EX23.1

BT ENGINEERING

Scarborough Subway Extension
Toronto Transit Commission
Value Engineering Study

November 17, 2016

BT Eng Project 16-017

November 17, 2016
BTE Project BTE16-017

Mr. Selim Gabra
Senior Project Manager
Scarborough Subway Extension
Toronto Transit Commission
5 Park Home Avenue, 4th Floor
M2N 6L4
Toronto ON

Dear Mr. Gabra:

Re: Scarborough Subway Extension Value Engineering Study

Please find enclosed our draft Value Engineering (VE) Report dated November 4, 2016 for the Scarborough Subway Extension.

The report documents the results of the 5-day workshop held September 12th to September 16th, 2016 in Toronto, Ontario. During the workshop, the team developed a common understanding of the problems and opportunities, and defined the project functions. This report documents the project review and the recommendations of areas for further investigation as the project progresses.

In parallel with the VE study a peer review of the current project risk assessment was carried out, the details of which are included as an appendix to this VE report.

Should you require additional information and/or clarification, please do not hesitate to contact me by telephone at **(416) 488-5353** or by email at **steven.taylor@bteng.ca**.

Very truly yours,
BT Engineering

Steven Taylor, P.Eng., M.Eng., CVS-Life
Value Engineering Team Leader

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Executive Summary

Project Introduction and Scope

This report summarizes the results of the Value Engineering (VE) Study carried out by BT Engineering (BTE) for the Toronto Transit Commission (TTC) for the review of the Scarborough Subway Extension project. The project location is the extension of the existing Bloor-Danforth subway line from the existing Kennedy Station approximately 6.25 km northeasterly to the Scarborough Town Centre, following an alignment along McCowan Road.

The Toronto Transit Commission initiated the Value Engineering (VE) Study to review the early design development of the Scarborough Subway Extension project. At the time of the VE study the TTC had completed an initial cost estimate and risk assessment, and had begun a review of potential delivery models for the project. This review allowed the City of Toronto, TTC, designers and independent team members an opportunity to examine the design at the 5% design milestone. The workshop was a significant project milestone to ensure that the final project is cost effective, constructible and in keeping with the project delivery objectives. The process focussed on identifying creative alternative solutions for the project while meeting the performance needs of the TTC, at the lowest life cycle cost. The review was also to validate the cost estimate and constructability of the design.

The key issues and objectives for the workshop included:

- Direction of senior management to review the project at the 5% design level to focus on cost effective investment while maintaining all performance requirements and considering life cycle costs;
- Review Design and Engineering;
- Validate magnitude of project cost;
- Review and provide input to Risk Register and Project Schedule; and
- Review and comment on the project delivery approach.

The project scope includes the following key elements:

- Extends existing Bloor-Danforth Line 2 from the existing Kennedy Station to a new Scarborough Centre Station (SCS)
- Building a new 6.25 km subway extension
- 10.7 m single bore tunnel (12 m cut diameter)
- New underground subway station
- Single level at-grade 34 bay bus station
- 3 Sub-stations and 8 Emergency Exit Buildings
- Launch and working shafts
- Fan Plants (3) and Ventilation Building
- Existing SRT Service to be maintained during construction

- Meet TTC's level of service standards

The basis of design that was considered at the workshop is the McCowan Alignment Revision J controlled, with an at-grade bus terminal. The baseline design available at the workshop was estimated to be approximately at the 5% design level (September 2016). The associated cost estimate reflects an earlier design development that pre-dates the current 5% design level.

The project contains two major elements including a linear single bore tunnel with associated Emergency Exit Buildings and ventilation shafts, and the future subway and at-grade bus station adjacent to the Scarborough Town Centre.

The construction cost estimate for the concept level baseline design is estimated to be approximately $2.7 billion (escalated to 2021 $) with the SCC Station, Bus Station and Running Structure (tunnel) representing 64% of the total project cost. The construction cost model is illustrated in **Figure E1**.

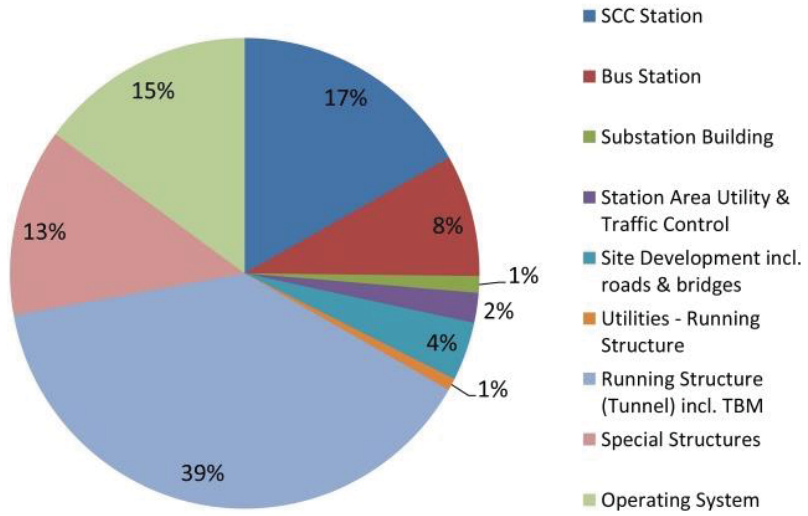

Figure E1: Construction Cost Model

This VE Review represents the consensus of the VE Team, based on the results of the Workshop session. This report is intended to focus the Design Team on select elements of the project which appear to offer the best opportunity to improve value and to ensure constructability of the project.

Value Engineering Review Process

The VE Study included pre-workshop activities reviewing the risk and cost estimating completed to date followed by a 5-day workshop from September 12th to September 16th, 2016. The workshop focus was to validate the current design, cost estimate, and risk assessment and consider the cost effectiveness of the design approach and functional requirements as well as generate, evaluate and develop innovative ideas for alternative value enhancements.

The mixed value engineering team was comprised of Toronto Transit Commission (TTC) management, engineering and operations staff, Design Team mem-

bers from AECOM and Hatch, as well as independent participants from Hanscomb, IBI Group, McNally Construction (tunneling contractor), Stantec, Thurber and Parsons. Toronto Transit Commission Senior Management staffs were present for the opening and closing presentation phases of the workshop.

The goal of the VE Study is to improve value. Value is best defined as the relationship of Function (quality or performance or benefits) versus Cost (monetary, time, environmental impact, etc.). The relationship between Value, Function, and Cost is expressed as: Value = Function (Performance)/Cost.

Value Engineering Workshop Results

The workshop reviewed the project planning and design completed to validate the progress to date. The cost review is described in Section 3.

The initial estimate was reviewed by Hanscomb Cost Consultants, a third party cost consultant, as part of the Value Engineering review, and substantiated as a valid and complete estimate that reflects the level of design.

Risk Review

An independent review of the initial TTC risk assessment was completed in parallel to the pre-workshop activity. This was followed by the VE Team providing input during the workshop to test the probability of occurrence and magnitude of effects of the top 20 schedule and cost risks identified to date. The independent risk review is documented in Appendix D. This review concluded that the approach has followed the best management practices of the industry and the risks identified to date are reasonable.

Schedule Review

The project schedule is based on initiation in 2016 with the initial 3 years allocated for utility relocations, 30% design, and procurement of a design–build contractor. In September 2019 the contract will be awarded. Construction is estimated to take approximately 6 years to complete with an initial 5 month start-up period for the contractor to start construction.

The VE Team validated that the timelines are reasonable forecasts for the construction. Specific ideas that could allow acceleration of the works by de-linking the station and tunnel construction operations are described in the VE proposals.

Project Delivery Model

TTC presented a brief summary of its Draft Contract Packaging Analysis in order to (i) survey the VE Team's experience and (ii) obtain feedback on the analysis process and evaluation criteria.

A brief summary of the presentation and feedback received is documented in the report.

Design Review

The workshop defined a list of candidate value proposals to assist in the delivery of a quality project. The study generated **181** ideas that had the opportunity to improve value (i.e. improve performance or reduce cost while meeting the required performance). From this long list the VE team short-listed **64** ideas which were most likely to be implemented. **Appendix E** presents the entire list of ideas (181) from the creative phase of the workshop and those short listed (64) are presented in Section 7.3, **Table 9** below.

The short listed ideas were carried forward for development into VE Proposals, including analysis and costing.

Summary of Recommended VE Proposals

Based on the creative brainstorming and the subsequent expert specialist review of the 64 short listed ideas, the Team built consensus for the following list of **35** VE Proposals for further investigation by the TTC and design team. (Note: The TTC carried forward 62 items. **See Section 7.3** below for further details).

A summary of the proposals and the magnitudes of the cost avoidance/ or recommended budget increases is presented in **Table E1**:

Table E1: Summary of VE Proposals and Cost Avoidance/Budget Increases

	VE Proposal	Magnitude of Cost Avoidance (excluding mark-up)
	Station	
1	New Bus Plaza – Elimination of Bus Terminal	$50M (TB-01/03/04/07/09/13/18/19/26)
2	Construct bus terminal over shifted subway station	$30M (TB-07)
3	Allow for 2 level bus terminal	$TBD (TB-14)
4	Allow future development opportunities	$TBD (TB-18/19)
5	Alternate bus terminal roof finish	$TBD (TB-29/30)
6	Revisit number of bus bays by reviewing network (routes terminate at SMART TRACK stations)	$TBD (TB-25)
7	Use short section of SRT for monorail and pedestrian link to stations	$TBD (RP-08)
8	Build Centre Platform terminal station	$TBD (BS-03)
9	Reduction in Station Program Space	$TBD (BS-06B)

	Mechanical	
10	Reduce number of fans by 2 in Station	$4.1M (CA-03)
11	Remove centre wall and increase fan size	$3.3M (CT-09)
12	Create service tunnel in invert space	$TBD (CT-13)
13	Provide hoist in Emergency Exit Building (EEB) structures to drop FLS equipment	$400,000+ (LS-01)
14	Investigate if number of substations can be reduced by new technology	TBD (O-01)
15	Eliminate 6 EEB structures except 2 EEB structures with fan plants and add cross passages	Significant savings (CT-21/ SS-01)
16	Use Ontario Building Code (OBC) life safety criteria in lieu of TTC criteria	$TBD (SS-06)
	Tunnel/Structural	
17	Support of excavation as permanent structure	$9M (BS-01)
18	Raise the station	$TBD (BS-02)
19	Allow alternate codes for elements including support of excavation (SOE) and structures	$TBD (BS-06)
20	Tie-back to minimize king piles and struts	$6.5M (BS-10)
21	Pre-cast for stairs and slabs	$2.2M (BS-18)
22	Shift alignment to McCowan and create at-grade Station	$100M - $150M range (CT-01)
23	Change the mass concrete in base slab to granular	$1.6M (CT-10)
24	Reduce track system concrete thickness	$14M (CT-14)
25	Use galvanized steel safety walkway rather than concrete	$TBD (CT-15)
26	Steel fibre reinforcement for tunnel lining	$TBD (CT-16)
27	Reduction in length of launch shaft	$TBD (O-15)
28	Use rubber boots rather than slab over rubber pucks	$TBD (LV-01)
29	Performance specification to achieve TTC requirements (Design Build)	$TBD (CC-02/R-07/R-12)
30	Change Progress Avenue to an at-grade tee intersection	$1.5M to $12M (O-09/A-B)
31	Complete entire tunnel from Kennedy launch and negotiate with Metrolinx	$ Property and Capital Savings TBD (SC-05)
	Other Design Suggestions	
32	GBR and geotechnical risk options	$TBD (R-01, R-02, R-04)
33	Share risk allowance (contingency) that allows contractors to have an interest in achieving an early schedule completion. At the end of the contract the allowance is shared equally	$ TBD (R-19)
34	Allow contract completion flexibility (use escalated penalty clause stepped at end to allow DB price not to be based on a fixed end-date) and bonus clauses	(SC-11)
35	Allow 24 hour work for tunnel (contractor flexibility)	(R-12)

Note: Cost avoidance forecasts are provided as an order of magnitude of potential savings only and the estimates do not include the contingency mark-up.

The most significant proposals include:

- Elevate the subway station to reduce the capital cost of temporary excavations and dewatering. This would allow a future extension of the subway under Highway 401 with shallow cover (it was noted a current project is using 2 m of cover under an MTO freeway)
- In conjunction with an elevated station, introduce a portal south of the station that will allow the tunnel installation to be entirely separated from the station
- Design the new station to support a joint use development with mixed use development over the station (the land will have a higher value after the subway and bus station are constructed)
- More compact bus station and potentially to salvage the existing station as a split bus terminal to minimize the investment in new infrastructure
- Elimination of 1 or 2 of the roadway bridges as both a safety improvement and cost avoidance
- Potentially reducing the number of Emergency Exit buildings by capturing the life safety benefit of constructing a wall between the sides of the tunnels (allows persons to have fire separation by using an exit door immediately through the middle wall)
- The tunnel will become a linear infrastructure corridor and there is a potential to use the space in the bottom of the tunnel for utilities and within the station for mechanical and electrical rooms
- The number of fans may be reduced

Context of the VE Review

It must be recognized that the proposals and recommendations from the VE Team represent the consensus of the team following five days of intensive review of the early concept level design of the McCowan Alignment Revision J. These recommendations will be the subject of more detailed review and analysis.

Conclusions and Recommendations

In conclusion, the VE Team validated the constructability of the 5% design for the project and built consensus for design changes that could allow it to be delivered more cost effectively. The opinion of the VE Team is that the proposed design modifications are viable approaches. These constitute a shopping list for the owner and design team to review at the implementation meeting post workshop. Detail design will refine the conceptual elements as described in this report based on the direction provided following the implementation meeting. A recommendation is that the design development should be reviewed at the 20% level of design to again focus on cost validation, risk assessment and innovation.

1.0 Introduction

1.1 Background

This report summarizes the results of the Value Engineering (VE) Study carried out by BT Engineering (BTE) for the Toronto Transit Commission (TTC). The mixed value engineering team was comprised of TTC management, engineering, and operations staff, AECOM, the City of Toronto, Hanscomb, HATCH, IBI Group, McNally, Stantec, Thurber and Parsons. Members of the TTC Senior Management were present for the opening and closing presentation phases of the workshop.

The project location is illustrated in **Figure 1.**

The elements of the Scarborough Subway Extension project include:

- Extends existing Bloor-Danforth Line 2 from the existing Kennedy Station to a new Scarborough Centre Station (SCS)
- 6.25 km extension of dual running track
- Single Bore 10.7m internal diameter tunnel
- New subway and at-grade bus stations constructed at Scarborough Centre
- Existing SRT Service to be maintained during construction
- Meet TTC's level of service standards

The VE Study included a 5-day workshop from September 12th to September 16th, 2016 to analyze functional requirements of the project, review the preliminary cost estimate and generate, evaluate and develop ideas for alternative value enhancements. The exercise focused on the 5% design drawings.

The purpose of the workshop was to provide an independent review of the project to date including cost estimate and risk analyses and define a list of candidate value proposals to assist in the delivery of a quality project.

The basis of design that was considered at the workshop is the McCowan Alignment Revision J controlled, with an at-grade bus terminal. The baseline design available at the workshop was estimated to be approximately at the 5% design level (September 2016). The associated cost estimate reflects an earlier design development that pre-dates the current 5% design level.

The basis of the 5% design is illustrated in **Figures 2** to **6** illustrating the running tunnel, Scarborough Town Centre subway station and bus station. **Figure 6** illustrates maintaining the existing road network over the new bus station with bridges over the new bus station.

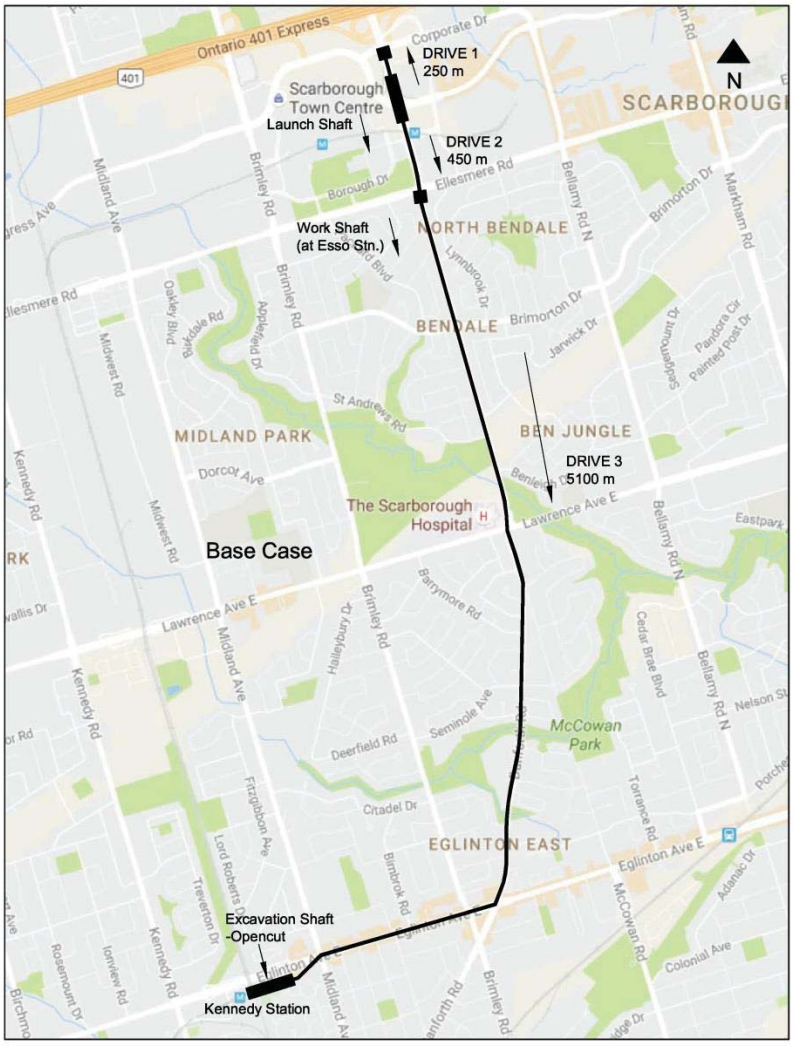

Figure 1: Project Location

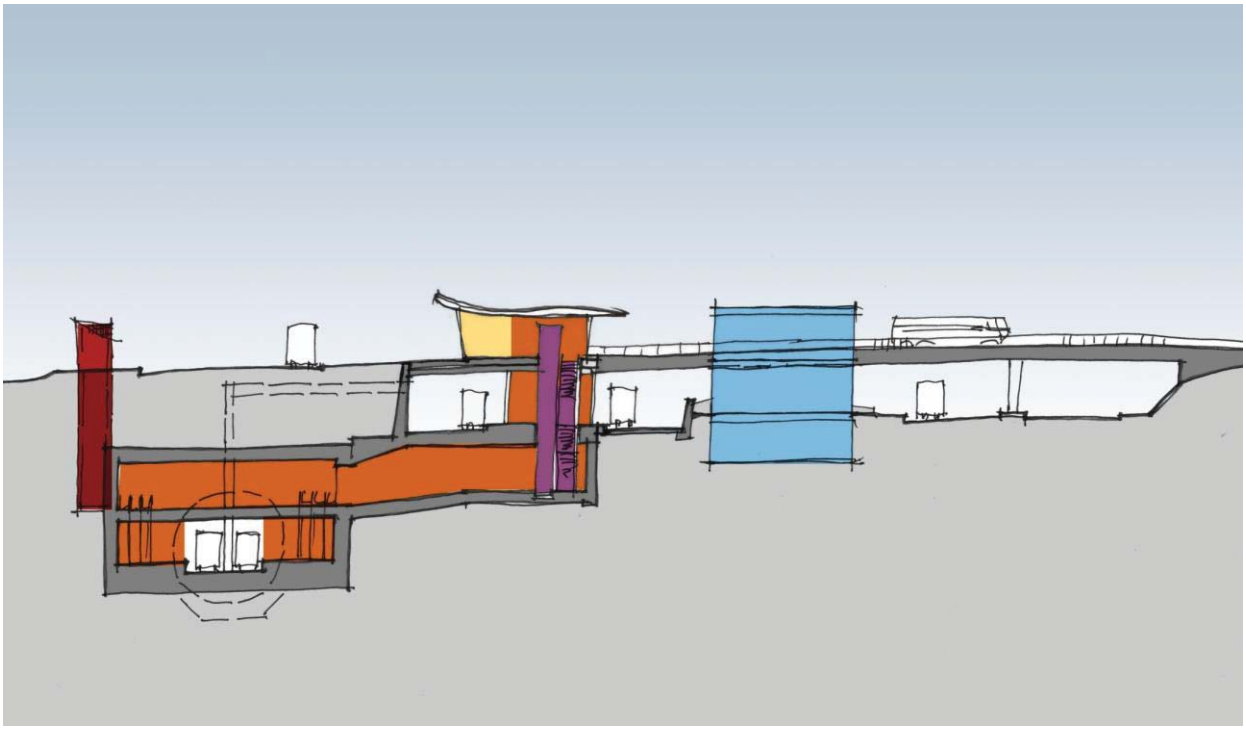

Figure 2: Scarborough Town Centre Station (looking north)

Figure 3: Scarborough Town Centre Station (looking northwest)

Figure 4: Scarborough Town Centre Station Cross Section of Subway and At-grade Bus Station

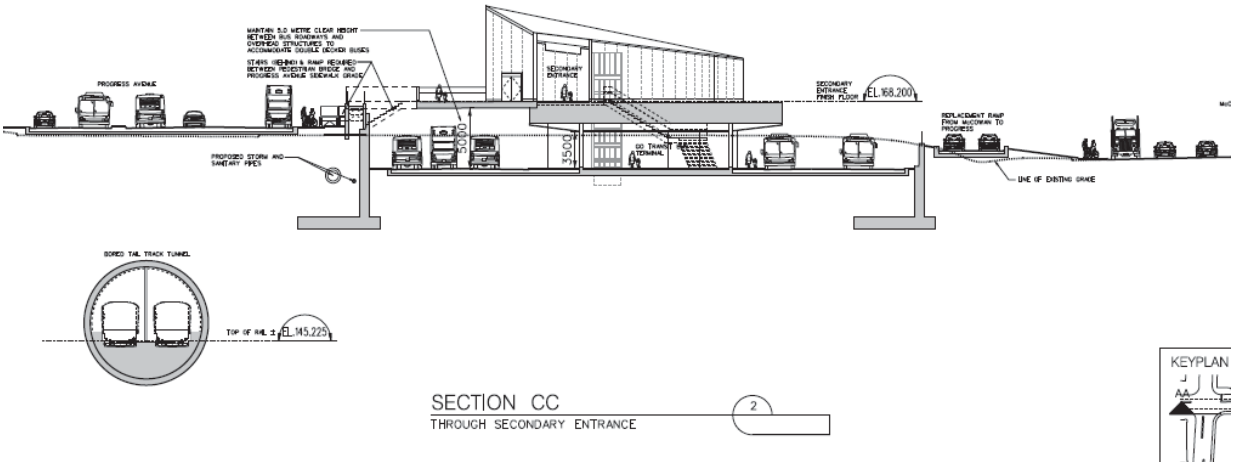

Figure 5: Scarborough Town Centre Station At-grade Bus Station

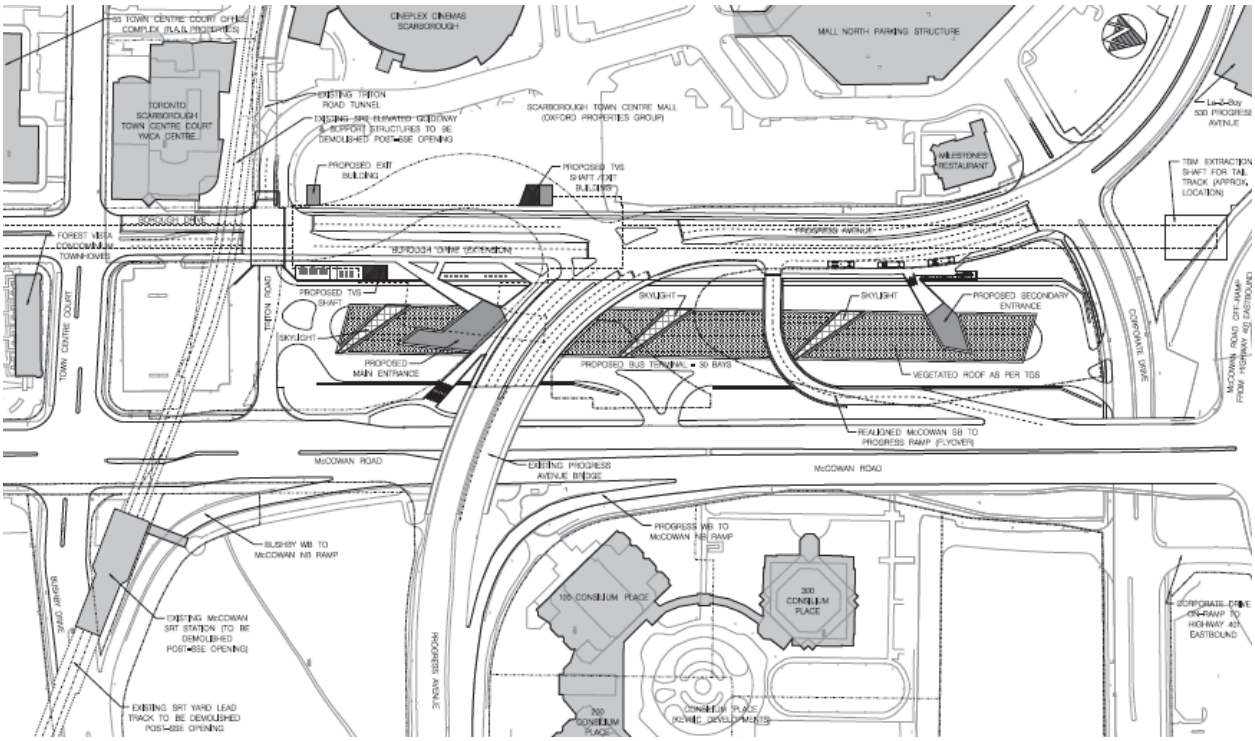

Figure 6: Project – Bus Station

1.2 Purpose of the VE Study

The purpose of the workshop was to provide an independent review of the project to date and define a list of candidate value proposals to assist in the delivery of a quality project more closely aligned with the initial construction budget of $2.7 billion. This considered:

- VE Milestone – 5% Design
- Question all previous decisions
- Focus on value
- Focus on constructability and risks
- Mandate to provide shopping list of ideas back to design team and TTC/City reflecting advice of industry experts
- Ideas present consensus of 5 days of review realizing verification will be required by design team after workshop

The workshop was a significant project milestone to ensure that the final project delivered is cost effective, constructible and in keeping with the project delivery objectives of the Toronto Transit Commission.

1.3 Value Engineering Process

The VE Study included a 5-day workshop on September 12th to September 16th 2016 to analyze functional requirements and generate, evaluate and develop ideas for alternative value enhancements as well as to validate the current design, estimated to be at approximately 5%.

The Value Engineering approach is a powerful decision-making process, which differs from the conventional scientific process by focusing on the project/process functions to allow both convergent and divergent thinking. Alternatives are then generated to appropriately deliver the functions required for the success of the project.

The study utilized the 6-phase job plan of SAVE International to define the necessary project requirements and prioritize elements. This was achieved through the three VE primary stages: pre-workshop, workshop, and post-workshop activities.

The workshop approach was to utilize a joint team comprised of both design team and independent team members. Additional members of the design team also participated in the information and presentation phases of the workshop.

The pre-workshop activities included data collection, analyzing and reviewing study materials supplied by the Design Team, and model development, which established the primary elements of the project design proposal. The pre-workshop tasks also included reviewing the preliminary cost estimate using an independent cost consultant and an independent review of the project's risk assessment using an independent risk consultant.

The workshop focused on reviewing functional requirements of the project and then generated, evaluated and developed ideas of alternative value enhancements (Value Proposals) to move forward with the project. The post-workshop activities involved further refinement of the ideas short-listed by the VE Team and screening by the owner and design team on which ideas to implement, as well as the preparation of the draft and final VE report.

1.4 Governing Principles

Discussions with the Toronto Transit Commission and the design team prior to, during, and following the workshop helped to define the principles that were important, and would contribute to the success of the study. The governing principles of the VE Study were defined to be:

- The VE Team will remain focused on necessary elements defined in the study scope, but will document generated ideas, outside the scope, that may be of benefit to others;
- All suggestions will be accepted by the VE Team and evaluated later for application and development;
- The VE Team will focus on the cost models, risk assessment, functions and value of components to ensure that the most appropriate and cost-effective solutions are selected; and
- The Owner (City of Toronto and Toronto Transit Commission) will continue to have the authority and responsibility to accept, modify, or reject any/all recommendations and estimate corrections made by the VE Team.

1.5 Workshop Agenda

The agenda included all phases of the Value Management Standard – Information, Function Analysis, Creativity, Evaluation, Development, and Presentation.

The full Agenda for the Workshop is presented in **Appendix B** and is summarized in **Table 1: Workshop Agenda.**

Table 1: Workshop Agenda

Activities
Information Phase
• Value Management Overview
• Project Overview Presentations
• Defining Opportunities/Commitments/Constraints
• Quality Modelling
• Team Site Visit
Analysis Phase
• Review of Cost Model
• Review of Top 20 schedule and cost risks
• Identifying Project Functions
• Preparation of FAST diagram
• Cost/Worth Analysis
• Target Costing Analysis
Creativity Phase
• Defining Targets
• Creative Brainstorming
Evaluation Phase
• Screening of ideas to be championed
Development Phase
• Technical write-ups of ideas
Presentation Phase
• Preliminary results presentation of ideas and concepts on final day of workshop
Post-Workshop
• Draft and Final Value Engineering Report
• Final workshop report
• Implementation Meeting

1.6 VE Team

The VE Study Team was comprised of technical specialists and select staff from TTC management, engineering, and operations staff, AECOM, the City of Toronto, Hanscomb, HATCH, IBI Group, McNally, Stantec, Thurber and Parsons.

The Workshop Team is shown in **Photo 1**.

Photo 1: VE Team

During the workshop the members who made up the VE Team were asked to set aside the perspectives of their individual organizations and act solely as knowledgeable experts in their fields of planning, design and operations. The VE Team recommendations/ideas do not reflect the approval of any agency.

The VE Study Team members and their affiliation, expertise, and attendance are listed in **Table 2: VE Team** and the workshop registration sheets are included in **Appendix C**.

The design team presented background information to inform the VE team members and workshop participants of the project scope and objectives on Day 1 of the workshop. The Top 20 schedule and cost risks were reviewed during the workshop. **Appendix G** includes an overview of the risk assessment provided for review by the independent risk consultant.

Steve Taylor, P.Eng., M.Eng., CVS-Life, BT Engineering, served as the VE Team Leader (VETL) for the Workshop session and oversaw the preparation of the VE report. **Table 2: VE Team** provides a listing of the VE Team members.

Table 2: VE Team

Name	Specialty	Representing
Steve Taylor	VE Team Leader	BT Engineering (BTE)
Wayne Hyde	Assistant VE Team Leader/Project Manager	BT Engineering (BTE)
Mary Jane Baron	VE Administration	BT Engineering (BTE)
Abbas Khayyam	Project Manager, Tunnel Ventilation	AECOM
Bryan Shaw	Architecture	AECOM
Dilip Shah	Tunnel Ventilation Systems	AECOM
Howard Jung	DPM/Structural	AECOM
Stuart Lerner	Structural/Stations	Stantec
Bill DeAngelis	Procurement/Constructability	City of Toronto
Mike Logan	Planning/EA	City of Toronto
Molly McCarron	Decision Support	City of Toronto
Dale Panday	Cost	Hanscomb
Nathan Thinagarippilai	Cost Consultant	Hanscomb
Brian Garrod	Tunnels	HATCH
Matthew Geary	Tunnel	HATCH
Nima Eslaminasab	Tunnel Ventilation Systems/Mechanical	Hatch
Tomas Gregor	Project Management, Tunnel Design	HATCH
Richard Stevens	Architect	IBI Group
Steve Skelhorn	Construction	McNally
Veeramany Harharaiyer	Planning/Scheduling	Stantec
Masoud Manzari	Geotechnical Engineer	Thurber
Damien Forbes	Owner	Toronto Transit Commission
Rick Thompson	CPM	Toronto Transit Commission
Selim Gabra	Civil/Structural	Toronto Transit Commission
Desmond Chiu	Cost Estimating	Toronto Transit Commission
Dragomir Jeyremonic	Construction	Toronto Transit Commission
Ed Poon	Civil/Structural	Toronto Transit Commission
Fulvio Fanti	Manager - Estimating	Toronto Transit Commission
Geoffrey Creer	Geotechnical	Toronto Transit Commission
Gordon Torp-Peterson	Director of Design and Engineering	Toronto Transit Commission

Table 2: VE Team

Name	Specialty	Representing
Jey Vellauthapillai	TTC Estimator	Toronto Transit Commission
Jordan Schreiner	Utilities	Toronto Transit Commission
Les MacDermid	Director - Systems	Toronto Transit Commission
Michael Ruel	Civil/Structural	Toronto Transit Commission
Michael Tham	Track Alignment	Toronto Transit Commission
Natasha Jailal	Property	Toronto Transit Commission
Reza Salamat	Senior Scheduler	Toronto Transit Commission
Stephanie Rice	SSE - Third Party Planning and Property	Toronto Transit Commission
Susan Reilly	SSE - Project Administrator	Toronto Transit Commission
Tessa Mackey	Permits and Approvals	Toronto Transit Commission
Troy Cui	Engineering Coordinator	Toronto Transit Commission
Vincent Teng	Stations	Toronto Transit Commission
Yesika Beer	Risk Assessment Office	Toronto Transit Commission
Rene Lipp	Track	Parsons

1.7 VE Job Plan

The Job Plan prepared for the VE Study follows the standard VM methodology (October 1998) of SAVE International (authority to accredit Value Management). The VE Job Plan (refer to **Figure 7**) is conducted in three stages – Pre-Workshop, Workshop, and Post-Workshop.

The Job Plan originally prepared for the VE Study was essentially maintained, although several activities were adjusted in scope to accommodate a greater thrust in some areas. The VE Study results serve as key input into the project.

1.7.1 Pre-Workshop Activities

The pre-workshop activities included data collection, analyzing and reviewing study materials supplied by the Design Team for the McCowan alignment Revision J. The pre-workshop also included an independent review of the cost estimate by Hanscomb cost consultants and a review of the project risk assessment by the independent risk consultant (Gannett Fleming). The planning estimate was prepared by the TTC and established the project 5% design budget. The risk assessment was completed by the TTC and was also used as the basis of the independent review.

1.7.2 Workshop Activities

The work plan prepared for the VE Workshop followed the VE work plan consisting of the Information, Function Analysis, Creativity, Evaluation, Development, and Presentation phases of the SAVE International value methodology standard. The workshop analyzed functional requirements and generated, evaluated and developed ideas of alternative value enhancements to move forward with the project.

Post-Workshop Activities

The FAST (Function Analysis System Technique) diagram was finalized based on the draft FAST diagram and the functions identified during the Workshop. Each idea was assessed in terms of how it will (or should) be used during the project. The Post-Workshop activities involved the review of the input from the VE Workshop, finalization of the cost estimates for the Value Proposals and the preparation of the VE report.

Figure 7: Value Engineering Job Plan