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The Toronto – York Spadina Subway Extension (TYSSE) Project – Introducing a Major Subway Project to the Tunnelling Fraternity

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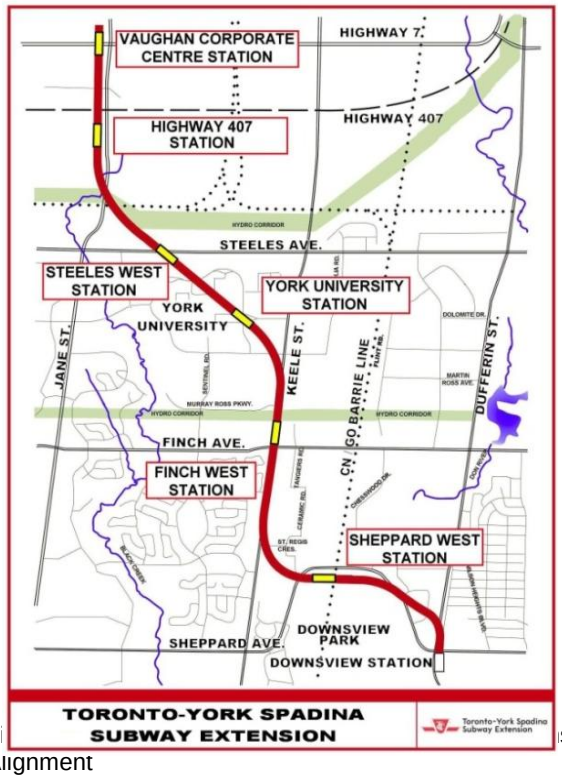
ABSTRACT
The Toronto – York Spadina Subway Extension Project (TYSSE) extends the existing Toronto Transit Commission's (TTC) subway system by approximately 8.6 km in a general radial north-west direction. The Project's major components include twin TBM bored tunnels and six subway stations. The TYSSE project crosses Toronto borders and connects the City of Vaughan, and the Regional Municipality of York to the TTC subway system. All major construction contracts for tunnels and stations have been awarded within four years of project staffing. Several advanced and enabling construction contracts have been completed and construction work on the tunnels and stations are well underway. This paper focuses on the process of advancing a $2.634 billion schedule-driven subway project with an emphasis on the current state of construction progress.
RÉSUMÉ
Le projet d'extension de la ligne de métro Toronto-York Spadina (TYSSE) agrandit le réseau de transport en commun de Toronto de près de 8,6km sur une direction nord-ouest. Les composants principaux de ce projet incluent deux tunnels fait a TBM et six stations de métro. Ce projet s'étend au-delà des frontières de Toronto et relie les villes de Vaughan et la municipalité de York au réseau de métro de Toronto. Tous les contrats pour les tunnels et stations ont été accordés ces quatre dernières années et certains contrats ont déjà commencé. Cet article décrit l'avancement de ce projet d'une valeur de $2,634 milliard et met l'accent sur les progrès actuels de construction

1 INTRODUCTION

The Toronto – York Spadina Subway Extension Project (TYSSE) is the first major subway extension project since construction of the Sheppard line in the 1990s. The TYSSE project is 8.6 km in length extending from the existing Downsview Station through York University to the future terminus station at Vaughan Metropolitan Centre in the Regional Municipality of York. The Project's major components include twin bored tunnels, six subway stations, three double crossovers, a tail track, and a double-ended pocket track s. This paper focuses on introducing the project, the main phases through which the project has evolved, components of the project, and the process of advancing a $2.634 billion schedule-driven subway project.

Three levels of government in Canada have contributed as funding partners to fully fund the TYSSE project. These stakeholders are the Government of Canada, the Province of Ontario, the City of Toronto and the Regional Municipality of York. The provincial funding for the TYSSE was placed in a trust account , hence providing a provincial-politics-indifference commitment and protection for the project. The funding agreement commits parties to the project with punitive conditions of default.



Fi sion Alignment

The TYSSE Department was formed within the Engineering & Construction branch of TTC and is

responsible for the design and construction of the project. An Executive Task Force (ETF) consisting of members of the two municipal funding partners provides general oversight of Project expenditures and schedule on behalf of funding partners. Revenue Service is forecast for the first quarter of 2016. Figure 1 exhibits the high level responsibilities schema for the project.

This paper will further elaborate on the project milestones, current state of the project, and share some lessons learned in advancing a schedule driven project.

2 BACKGROUND

In April 1990 the Province of Ontario signalled a $5.0 billion investment in rapid transit in the Greater Toronto Area (GTA) with the announcement of the *Let's Move* Program. This program included, among other extensions, a proposed loop of the Yonge and Spadina lines along Steeles Avenue.

During 1993-1994 TTC and the former Metropolitan Toronto completed an Environmental Assessment (EA) Report for the Yonge-Spadina Loop project. The study concluded that extending and connecting the north ends of the Yonge and Spadina Lines across Steeles Avenue was the preferred alternative.

In 1994, upon review of the TTC/Metro Toronto Environmental Assessment report, the Minister of Environment and Energy authorized the extension of the Spadina Subway from Downsview Station to York University only. However, design and construction of the approved extension to the Spadina Subway did not proceed due to lack of funding.

Since 1994, subsequent planning initiatives, land development decisions and property acquisition activities occurred in the area. Key changes were:

• The August 2001 Rapid Transit Expansion Study (RTES) concluded that a future subway "loop" along Steeles Avenue is no longer needed and that alternatively a "radial" extension via York University is preferred.

• The Downsview lands have changed from a Canadian Forces base to Parc Downsview Park to consist of parkland, a future technology park and housing.

• As a result of the RTES initiative, York University's new buildings protect for a possible subway alignment under Ian MacDonald Boulevard.

From 2004 to 2006 a new EA was undertaken to develop, review and analyze potential changes to the 1994 EA. Provincial Environmental Assessment Approval for the Toronto Section was received in March 2007. Approval of the York Region Section, with conditions, was received in November 2006 with subsequent final approval in June 2007. Federal Canadian Environmental Assessment Act approval for the entire project was received in March 2008.

3 ENVIRONMENTAL ASSESSMENT (EA) STUDIES

The TYSSE project has received approval under the Ontario Environmental Assessment (EA) Act under two separate EA studies:

- Spadina Subway Extension Environmental Assessment from Downsview to Steeles Avenue (February 2006) – City of Toronto / TTC.
- Highway 7 Corridor Vaughan North-South Link (VNSL) Public Transit Improvements Environmental Assessment (August 2005), including the Response to Conditions of Approval, Vaughan North-South Link Subway Alignment Optimization Report, June 2007

The Spadina Subway Extension Environmental Assessment from Downsview to Steeles Avenue addressed the 6.2 km, 4 station underground extension of the Spadina Subway from Downsview Station to Steeles Avenue, with related commuter facilities. The second EA addressed the extension of the Spadina Subway north of Steeles Avenue to the Vaughan Corporate Centre (VCC) at Highway 7 within York Region.

The Canadian Environmental Assessment Agency (CEAA) Screening Report for the TYSSE from Downsview Station to Vaughan Mertopolitan Centre was approved by Transport Canada on March 13, 2008

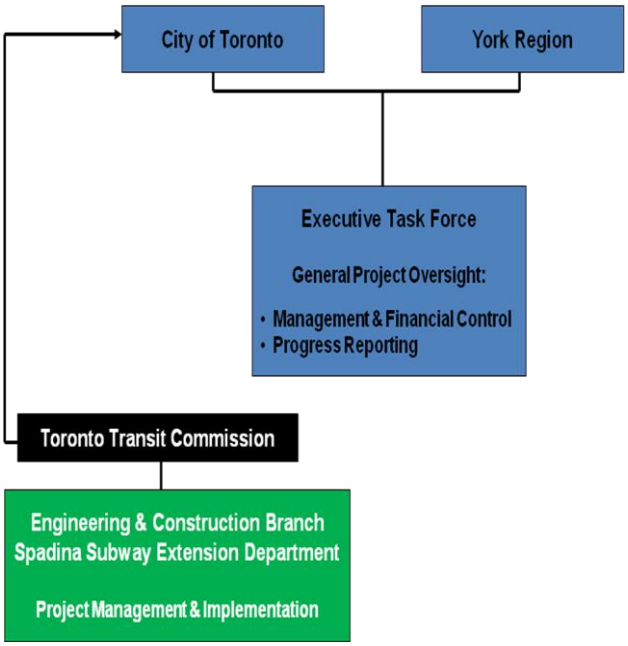


Figure 2: Project Responsibilities Schema

4 PROJECT MILESTONES

4.1 Initiation

The Project start-up milestone was achieved on April 1, 2008 when governance agreements, project approvals, and funding were established to proceed with project implementation.

An integrated project management team was formed under the leadership of the TTC assigned Chief Project Manager. The TYSSE team includes TTC staff and the Spadina Link JV (Hatch Mott MacDonald, MMM Group and Delcan Corporation) and Stantec Consulting Ltd. Who is responsible for Project Controls.

Requests for Proposals (RFP) were developed and several geo-engineering consultants and design teams were awarded geo-engineering investigations and design contracts in an open and competitive bidding process to carry out subsurface investigations and design of tunnels and subway stations. Consultants for the individual stations design were retained in October 2008 and for the bored tunnels in November 2008, enabling preliminary engineering to proceed.

The design teams include Hatch Mott MacDonald responsible for the design of twin tunnels, AECOM the designer of Sheppard West and HWY 407 stations, ARUP responsible for designs of York University and Vaughan Metropolitan Center (VMC) stations and TSGA Group responsible for Finch West and Steeles West stations.

In order to meet the project schedule requirements and to keep quality and project-wide consistency among all factual data, design, and baseline reports, geo-engineering works were separated into field investigation and technical oversight roles. Golder Associated Ltd, Coffey Geotechnics Inc., and Inspec-Sol Inc. are geo-engineering consultants for the project.

4.2 Project Delivery Strategy

In the third quarter of 2008, TYSSE held a series of project delivery strategy workshops in order to assess, optimize, and strategize potential phasing and contracting alternatives. As an extension of an existing subway system with full funding in place the "operate and financing" options were eliminated from further consideration. Consequently Design-Build (DB) and Design-Bid-Build (DBB) options were explored in detail.

From TYSSE's project delivery stand point, the most critical quality indicators that were used as evaluation criteria were identified as schedule, quality, constructability, operation and maintenance, life cycle cost, and competitive contracting.

Although the DB option arguably benefits from eliminating the need to manage interfaces between contractors, several other factors were discussed during debates on the project delivery model. The expected service life of TTC structures spans between 75-100 years; hence TTC, as a publicly funded transit authority is philosophically concerned about "loss of control" with respect to cost cutting and substandard work. TTC has developed design and construction standards based on a long history of operating experience. Standardization of plant and equipment promotes maintenance efficiency.

The TTC still reviews designs for safety, ease of maintenance, standardization, and labour practices.

The TTC is an agency of the City of Toronto and is overseen by a board of Commissioners comprised of elected City Councillors. Hence TTC follows property agreements, permits and regulatory agency approvals in a centralized manner. The need for utilities protection and relocation, some of them being City utilities, was also considered as an important factor in choosing mode of project delivery.

Resolution of the above issues with a design-build contractor, not to mention the risk of lack of competition in tendering mega projects, could be very expensive due to unwieldy interaction among owner, third party stakeholders and the builder.

However, in order to maintain the objectivity of the option selection process, a set of various feasible contract alternatives, in terms of number of contracts and types of contracts, where evaluated against a baseline alternative. As a result three options were ranked the highest, namely, 6-contarct DBB, 1-contract DBB and 1-contract DB respectively. After qualitative risk assessments it was concluded that the 6-contract DBB alternative poses the lowest level of risk among three alternatives and therefore is the most appropriate mode of project delivery for the TYSSE project. Table 1 summarizes six the main DBB contracts and packages.

Table 1: Main Contracts and Packages

Main Contract	Contract Packages
Sheppard West Station and the Southern Tunnels (Awarded in Nov. 2010 in the amount of $270,078,688.00)	-Sheppard West Station -South Twin Tunnels (Including EEBs, CPs, Connection to Downsview Station Tailtrack) -Finch West Extraction Shaft
Finch West Station (Awarded in June 2011, in the amount of $125,630,118.00)	-Finch West Station -Double Crossover -Surface Facilities, Bus Terminal, PPUDO
York University Station (to be awarded in the 4th quarter of 2012)	-York University Station (Excluding Siteworks)
Steeles West Station (Awarded in Sept. 2011 in the amount of $165,925,000.00)	-Steeles West Station -Double Crossover -TBM Extraction Shaft #2
HWY 407 and the Northern Tunnels (Awarded in Jan. 2011, in the amount of $404,387,479.00)	-HWY 407 Station -North Twin Tunnels -Double Ended Pocket Track -Compensation Grouting under Schulich Building -Steeles West Launch Shaft (Permanent works) -York University Station Siteworks -Finch West Station Traffic Management Plan Staging
Vaughan Metropolitan Center Station (Awarded in June 2011 in the amount of $197,821,000.00)	-Vaughan Metropolitan Centre Station -Double Crossover and Extraction Shaft #3 -Tailtracks

4.3 TBM procurement and Segmental Pre-Cast Tunnel Liners

Tunnel boring machines and tunnel liners are normally supplied as part of the tunnelling contract. The TYSSE chose to purchase these items directly and hand them over to the successful tunnel contractors to avoid the long

lead time required for design and procurement. At an early stage of the project in 2008, TYSSE prepared Request for Proposal (RFP) to procure four earth pressure balance (EPB) tunnel boring machines (TBMs) with backup trailing gear and muck handling systems. All four TBMs, manufactured by Caterpillar Canada (formerly Lovat), are operational and are mining the twin tunnels. The TTC owns TBMs and contractors operate and maintain them according to the schedule provided by the manufacturer.

TYSSE also furnishes to the tunnel contractors the segmental pre-cast concrete tunnel liners (PCTL). As one of the high priority assignments, the consultant for tunnel design, Hatch Mott MacDonald, prepared the necessary technical documents to support these procurement contracts.

The adopted strategy for early procurement of TBMs and PCTL, is consistent with the project schedule and indicated the extent of TTC's commitment to the project and readiness to take far reaching steps in order to complete the project in compliance with the schedule.

4.4 Geo-engineering Investigation and Design

4.4.1 Geo-Engineering

All geo-engineering filed investigations and preparation of factual data reports, design reports, soil and groundwater management reports, geotechnical baseline reports, and environmental site assessments were completed in a centralized manner. This approach promoted high quality, harmonious and consistent subsurface investigation results and design parameters across the project.

Geo-engineering works were divided into two main categories. All field activities and site investigations were to be performed by two geotechnical engineering consultants (GECs) while a principal geo-engineering consultant (PGEC) was to assume responsibilities for establishing project wide site investigation programs and work plans, reviewing factual data for consistency with project standards, interpreting subsurface data, and preparing geo-engineering design reports and geotechnical baseline reports.

An early geotechnical investigation contract was awarded in 2007 to perform preliminary geotechnical investigations for Steeles West station. Subsequently in the second quarter of 2008, RFPs were prepared by TYSSE and in the last quarter of 2008 two more contracts were awarded, followed by the last contract that was awarded in January 2009. The first borehole for the design phase of the project was advanced on the day before Christmas of 2008. The bulk of site investigation works were completed by the third quarter of 2010.

Although the award of contracts for geo-engineering consultants were almost simultaneous with the award of the station and tunnel design contracts, the adopted strategy assisted with completion of a phased and accelerated geo-engineering investigation such that at all times the subsurface data and geo-engineering design parameters where provided for TBM manufacturing, and to the tunnel and station design consultants in a timely manner and consistent with the phases of design. Bidhendi, et al. (2011) reviewed the geo-engineering investigation works for the TYSSE project in more details.

4.4.2 Design Works

In the third quarter of 2008, several design contracts were awarded in an open and competitive bidding process. The major design contracts were as follows:

- Design of twin tunnels and double ended pocket track structure (which is to be excavated using the sequential excavation method), design of precast concrete tunnel lining (PCTL), emergency exist buildings (EEB), cross passages (CP), launch and extraction shafts (LS and ES), Tunnel-Station interfaces, related site works, and tunnel equipping.
- Design of six subway stations and their ancillary structures, including and as applicable, crossovers, tail tracks, Passenger Pick-up and Drop-off (PPUDO), parking lots, and related site works. Six design teams (two teams from each of three design consultants) were successful in their proposals.

4.5 Advanced Construction Contracts

Advanced or early contracts that are usually adopted in schedule-driven projects can help accelerate implementation of construction phase. Although the main intention is to remain on schedule, if properly planned and implemented, they can assist with relieving pressure from the early stages of main construction activities. However these contracts impose a surcharge on already stretched investigation and design teams to prepare design and contract documents when the project is still in a fluid stage and many design and construction interfaces are evolving and are not yet thoroughly defined.

Considering the above factors and by strategizing contract packages, several early and advanced contracts have been awarded. Table 2 summarizes advanced contracts and award dates.

Table 2: Advanced Contracts and Award Dates

Advanced Contract	Award Date
Downsveiw Station connection to Wilson Yard	Oct.2009
Manufacturing of TBMS	July 2009
Manufacturing of Tunnel Segments	Dec. 2009
Advanced TBM Launch Shaft –Steeles	Oct. 2009
Advanced TBM Launch Shaft –Sheppard	April 2010
Finch West Station Roadworks and Utilities	Sep. 2009
Fire Station 141	July 2009
Hwy 407 Station Advanced Contracts	July 2010
York University Station Detour Phase 1	May 2010
York University Station Detour Phase 2	July 2010

5 PROJECT ALIGNEMENT AND COMPONENTS

5.1 Running Structures

5.1.1 Downsview Station Connection to Wilson Yard

The TYSSE alignment is shown in Figure 1. Downsview station is the current terminus station on Yonge – University - Spadina line (YUS). Wilson Yard is the main vehicle storage and maintenance facility for the subway vehicles on the YUS line within the TTC subway system. After completion, the TYSSE project will intensify the use and operational demands on this facility. To accommodate this operational demand, an additional connection was needed between YUS and Wilson Yard.

5.1.2 Twin Tunnels

The twin tunnels are mined using EPB TBMs. The centerline length of the tunnelling sections is 6.2 km. Approximately 9000 rings (of precast concrete tunnel linings (PCTL) will be required for the twin tunnels (Figure 3). Moreover, for the first time, on a trial basis, 100 rings of steel fibre reinforced concrete (FRC) linings are being installed in two designated sections along twin tunnels south of Finch West Station.

The internal diameter of bored tunnels is 5.4 m which is slightly larger than the tunnel diameter for Sheppard Subway Extension. The larger diameter is required to be compliant with NFPA130 (2010).

There will be seven cross passages (CP) between the twin tunnels. CPs provide maintenance access between tunnels, and will be hand mined after the twin tunnels are complete. The internal diameter of the circular section is about 3.75 m. CPs also house some Signal-Electrical-Communication (SEC) equipment.

Seven emergency exit buildings (EEB) will also be constructed. Emergency exit structures extend from the underground tunnels to grade and are designed to provide an emergency exit for passengers and an emergency access for fire fighting crews. They can also provide emergency ventilation and secondary power sources. EEB structures are typically constructed from surface in supported open cut excavation and then will be partially backfilled for the passage of the TBM. After tunnel faces have passed the EEB location, other construction stages will be completed by breaking in from tunnels, forming concrete slabs and walls, and other restoration works.

Total of five TBM launch shafts (LS) and five extraction shafts (ES) are considered for TYSSE. Two of the LSs are within HWY 407 station footprint. ESs are within the foot print of other open cut excavations such as crossovers.

5.1.3 Double Ended Pocket Track Structure

The double ended pocket track structure is designed to allow short turn of trains. It is located north of Finch West Station and beneath a Hyrdo-One transmission corridor. The construction methodology adopted for the tunnelling section of the structure is sequential excavation methods (SEM or generally known as NATM). This is mainly due to existing over head power lines, to maintain the flow of traffic at Keele Street and Murray Ross intersection, and in order to avoid interface with oil and gas pipelines and other utilities. The north and south Wye excavations, on either side of the NATAM tunnelled section, will be constructed using open cut supported excavation methods).

5.2 Stations

5.2.1 Station Design Objectives

At the beginning of the design phase of the TYSSE project the Design Basis Memorandum (2008) stipulated the architectural design philosophy of stations. The requirements were gearing toward departure from traditional functional subway stations toward integrated design of all elements with strong aesthetic and public artwork, column free structures with high ceiling and simple flow of space, bright, open spaces with deep daylight penetration into station, and green ideas, while standard elements are incorporated into the design.

The architectural design objectives for the Toronto-York Spadina Subway Extension (TYSSE) station design can be summarized as follows:

- Provisions for daylight to reach the interior of the station
- Intuitive circulation paths for patrons
- Integrate public art in the design of the station
- Incorporate sustainability principles consistent with Toronto Green Standard
- The station platforms to be designed for a six car consist
- The total length of the station at platform/track level to be approximately 163 m.

The TYSSE website (www3.ttc.ca/spadina) provides general information for the subway extension stations. The subway stations names may be subject to change upon consultation with public.

5.2.2 Toronto Green Standard

The Green Standard is a two-tier set of performance measures that promote sustainable development. They represent Toronto's approach to greening development practices in multi-unit high-rise residential buildings, institutional, commercial and industrial buildings and low-rise residential and non-residential development (City of Toronto, 2008).

The Toronto Green Standard (TGS) provides an integral set of targets, principals, and practices to guide the development of City-owned facilities and to encourage sustainable development among the private sector. The areas outlined in the TGDS for new construction are:

- Air Quality
- Greenhouse Gas Emissions/Energy Efficiency
- Water Quality
- Water Efficiency
- Solid Waste
- Ecology

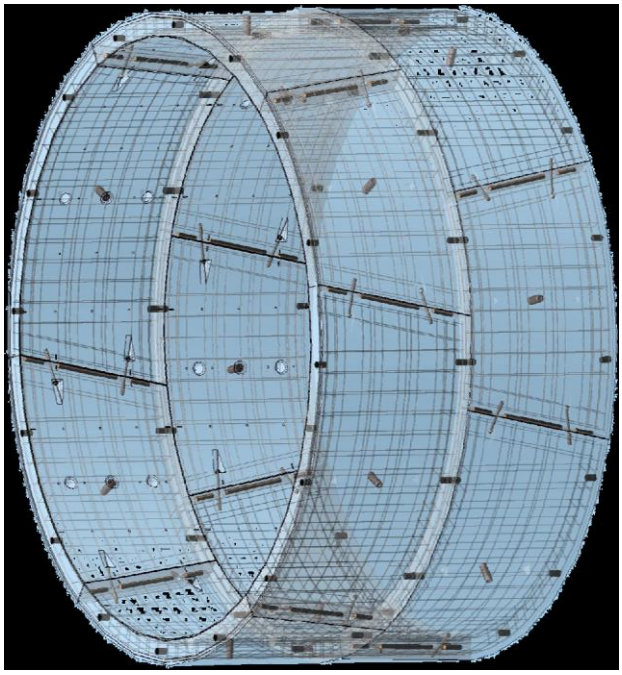


Figure 3. Precast Concrete Tunnel Lining Rings

5.2.3 Geothermal Studies

A key commitment of the TYSSE project is to meet the requirements of the Toronto Green Standard. One means of meeting those requirements is utilizing “Green” energy systems, such as ground source geothermal systems for heating and cooling of the subway stations. In January 2009 a TYSSE task force was created to evaluate the application of ground source geothermal systems to the TYSSE project. The study summarized the available technology, considered the applicability of the technology to the TYSSE project, assessed the suitability of station sites, and assessed various options. The task force concluded that the application of ground source energy could not be justified for the TYSSE project on the sole basis of financial considerations. However the task force did recommend that the TTC consider the installation of a “pilot” geothermal system at York University station or Sheppard West station.

However TYSSE concluded that the recommendation to proceed with a “pilot” installation would not be pursued due to the following considerations:

- The heating and cooling energy loads for a typical TTC subway station are not particularly large, given the indoor air temperature range that the TTC maintains in its stations.
- Because the heating and cooling loads for the stations are relatively small, the potential energy savings are small in comparison to the capital cost of installation and the payback period is quite long.
- Installation of ground source geothermal systems will increase the capital cost of the project and there is already pressure on the project to cut costs to meet the approved budget.
- At the time of study, preliminary station energy modeling was undertaken and it was anticipated that the energy performance requirements of the Toronto Green Standard will be met through energy conservation measures such as energy efficient lighting & controls, energy efficient heating & cooling systems, HVAC systems heat reclaim and low hot water flow faucets.

5.2.4 Sheppard West Station

The Sheppard West Subway Station will be located south of Sheppard Avenue entirely on Parc Downsview Park (PDP) lands. This station will buttress the existing CN/GO Barrie Line and will provide an integrated passenger connection between the subway station and Downsview Park Go Rail Station. The Sheppard West station will play a crucial role for development of PDP lands. Moreover this station is to provide access for existing and future facilities in the Keele Industrial Area located to the north of Sheppard Avenue.

5.2.5 Finch West Station

Located north of the intersection of Finch Avenue West and Keele Street, Finch West Station is comprised of a two-storey, underground structure, with a concourse and a platform level, and a single-storey crossover structure on the south-end of the station. The station also has associated infrastructure and bus terminal connections at grade level.

5.2.6 York University Station

The York University Station is located in the centre of the York University Keele Campus straddling diagonally between Schulich School of Business and York Lanes Building which is adjacent to the Ontario Provincial Archives Building. The station provides pedestrian access to the subway line for York University students and future developments in the area. Unlike some of the other TYSSE stations, the York University Station will have no associated off-street bus terminal, no Passenger Pick-up and Drop-off (PPUDO) and no commuter parking. Currently the road around the York University Common provides a drop off and pick up location for the approximately 1400 buses a day that provide transport to and from the University. On completion of the station, the Common area will no longer be served by any bus traffic.

York University station is the only station where tunnelling will be completed through the station area prior to construction of the station. The tunnel contractor will be responsible for installing the station headwalls at the north and south ends of the station. The TBM will be boring through these headwalls. During station construction, sections of tunnel liner within the station footprint will be demolished.

5.2.7 Steeles West Station

Steeles West Station straddles between the City of Toronto and the Region of York crossing Steeles Avenue West in an oblique fashion. Steeles West Station is a

sub-surface two-level structure. The lower level comprises a track level running structure accommodating two tracks and a central passenger island platform. The upper level is a concourse located at either end of the station box facilitating passenger access and egress to surface entrance structures including: YRRTC and TTC bus platforms, the future LRT connection, commuter parking and PPUDO. To accommodate the proprietary YRRTC and TTC fare systems, the north concourse area will have a staffed fare line and both paid and unpaid zones. Access/egress from platform to concourse and street level is by stair, escalator and elevator through the station entrances. Provisions will be made for full accessibility between all levels of the station.

5.2.8 HWY407 Station

The Highway 407 subway station is located west of Jane Street, South of Highway 407 on a greenfield site owned by the Province of Ontario and controlled by the Ontario Realty Corporation. Highway 407 Station is an intermodal station and will incorporate 18 bay bus terminal, a 600 space commuter parking lot, 30 space passenger pick-up/drop-off (PPUDO) and will be designed to provide access to the future MTO Highway 407 Transitway. Access to the bus terminal and parking lot will be facilitated by a new bridge structure spanning Black Creek, which has been realigned around the station box.

Highway 407 Station will be the site of Tunnel Boring Machine (TBM) launch shafts for the tunnels at each end of the station. The subway will extend in twin bored tunnels from the north end of Highway 407 Station, north to Vaughan Metropolitan Centre Station and also from the south end of the station box southerly to Steeles West Station. The Highway 407 Station and the adjacent tunnel segments will be constructed under a single construction contract.

5.2.9 Vaughan Metropolitan Centre Station

VMC station will be the north terminus of the TYSSE project and will serve the Vaughan Metropolitan Centre and the existing and future developments in the City of Vaughan. The station has been located to serve local existing and planned YRT and VIVA BRT routes and will be the primary station for the local feeder bus service. In addition to walk-in ridership, the station will serve transit users transferring from VIVA and local YRT routes, users being picked up and dropped off by car, bicyclists and riders coming from Toronto.

VMC station will be located at the intersection of Highway 7 and Millway Avenue with the subway alignment being approximately north-south. The station will serve the current and, in particular, the future development of the proposed Vaughan Metropolitan Centre urban redevelopment, and provide an inter-modal facility with connections between the subway station and the local YRT and VIVA bus routes.

Due to the hydrogeological conditions, a groundwater cut-off system has been designed for VMC station. The cut-off consists of cement bentonite enclosures and jet grouting sections in the vicinity of station and around utilities.

5.3 Systems and Commissioning Test Program

The Systems Design and Installation group of TYSSE is responsible for transit operating systems design, procurement, installation, testing and commissioning. The scope includes:

- System Operating Requirements Definition
- Trackwork and Track Support Systems
- Signalling / Train Control
- Traction Power Supply and Distribution
- Communications and Supervisory Control
    - Public Address System
    - Closed Circuit Television System
    - Fibre Optic Backbone Communications System
    - Subway Radio System
    - Passenger Assistance Intercoms
    - Telephones and Telephone Services
    - Passenger Information Displays
    - Integrated Station Control / Supervisory Control and Data Acquisition System
- Tunnel Ventilation System
- Fare Vending and Collection System
- Provision for Future Platform Edge Doors
- Systems Design Interface
    - Station Facilities, Rooms/Elevators/Escalators/Lighting, etc.
    - Fire Alarm and Detection
    - Transit Control Centre
    - New and Existing Subway Vehicles
    - Embedded Conduit Requirements for Tunnels and Stations
- Systems Safety Assurance

Systems Design and Installation activities are continuous throughout the project commencing with the definition of the operating characteristics of the subway extension to provide a framework and common reference for detailed design phases of the operating systems and their associated facilities interface requirements. Systems procurement packages are prepared and the SD&I Group manages the installation, commissioning and handover of the project to TTC's Subway Operations Department.

The Commissioning Program will encompass testing, training, manuals, as-built drawings, mobilization, warranty and deficiency management. A Commissioning Test Program will be conducted to:

- Demonstrate that elements of the system provided under the various construction, procurement and installation contracts conform to the system design specifications
- TTC personnel are trained on the operations and maintenance requirements to provide safe and dependable revenue service
- System safety assurance requirements are verified.

- Demonstrate that the TYSSE is ready for revenue service.

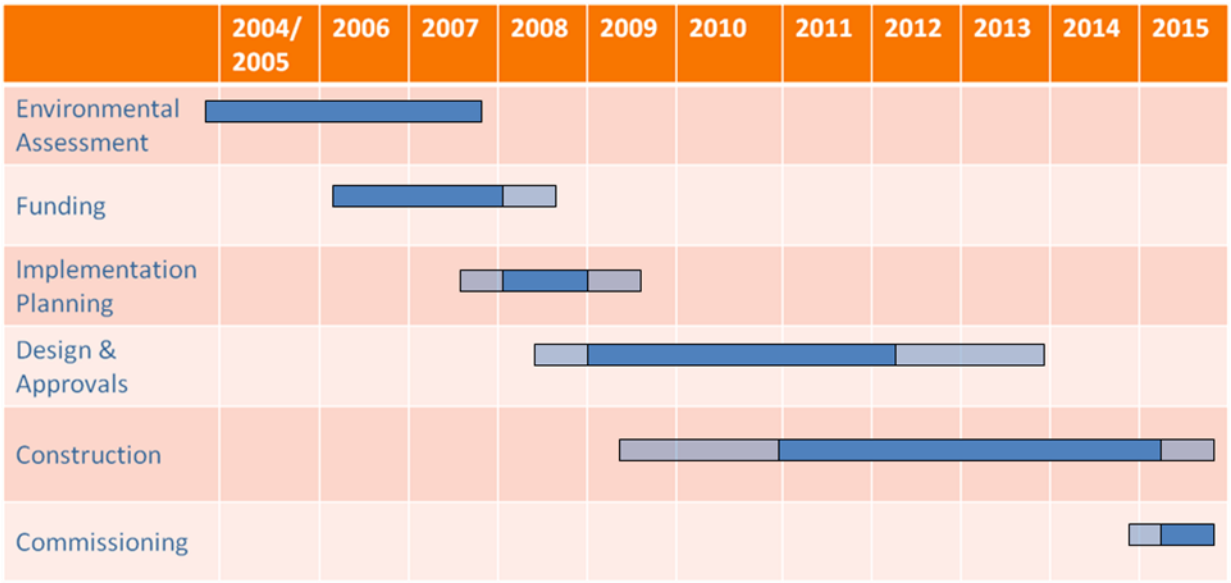


Figure 4: Project Timeframe

6 PROJECT CHALLENGES

The long construction horizons of large infrastructure projects present a particular challenge from the political perspective within a context of the often changing political and economical landscape. The Federal and Provincial governments have remained in place since the beginning of the project.The change of Toronto's mayor had no adverse effect on the TYSSE project. The Federal and Provincial governments are taking a hands-off approach. They have committed the funding and require periodic reporting on progress and expenditure. Active project oversight is managed by a task force representing the City of Toronto and the Region of York. Politicians and administrators at the municipal level are generally supportive, but they have their own agenda due to their direct exposure to the public and design approvals.

Other stakeholders such as land owners, businesses, and residents are typically focused on "not in my backyard" syndrome. The coordination intensive, time consuming, and at time costly resolution of the "nuisance factor" are compounded for large projects.

6.1 Project Schedule

Inherent in the nature of large infrastructural transit projects, in an urban environment, is the multitude of interfaces that will be created. In the following some features based on the TYSSE project experience are discussed. However prior to paying attention to "outside" factors it is needless to mention that the aggressive project schedule is the most overall challenging aspect of the project. Figure 4 exhibits a simplified project timeline. However as a result of efficient management and team work the project has generally remained on schedule although there are pressure points for delays mainly due to construction issues. It is anticipated that with schedule recovery attempts through some construction staging changes the official project schedule can be achieved.

6.2 Interface Issues

6.2.1 Utilities

Perhaps the most challenging aspect of project implementation is dealing with the 16 utility companies that are involved.

There is a status quo of old infrastructure in poor condition which are difficult to locate. Further, it is not unusual to encounter utilities which are not in the record. Due to lack of urgency, utility companies are unresponsive to the tight project schedule requirements. Utility companies' internal procedures for relocation, contractor procurement policies, conflicting relocations with companies' existing development or relocation plans, and predetermined priorities all contribute to create a complex entanglement of competing priorities.

TYSSE's approach in dealing with utilities has been to assign utilities coordinators to communicate and negotiate with companies, use of various levels of government leverages in case of unresponsive companies, and incorporating utilities relocation into early contracts. However, despite all precautionary measures, cost overruns and schedule delays are causing considerable delay to overall progress of the project.

6.2.2 Multiple Contractors

Both advanced contracts and main contracts require interfaces between adjacent contractors. By the Ministry of Labour requirements, contractors must be separated in time and/or in space.

Contractors' level of competence, sophistication, and their local experience contribute to interface issues. The bidders for major contracts have undergone a

prequalification process. However for subcontractors and for advanced contracts no pre-qualification was required.

Despite attempts to remove or reduce consecutive construction works at an interface there are inevitable activities that tie in two or more contractors; a condition which is fertile ground for delays.

6.2.3 Regulatory Agencies, Permits, and Approvals

Regulatory agencies are not always prepared to cope with the urgency of accommodating timely review process needed for large projects. The lack of staffing and internal procedures are contributing factors as well. Perhaps the most challenging aspect of regulatory agencies' involvement is when the agency is unable to clearly define and state their requirements, resulting in extensive redesign effort.

At times permits and approvals are somehow conditioned to specific enhancements to the project. While enhancements may be a benefit in a general sense, they are beyond the scope of project.

The TYSSE project has maintained effective communication with all agencies involved and on a technical basis responded to all regulatory requirements. At times the TYSSE project entered into an agreement to assist the agency by contributing funds for additional staff. The TYSSE has applied a logical and task oriented approach in balancing various demands and maintaining project priorities and direction while navigating the complexities of regulatory requirements and other stakeholders' demands.

7 RISK MANAGEMENT

An integrated and systematic process for risk identification, risk assessment, and risk management has been conducted as part of the Project Management Plan. An evolving TYSSE Risk Register has been maintained which contains project risks, risk assessments and mitigation plans. The Risk Register forms a basis to follow up, monitor and reduce project risks on an on-going basis.

The objective of the Risk Management Plan is to define the methodology used to identify and assess risks associated with the various phases of the TYSSE project and develop a Risk Register to manage the risks to an acceptable level.

The "acceptable level" for each risk item is obtained through an iterative process until the cost and schedule impacts (probability and severity) are within tolerances defined by the project management team and issues such as health and safety, environmental impacts, public disruptions, and assuring that the quality of delivered products are at levels defined by applicable regulations and authorities. Figure 5 provides risk assessment scale and risk rating scale for the TYSSE project. The risk ratings 1-4 are acceptable risks, or Green risks. Yellow risks rated 5 to 14 require monitoring. Risks rated 15 and above (Red) require mitigation. The borderline Orange zone is categorized such that if the impacted area is related to the schedule and the activity is on the critical path, risk will be closely monitored for potential mitigation measures.

Probability Rating	1	2	3	4	5
	Very Low - 1% to 10%	Low - 10% to 30%	Medium - 30% to 50%	High - 50% to 70%	Very High - 70% to 99%

Severity Rating	1	2	3	4	5
Cost	$1 to $100,000	$100,000 to $300,000	$300,000 to $1,000,000	$1,000,000 to $5,000,000	> $5,000,000
Schedule	0-1 week	1-4 weeks	4-8 weeks	8-24 weeks	> 24 weeks
Health & Safety	Medical attention/ no lost time injury	Medical attention/ lost time minor injury	Critical injury/ multiple lost time injuries	Critical injury/ permanent long term disabilities	Fatalities
Environment	Insignificant/little impact on local, regional or global scale	Impacts the environment (directly or is a contributing factor) on a small or local scale	Impacts the environment (directly or is a contributing factor) on a medium scale (regional or global).	Impacts the environment (directly or is a contributing factor) on a large or global scale	Catastrophic/Large-scale detrimental effect on the environment
Public Disruption	Insignificant/little impact on traffic, business, services etc.	Minor impact on traffic, business, services etc.	Multiple complaints. Moderate impact on traffic, business, services etc.	Disruption to traffic, business, services etc.	Extended disruption(s) to traffic, business, services etc.
Quality of Delivered Product	Insignificant/little effect on non-critical items	Minor effect on non-critical items	Moderate effect on critical items	Serious effect on critical items	Major quality issues

		Severity Score				
	Risk Rating	1	2	3	4	5
Probability Rating	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5

Figure 5: Risk Assessment Scale and Risk Rating Scale.

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