC[6]. The Sheppard fleet will require ATC equipment for carhouse moves over the YUS to Davisville and Greenwood. As we will see later, the BD line may not consume all of the T-1 fleet, and any T-1 cars used on YUS will also require ATC equipment.

Once ATC is fully implemented on the YUS line, it will allow closer headways primarily by reducing the clearance between trains moving at low speeds. The existing block signal system assumes trains are moving at the allowed track speed and, therefore, the signals must keep trains spaced so that they could be stopped from full speed before hitting the preceding train. A moving block system, such as used on the SRT, allows trains at low speed to creep right up to their leader. This is important at stations with long dwell times where getting a train onto the platform as quickly as possible is vital.

ATC may permit a slight reduction in round trip time, but this value is constrained mainly by safe track speed and by station dwell time. Any saving in station approach times could be offset by larger dwell times as demand grows.

The 1988 Improved Headway Study concluded that running times could be maintained down to a 112 second headway (1'52"), but that they would go up at a 90 second headway because trains would be too close together to operate at full speed.

The timing of a full rollout of ATC on the Yonge-University-Spadina line depends on the anticipated date when much more frequent service will be needed and on the expected lifespan of the various generations of signals now in use. All YUS and Sheppard fleets will require ATC, and it would not be surprising to see a proposed retrofit of the remaining T-1 fleet to allow diversion of trains from BD to YUS in emergencies.

[6] The Sheppard line stations can only hold 4-car trains and, therefore, TR trainsets cannot operate on that route.

Future Service Improvements

Many service improvements are planned or possible within the 10-year budget horizon.

- Extension of the Spadina short-turn operation north to Glencairn (planned for 2010) or to Downsview (proposed for the York/Vaughan extension)
- Extension of the Spadina subway to Vaughan City Centre from Downsview
- Extension of the Yonge subway to Langstaff from Finch
- Reduced headways on all lines

Each of these requires additional cars.

Extensions

This section reviews the impact of extensions based on the current level of service. Estimates of running times are based on information in the Subway Operations Report, Appendix Q of the Spadina Subway Extension EA.

Yonge-University-Spadina Subway Service Extension Options			
	Added Round Trip Time	**Headway**	**Additional Trains**
Extend Short Turn from St. Clair West to Glencairn	14’	4’40”	3
Extend Short Turn from Glencairn to Downsview[7]	9’20”	4’40”	2
Extend Through Service from Downsview to Steeles West	23’20”	4’40”	5
Extend Through Service from Steeles West to VCC	9’20”	4’40”	2
Extend Through Service from Finch to Langstaff	18’40”	4’40”	4
Additional train for Finch Farside Turnback[8]			1
Total Additional Trains			**17**

[7] Note that the need to maintain trip times as a multiple of the headway causes some fractional numbers of trains to be rounded up. However, the cumulative values correct for this notably in the Glencairn to Downsview short-turn extension which is timed “tight” because the previous extension has a slight excess of running time.

[8] Operation of frequent service will require a short-turn on the Yonge side of the line to avoid terminal congestion. This is only practical as a farside turnback at Finch (as is done today at St. Clair West), and this adds one train to the schedule requirement.

The fully built out service shown by the preceding table would give:

- A 4'40" headway from Langstaff to Finch,
- A 2'20" headway from Finch to Downsview, and
- A 4'40" headway beyond Downsview to York University and VCC.

The total service requirement for YUS would rise from 49 to 66 trains, or from 55 to 74 trains with spares at 12% (see table below).

This is 14 trainsets more than the planned TR fleet before any provision for headway improvements.

Shorter Headways

Increased capacity is only possibly by running more trains per hour, and this means that the headway must be shorter. Provided that the average running times are maintained, more capacity requires more cars in direct proportion to the added capacity, or inversely proportional to the headway change.

If the line bogs down, even more trains are required. This is important for close headways and their behaviour at busy stations and terminals.

For the purposes of this discussion, I have not attempted to work out service plans for various headways, but have simply scaled the fleet requirements relative to the service level. For certain headways this might result in a fractional overstatement of fleet size, but the difference will be at most one train[9].

Yonge-University-Spadina Subway Headway Reduction Options						
	Headway	Trains Per Hour	Service Req't	Change Off Train	Mtce Spares @ 12%	Total Trainsets
2008 Service	2'20"	25.7	48	1	6	55
Base Design: Langstaff-VCC Finch-Downsview	 4'40" 2'20"	 12.8 25.7	65	1	8	74
	2'10"	27.7	70	1	9	80
	2'00"	30	76	1	9	86
	1'50"	32.7	83	1	10	94

The capacity increase to 32.7 trains per hour is about 27%. Adding roughly a 10% increase for TR trainset capacity versus a 6-car H train gives a combined improvement of 40% in the capacity of the YUS.

[9] Some offsetting saving in total trains may be available by reducing the number of gap trains below the current 4.

Note, however, that this will require 34 more TR trainsets than are now on order and, moreover, that the TTC does not have yard space for all of this additional equipment. A possible offset would be the retention of some T-1 cars for YUS service, but they would require ATC equipment and would have slightly less capacity than the TRs. This depends on requiements for other lines.

Station Capacity

A third platform option for Bloor Station is described in detail in the 1988 Improved Headway Study. That study details the extreme difficulty of adding a platform to the existing station including construction impacts on nearby buildings and a temporary closing of Bloor Station that would force all transfer traffic to St. George. The cost of this option, not to mention the disruption during construction, must be weighed against the actual benefit and the alternatives available.

Concentration of so much demand on one corridor, the Yonge line, requires detailed analysis of how the failure of this line would affect the system. Earlier this year, Toronto saw the effect of losing the subway due to damaged signal cables at Eglinton. "Normal" day-to-day delays are commonplace, and the ability of the system to handle a service interruption at a closer headway and higher capacity requires careful review.

Finally, the impact of added passenger flows at other stations must be studied along with Fire Code implications. Construction projects that significantly affect the passenger load on a station have triggered second entrance projects (notably at Spadina). Does a 40% increase in line capacity trigger the same requirement for the YUS route as a whole?[10]

Even without considering Fire Code, how can existing stations operate when their exits are partly closed by escalator maintenance?

[10] Over a dozen YUS stations have only one exit path from platform to street level. Although there may be multiple stairways and escalators, they pass through common mezzanines.

The T-1 Fleet

Current service on the Bloor-Danforth line requires 252 cars, and a further 16 are needed for Sheppard. Adding spares at 12% brings the total requirement to 322 cars.

Assuming that the T-1 fleet will be used for the BD and Sheppard lines, the fleet situation with fall 2008 service level would be as below.

Bloor-Danforth & Sheppard Subway Fleets (Current Service Level)			
	Trains	Cars	
BD Service	42	252	
Sheppard Service	4	16	
Change Off Trains	2	10	
Subtotal		278	
Spares @ 12%		34	
Total Required			312
T-1 Fleet			372

Improving capacity on the YUS will place pressure on the transfer stations at Bloor-Yonge and at St. George, and will require additional service on the BD line. This will be extremely challenging because of track layout constraints at the terminals, and at best the existing headway could be reduced from 140 to 130 seconds. Such a change would require 3 more trains, but would only improve capacity by about 7.5%.

The subway fleet plan provides for an additional 7 trains on BD that would bring the scheduled headway down to about 2'00". I do not believe that this is physically possible at Kennedy or Kipling terminals for the same reasons cited in the 1988 headway study for Finch terminal. The crossovers are too long to permit trains to enter and leave on a 120-second headway on a sustained basis.

Any attempt to run closer headways on BD should also be accompanied by a reduction in running time to clear the existing backlog of trains at the terminals. Tight headways and padded running times are not a viable option, and terminal operations must improve in both speed and discipline to achieve the shorter headways. This might save one train while preserving existing headways, or allow a slight service improvement with the existing fleet.

On a ten year timeframe, it is reasonable to plan for some growth in demand on Sheppard, and one more train at a minimum should be provided for this, although the fleet plan does not include any.

The resulting fleet requirement is shown below.

Bloor-Danforth & Sheppard Subways Fleet (Future Service Level)			
	Trains	Cars	
BD Service	45	270	
Sheppard Service	5	20	
Change Off Trains	2	10[11]	
Subtotal		300	
Spares @ 12%		36	
Total Required			336
T-1 Fleet			372

This leaves 36 cars available for use on the Yonge line to offset its equipment needs, but these will require ATC equipment. These trains should also be scheduled so that they do not pass through the peak point and direction. On a line stretching from Langstaff to VCC, this should not be difficult.

Given the length of the extended YUS, it should also be possible to concentrate the shortest headway in a "wave" so that the highest capacity did not operate over the entire line. This would save on fleet size, but I have not incorporated any such allowance here.

[11] One six-car train for BD plus one four-car train for Sheppard.

Capital Budgets for the VCC and Langstaff Extensions

Both of these projects contain line items for "Vehicles and Other".

Route	Vehicles and Other Budget Line
York/VCC Extension	$268-million
Yonge Langstaff Extension	$257-million
Total	$525-million

Taking the present-day price for a TR trainset as $18-million, this means that on a best-case basis 29 TR trainsets are provided for in the budgets for the extensions. If so, these, plus the available cars from the T-1 fleet would just about cover the shortfall in current fleet plans. However, this would not cover the cost of new yard space for the trains.

The Capital Budget needs to be adjusted to remove the cost of additional trainsets from the projects into separate items, and to add a project for an additional yard. I understand that expansion on the scale required is not possible at any current site.

An important consideration for system planning after the Langstaff extension opens is this: will the entire 40% additional capacity be needed from day 1, and if not, how many years of growth will remain within the capacity of the Yonge line?

Capital Budget for ATC Implementation on YUS

Comments in the capital budget make the exact scope of the current ATC project unclear. Specifically, we need to verify that all of the existing YUS will be ATC-equipped by the time the Langstaff extension opens if, indeed, the service will be improved to handle added demand from that extension.

Consolidated service, fleet and signalling plans are needed to put everything in context and to establish timelines for various projects.

Appendix: Summary of Issues for Discussion and Investigation

Demand Projections

To evaluate the impact of and requirement for various proposed capital projects, a demand simulation of the Metrolinx network is require for year 2016 taking into account the following network changes.

Group 1: Planned to be operational by 2016

- TYSSE extension to Vaughan
- YSNE extension to Langstaff
- Finch West LRT
- Sheppard East LRT
- Eglinton LRT
- Don Mills LRT (to Danforth)
- GO Lakeshore Express
- YRT and VIVA service upgrades

Group 2: Optional

- GO Richmond Hill Express (advanced from 25-year plan)
- Downtown Relief Line (advanced from 25-year plan)
- DRL optional extension to Eglinton in place of the Don Mills LRT

Line Capacity and Fleet Projections

- What is the minimum operable headway on the BD subway at Kennedy and Kipling terminals (verify or disprove my assertion that it is about 130 seconds).
- What network configuration keeps the demand on BD from exceeding the capacity at the minimum headway? Is this a multi-stage question depending on future overall riding growth (network "A" in 2016, network "B" at a future date)?
- What is the impact on Yonge subway demand of the Richmond Hill and/or DRL services relative to the base case? Can the requirement for additional Yonge subway capacity be kept within current operational and station capacity constraints?
- What strategy would be appropriate for yard expansion or construction depending on where additional trains will be needed (YUS, BD, DRL)?
- If the YUS moves to tighter peak headways, will the length of the extended line allow the use of a wider counterpeak headway to save on overall fleet requirements? (For example, operate a wider headway southbound on Spadina and northbound on Yonge in the AM peak.)

YUS Extension Budgets and Fleet Provisioning

- How much of the projected cost of the TYSSE and YSNE projects has been allocated for vehicles and yards, and why are these costs not split out explicitly?
- Are these provisions adequate for future demand depending on which network scenario is assumed?

Station Capacity

- Can requirements for added station capacity especially at St. George and Bloor-Yonge be reduced or eliminated by diversion of demand to other corridors such as Don Mills, the DRL and the Richmond Hill GO?
- What is the operational risk of concentrating all north-south flow on one route?
- Can existing stations handle added passenger demand especially when exit capacity is constrained by maintenance work?
- Does a substantial increase in capacity of the Yonge line trigger Fire Code rules forcing construction of second exits that might not otherwise be built in the next decade?

Signalling

- Does the current ATC Capital Project complete the conversion of the entire YUS and Sheppard to ATC including onboard equipment for all of the affected fleets?
- What are the implications of an inability to divert a T-1 BD train with non-ATC controls onto the YUS?
- Does any of the BD ATC project lie within the 10-year capital budget window?

Don Mills and DRL Route Options

- Based on the Metrolinx 25 year projections, the DRL demand south of Danforth is above the level that can be achieved with LRT technology especially if the line runs on the surface. What alternate routing options are available if we assume the line will be underground from Danforth to somewhere north of the Don Valley?
- If longer LRT trains were used with a view to through-routing to a DRL, this could be incompatible with surface operations on the north end of the line. How would this affect the design of the Don Mills & Eglinton interchange?
- What are the operational and cost tradeoffs of using this corridor to relieve the Yonge line including subway fleet and yard needs for substantial additional capacity on the YUS?