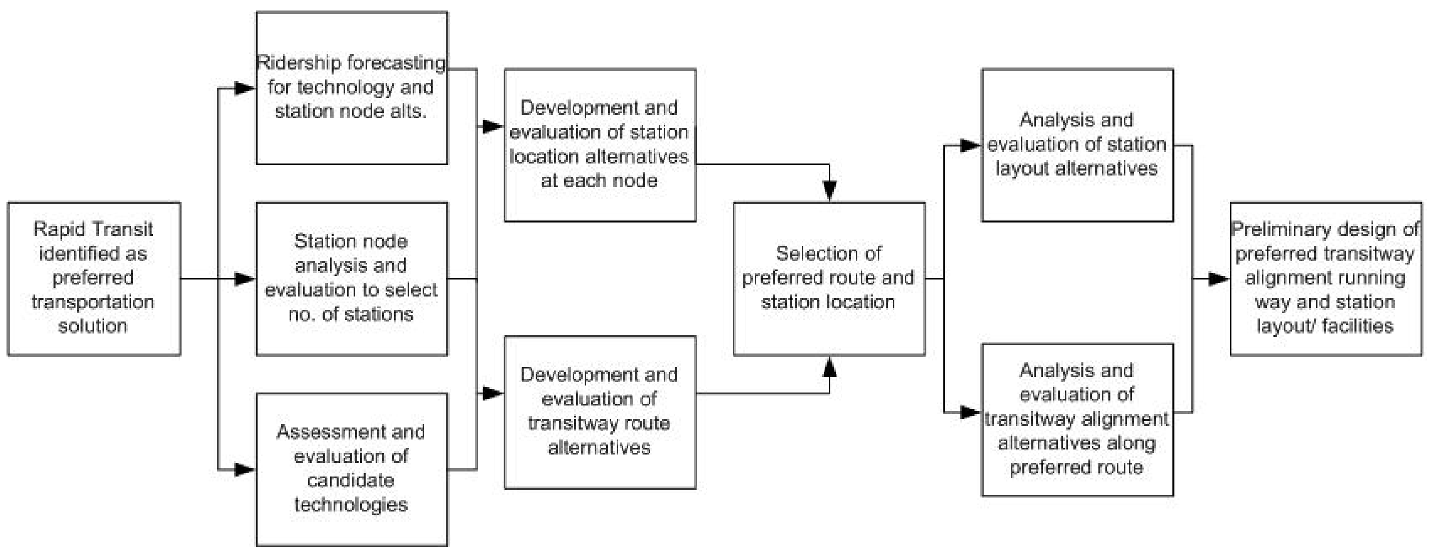
5. IDENTIFICATION OF ALTERNATIVES AND EVALUATION PROCESS

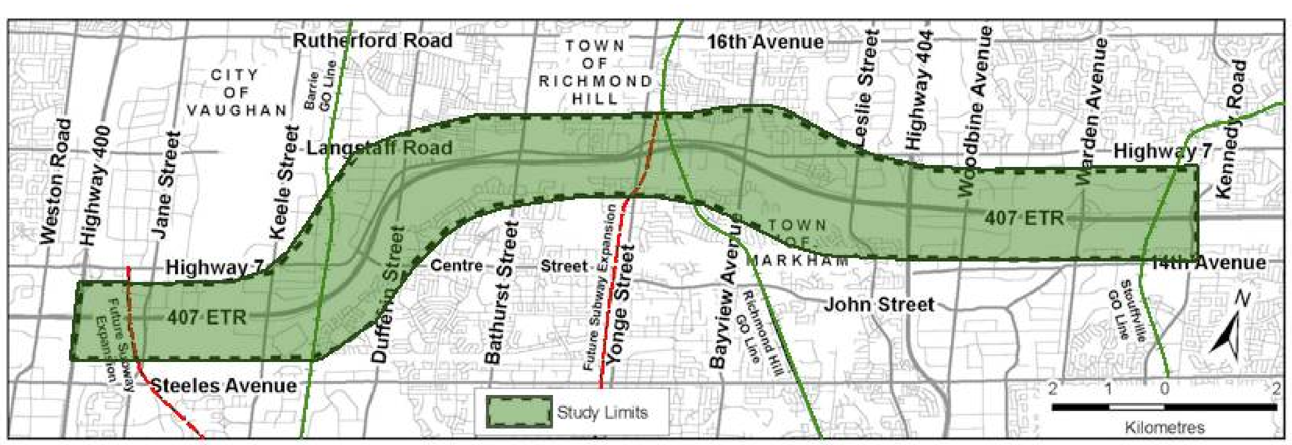
The Transit Project Assessment study was undertaken to develop the technically preferred alignment, stations and operation and maintenance facility, for a BRT system with the ability to convert to a LRT system. Through the Planning and Preliminary Design Stage of the study, the development of alternatives to the technology implemented, the station locations and layouts, and the route alignment have been completed. **Figure 5-1** illustrates the process from study initiation to the completion of the Preliminary Design Stage of the 407 Transitway study.

Figure 5-1: 407 Transitway, Central Section, Planning and Preliminary Development Stage



This project involves constructing a 23km separately dedicated running way for transit vehicles, an operation and maintenance facility, and seven stations within the project limits: Jane Station, GO Barrie (Concord) Station, Bathurst Station, Yonge Station, Leslie Station, Woodbine/Rodick Station, and Kennedy Station. The project limits are illustrated in **Figure 5-2**.

Figure 5-2: Study Area



Study Purpose & Objectives:

The primary objective of the 407 Transitway is to foster and support sustainable travel behaviour and a more compact urban structure in the GTA. In this regard, the 407 Transitway is an integral element of the Growth Plan and has the following attributes:

- In its final form, the 407 Transitway would transform the existing predominantly radial system of high order regional transit facilities into a network configuration, thereby expanding travel choices as well as reinforcing the utilization of the existing system.
- It reinforces the emergence and development of mixed use UGCs in the vicinity of the Highway 407 Corridor, mostly comprised of office, retail and institutional elements.

A primary focus is to enable gateway opportunities through the provision of modal interchange facilities.

More specific objectives of this study are to design the 407 Transitway, maintenance facilities and stations to accommodate an initial bus service with provision for future conversion to LRT, including local bus access to and egress from the stations, platforms, access to/from the adjacent arterial road, parking, PPUDO, buildings, shelters and other miscellaneous amenities. To support these objectives, the scope requires that the following activities be undertaken:

- develop detailed ridership forecasts for 2011, 2021, 2031 and 2051 horizon years;
- develop a set of design standards for the defined section of the transitway for both bus operation and LRT operation (including the associated maintenance and storage yard, stations and transit equipment) that will also be applied in the future to the remaining sections of the 407 Transitway;
- develop a cost-effective, safe and innovative preliminary design and construction staging for the 407 Transitway, both for bus services and LRT service, involving minimum throwaway for conversion to LRT;
- present a recommended phased implementation strategy for this first section of the bus transitway;
- incorporate design features of the 407 Transitway to provide for integration with existing and proposed municipal transit services; and,
- develop a Marketing Plan to provide a framework for advocating the benefits and value of the project and to encourage funding for the project.

5.1 Study Assessment

For the evaluation of alternatives and the evaluation process, several varying workshops were undertaken throughout the Planning and Preliminary Design. These workshops facilitated the assessment of the study and led towards the development of the Transitway's Design Standards as well as the generation of the transitway's route and station alternatives. The following section describes the Functional Performance Specification (FPS), Risk Based Cost and Schedule Analysis (RBCSA), and Valued Engineering (VE) workshops that were conducted in the study assessment.

5.1.1 Functional Performance Specification and Design Criteria

A major component of this study was to develop Transitway Design Standards for the 407 Transitway alignment, stations, and operations, maintenance and storage facilities. The design standards were to be developed through a review of standards and practices used by other transportation and transit authorities and through a series of functional performance specification workshops. Participants to the workshops included the study team, representatives from Metrolinx, Human Factors North, York Region Transit, and OC Transpo and MTO.

The first Functional Performance Specifications Workshop was held in September 12-14, 2007. To discuss the principles for the Functional Performance Specification Process, project background, needs and opportunities, jurisdictional review of other transit systems and the project's study area.

As part of the first workshop, the Study Team visited Ottawa to inspect the OC Transpo operating system and identified factors for success and lessons learned. The workshop included brainstorming session for functional performance requirements which resulted in "high-level" visions for the 407 Transitway. The functional analysis produced a general functional tree to identify and organize all functional objectives to be met by the project.

Following the first workshop, all reasonable "Alternatives To" the undertaking were identified based on the results of the workshop. The "Alternatives To" was selected and a set of Alternative Methods for the transit technology was then developed and analyzed, resulting a recommendation of the preferred transit technology.

A second workshop held in October 31, 2007 to November 2, 2007 developed a more detailed, functional performance specification for runningway, stations and maintenance and storage facilities.

Based on the two workshops, MTO developed the Transitway Design Standards Manual to achieve safe, high speed (90-100 km/hr), initial BRT operation while not precluding future conversion to LRT.

5.1.2 Risk Based Cost and Schedule Analysis Workshops

Two risk-based cost and schedule analysis workshops for the 407 Transitway were held in the Fall of 2008 and in the Spring of 2010. Participants to these workshops included members for the study team, experts in transit, traffic and highway engineering, urban design/landscape architect expert, structural and drainage engineering, elicitors, project management and representatives of Metrolinx, OC Transpo and MTO. The intent for these workshops is to consult with technical experts in the review of the project schedule and cost estimate, which would form part of the overall decision making. The purpose of these workshops was to:

- analyze and document the potential range in both total project cost and schedule due to risks or opportunities; and,
- identify and prioritize risks and opportunities.

The workshops identified significant opportunities and risks to the overall project cost and project schedule. It also identified a list of considerations to minimize critical risks and to exploit critical opportunities.

The intent of the results was to form the basis for overall decision making as well as provide input into both VE and Risk Management (RM) strategies that may be undertaken by the project team to optimize delivery and value of this project.

5.1.3 Value Engineering Study

Two Value Engineering Study workshops were planned for this project. Participants to these workshops included members of the study team, experts in transit, traffic and highway engineering, urban design/landscape architect expert, structural and drainage engineering, human factors and representatives of Metrolinx and MTO. The first 5-day VE Study was conducted in the Fall of 2008 to analyze/evaluate the Technically Preferred Alternative for the 407 Transitway from Highway 400 to Kennedy Road. VE proposals were developed to address overall capital cost savings; life cycle cost savings and/or improved project performance while still achieving the functional requirements of the project (i.e. best value for the money spent). VE proposals were combined into the overall project scenarios and evaluation of these scenarios against the base case concept design was done to determine the overall preferred alternative to take forward into preliminary design. New perspective and ideas were received and identification of project risks and their mitigation were determined. Lastly, identification of unnecessary costs from the base case concept for 407 Transitway were made. The base case was the **conceptual design** of the technically preferred planning alternative of the 407 Transitway at the start of the workshop (October, 2008), approximately 60% completed at the time of the workshop.

The most significant VE proposals discussed at the VE Study were:

- dedicated lanes adjacent to existing Highway 407 lanes;
- reduce runningway width to have a single operational shoulder;
- six stations by eliminating Bathurst Street Station;
- build transit station on top of Highway 407 at Leslie;
- relocate GO Barrie (Concord) Station and transitway south of Highway 407;
- locate stations over parking lot where appropriate;
- span stations across arterial roads;
- reduce skew of structures (e.g. west of GO Barrie Line);
- reduce length of spans; and,
- use of B5 Alignment (407 Transitway alignment south of Highway 407) and B1 Alignment (407 Transitway north of Highway 407) between Keele Street and Bathurst Street.

The VE Team determined which VE proposals best fit together into VE Scenarios that make sense and could be presented as cohesive, complete conceptual design solutions for the 407 Transitway. Two VE scenarios were developed, removing any cost overlaps between the proposals composing each of the scenarios.

Due to the conceptual stage of the project, the results of the evaluation were considered as guidance for the 407 Transitway preferred planning alternative being carried forward into preliminary design.

The second VE Study workshop was conducted in the Spring of 2010 to analyze the preliminary design of the Technically Preferred Alternative for the 407 Transitway. The Base Case and four VE scenarios based on inputs received from the VE Team were developed.

The base case was the **preliminary design** of the technically preferred alternative of the 407 Transitway at the start of the workshop (May, 2010), approximately 70% completed at the time of the workshop.

The first scenario consisted of a series of minor modifications to the Base Case designed such as relocation of bus loops at Bathurst Street Station and GO Barrie (Concord) Station, changes to the width of the runningway shoulder, etc.

The second scenario consisted of major modification to the Base Case design such as raising the grade of the south end of the parking facility at Bathurst Street Station to eliminate stairs/elevator to the elevated pedestrian bridge over Highway 7, move the YRT/Viva stop closer to the GO Highway 7 bridge, changes to the runningway horizontal alignment and provision of an underground tunnel connection from the transitway stop platform to the intermodal station at Jane Street.

The third scenario consisted of a combination of modifications to the Base Case directed at enhancing the customer experience of using the 407 Transitway.

The fourth scenario was a combination of modifications to the Base Case directed at developing an elevated alignment for the 407 Transitway (skytrain) at both the Kennedy Station area and the Yonge Station area.

The Base Case and four scenarios were evaluated. Due to the 70% design stage of the project, the evaluation analysis did not result in a single firm recommendation by the overall VE Team. However, the conclusions provided insights that were considered throughout the remaining design process.

5.2 The Technology

Rapid Transit Technology Alternatives:

Five candidate technology alternatives were considered in developing a response to the need for inter-regional rapid transit in the ultimate 160 kilometres Highway 407 Corridor. These technologies encompassed the full range of system capacities and vehicle/infrastructure configurations that could be considered compatible with the transportation service and implementation needs of the corridor. Very high-speed inter-city rail technology (over 200km/hour) is not applicable to serve the distribution of ridership in the corridor and incompatible with the physical constraints of the Parkway Belt corridor. A description of the characteristics of each candidate technology listed below is presented in **Table 5-1** which discusses the general definition, vehicles, runningway and station requirements, control and information systems, fare collection, system capacity and capital costs.

1. BRT;
2. LRT;
3. Automated Guideway Transit (AGT);
4. Heavy Rail Transit (e.g. subway); and,
5. Commuter Rail.

Each of the above candidate technologies was evaluated against four major criteria reflecting the near- and long-term needs and objectives for the Highway 407 Corridor. These included:

- transit service quality encompassing capacity required, user convenience and comfort, service speed and reliability and network connectivity/interlining;
- planning considerations addressing infrastructure integration and the system's support of Provincial growth and planning policies;
- environmental compatibility covering effects on the natural and socio-economic environment and energy consumption; and,
- implementation considerations including ROW property needs, cost-effectiveness and implementation staging.

The findings of the evaluation of the five candidate technology alternatives are presented below in **Table 5-2** and the following section provides a discussion on the rationale for the selection of the preferred technology.

From the evaluation, it is evident that initially, BRT would be the preferred technology for the 407 Transitway but that conversion to LRT technology in the future should be protected to respond to the anticipated growth in ridership volumes beyond the 2031 planning horizon. In addition to significant implementation staging flexibility to transition from operation in mixed traffic on the 407 ETR to higher speed service on a fully exclusive runningway, BRT provides capacity for the projected demand at the desired level of convenience and comfort.

Like the other line-haul operating technologies, it offers the same benefits of network connectivity with three GO Rail lines and two subway line extensions to the corridor; and as well, being bus-based, it does not need feeder services at all stations as the vehicles are able to interline by operating on city streets or highways to reach key off-line destinations such as Pearson Airport or the 400-series highways. Also, the planned service quality has significant potential to increase transit use, encourage transit-oriented land use by directly linking the 407 ROW to the three regional centres (Vaughan Metropolitan Center, Richmond Hill Centre and Markham Centre).

Other technologies that only indirectly link to the regional centres will only partially reinforce urban form and development objectives, as would be the case at Vaughan regional centre which would require an additional transfer if rail-based technologies were adopted. Similar to the other technologies, BRT is a low emission vehicle technology that is becoming more available, energy efficient and with improved emission control. Other important advantage of the BRT system is the implementation staging flexibility, allowing the opportunity to build specific segments of runningway at a time, maintaining the transitway operation on the 407 ETR Highway along un-built or under construction segments. Being Lastly, BRT's capital and operating costs are compatible with the size of the market for rapid transit service in the corridor compared to the other high capital investment technologies and the runningway and station infrastructure can be shared by other transit operators providing compatible services.

LRT technology is recommended as the best candidate technology for later implementation in the 407 Transitway to meet the potential future increase in service demand. Unlike the Diesel Multiple Units (DMU) and Heavy Rail, the alignment geometric standards do not limit alignment planning options and it can be implemented with adequate measures to mitigate most natural and socio-economic impacts. Further, it allows flexibility to stage implementation across the study area with convenient transfers along the ROW; however, it is only viable if the segments exceed 10 to 12 kilometres in length. Conversion to automatic train operation is also feasible if east-west trip volumes in the corridor ever justified higher capacity (over 15,000 passengers per hour per direction) in the distant future.

Table 5-1: Technology Characteristics

	Bus Rapid Transit (BRT)	Light Rail Transit (LRT)	Automated Guideway Transit (AGT)	Heavy Rail Transit (e.g. Subway)	Commuter Rail
General	 BRT technology is defined as the operation of conventional transit vehicles, or purpose built rubber-tired vehicles, or both, on an exclusive or partially exclusive right-of-way to provide a higher capacity and higher quality rapid transit service than conventional bus service, nearer to that of higher speed rail-based systems. Being bus-based, a significant feature of BRT technology is the ability to serve off-line key destinations without requiring an additional passenger transfer.	 Light Rail Transit (LRT) technology, in its current form, usually comprises electrically-propelled rail vehicles operating singly or coupled to form short trains operating on a partially or fully segregated right-of-way. This intermediate-capacity rapid transit technology can be based on a range of vehicle and infrastructure characteristics	 Automated Guideway Transit systems such as those in Vancouver, Scarborough and Lille, France with automated, mostly driverless operation require a rail right-of-way totally separated from other traffic over its entire length. These systems are typically electrically-powered providing intermediate to high capacity on elevated or underground guideways	 Heavy rail rapid transit or Subway technology is traditionally adopted for congested, densely-developed urban corridors or to carry large volumes of passengers to major CBDs. Establishing a fully segregated right-of-way allows the use of longer trains at close headways giving a high capacity, high-speed, typically underground system	 Locomotive-hauled cars or diesel multiple unit (DMU)-based commuter rail technology is generally used to carry large volumes of passengers to a central work zone on a limited stop fixed schedule Typically, the operating characteristics require a dedicated right-of-way with standards similar to existing inter-city rail corridors. This limits route opportunities and generally results in wider station spacing to maintain reasonable service speeds.
Vehicle technology	Available propulsion options for vehicles range from low-sulphur diesel and CNG to various electric hybrids and all-electric trolleys. Low-floor, multiple wide-door designs and optional guidance into stations speeds boarding and alighting thus reducing station dwell time. Vehicle lengths range from 12.2 metres (single unit) to 18 metres 25.5 metre(s) bi-articulated units are also used in some systems. Typical passenger capacities are 60 (single unit) to over 100 (bi-articulated unit) standing and seated passengers per vehicle.	LRT vehicles range from all-electric to diesel propelled, high and low-floor car designs. Lengths vary from 14 metres (single unit) to 45 metres (bi-articulated unit). Typical passenger capacities are approximately 75 (single unit) to as high as 200 (bi-articulated unit) standing and seated passengers per car. Vehicles can be coupled to form up to 3 or 4 car trains depending on vehicle length and demand. Normally, LRT vehicles do not meet railway collision absorption requirements. Where LRT shares existing rail lines, freight operation is restricted to hours when no LRT service is provided.	Generally, automated guideway transit vehicles also use electric propulsion, however the fully segregated secure right-of-way necessary allows the power to be distributed to the vehicles by a third rail at track level. Typically, trains comprise two to four cars in length with level boarding and passenger capacity between 75 and 130. The addition of communications and computer systems to control and regulate operations reduces the size of driver cabs, but requires a larger central control facility for the system.	Vehicles always feature level, no-step station platform to vehicle boarding/alighting through multiple wide doors. Lengths vary from 15 metres to 22.8 metres (mostly single unit) coupled in trains of 4-8 cars. Passenger capacities are up to 185 standing and seated passengers per car. Power is usually collected from a third rail; although an overhead contact system (catenary wire) may be used in some cases (e.g., Boston MBTA Blue Line).	Generally operated on freight or mixed freight/passenger rail corridors, the vehicles are typically loco-hauled or self-propelled, full-sized heavy rail cars. Many systems now use bi-level cars in the order of 26 metres (85 feet) long of the type currently in service on GO Transit's GTHA network. Many commuter rail vehicles require raised sections on platforms to permit accessibility by disabled passengers. In Quebec and Europe, self-propelled, diesel or electric multiple unit trains provide intermediate capacity service. Ottawa is using an example of DMU regional rail vehicles that has a capacity of 285 passengers and a length of 48 m.
Runningway	BRT can operate in general traffic, and/or exclusive bus lanes, and/or segregated transitways. The operating speed, capacity and reliability increases with the degree of segregation from general traffic and grade separation. The key objective in applying BRT technology is to provide a separate roadway for the transit vehicles to improve average operating speed and increase service reliability. Typically, a width of 10-12 metres is required to develop a segregated bi-directional running way if grading is not major. At stations or stops a larger right-of-way is needed to accommodate platforms (approx. 3-4 m wide) and passenger accessways. If the operation assumes that express service will overtake local service at stations, a much larger local right-of-way, up to 16 m, may be needed for stopping lanes each side of the through lanes.	LRT can operate mixed with general traffic (i.e. streetcar systems), and/or on exclusive lanes, and/or on segregated transitways. The operating speed, capacity and reliability increase with the degree of segregation from general traffic and grade separation. LRT requires an 8-10 metre wide right-of-way. Generally, it is separated from parallel traffic by a physical barrier such as a curb or curb and railing treatment. In many cases perpendicular roadways are crossed at-grade with signalized intersections through which the LRT is often given signal priority when headways permit. The overhead electric catenary system must be supported by new poles or suspended from lighting poles. In some key locations, the LRT may be grade separated from the road traffic to improve intersection function or provide access to a multi-modal station. Right-of-way along rail lines requires additional space for safety clearances.	AGT requires a 7.5-9 metre wide secure right-of-way. Generally it is elevated or, if at-grade, separated from parallel traffic by a physical barrier. Underground guideway can also be used when necessary. In all cases the right-of-way is grade-separated from perpendicular roadways. Computerized control systems can react to intrusions into the track area, and in driverless operation can handle the passenger interface issues, but are not sufficiently advanced to handle interaction with other vehicular traffic.	These high capacity systems require fully segregated and totally grade separated running ways. As subways are generally underground, the right-of-way width required is dependent on the method of tunnel construction. Cut-and-cover tunnels usually require a width of 12-14 m on the surface while twin bored tunnels occupy 18-20 m at the mid-height of the tunnel. Tunnels must allow a minimum cover of about 3 m to permit the crossing of utilities. The alignment required for high-speed subway operation generally consists of curve radii exceeding 300 m and profile grades of less than 3.5%.	Commuter rail technology requires an exclusive right-of-way with limited level crossings. Signalized gates control all crossings where rail traffic takes priority over road traffic. Rights-of-way are generally a minimum of 20 m wide to accommodate side slopes from the track grading. There are also geometric limitations to commuter rail facilities. Railways require a relatively flat track profile and space for large radius curves. These limitations are especially challenging in built-up urban corridors.

Table 5-1: Technology Characteristics (Cont'd.)

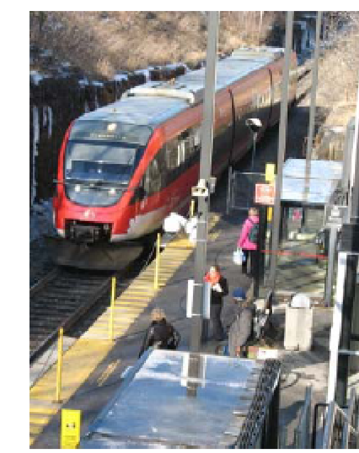
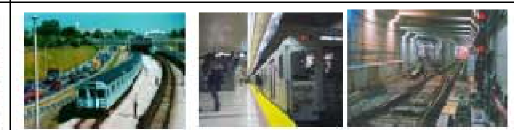
	Bus Rapid Transit (BRT)	Light Rail Transit (LRT)	Automated Guideway Transit (AGT)	Heavy Rail Transit (e.g. Subway)	Commuter Rail
Stations or Stops	Formal stations at key locations along the route are focused at major cross street intersections and at major trip origins and destinations. These generally comprise platforms varying in length from 15-55 m. The stations can range from shelters on simple curb-height platforms, to large inter-modal transfer stations at key locations with park-and-ride lots and passenger pick-up/drop-off facilities. They are generally designed to be accessible by the disabled. Station spacing is approximately 1 km in built-up portions of corridors increasing to 2 km in lower density areas. Facilities at stations are aimed at a high level of convenience and comfort with enclosures providing more protection from the elements. Another rail-like feature sometimes incorporated is the ability to load and unload at platforms with a small clearance using a guidance system allowing more precise docking. Transitions for vehicles to enter or leave the transitway are included at strategic locations. 	Stations generally comprise platforms varying in length from 15m (streetcars) to 90m (multi-car trains) with shelters and passenger amenities. They are designed to be accessible by the disabled and may also include support facilities such as park and ride lots or passenger pick-up and drop-off areas. Station spacing is approximately 0.75 -1 km in built-up portions of corridors increasing to 2 km in lower density areas. Platforms at the stations are generally matched to the height of the vehicle floor. The current generation of LRT vehicles is being designed with low floors, which allow for easy passenger movements and low platform station stops. Where high floor vehicles are used, high platforms are desirable or steps on the vehicle can be used to board and alight. Stops can comprise simple curb-height platforms and shelters or more elaborate enclosed, intermodal stations with facilities for transfer from feeder buses and park-and-ride. 	Station stops are generally spaced more widely than for transitway or conventional LRT systems. In the CBD, or commercial centre, stations can be 500-800 metres apart, with the distance increasing towards the ends of a line. Typical suburban spacing can be in the 1-1.5 km range, wider if necessary. Platforms at the stations are generally matched to the height of the vehicle floor. The current generation of AGT vehicles is being designed with high floors, requiring high platform station stops. Stations tend to be more elaborate, often elevated to accommodate the fully grade separated right-of-way and with circulation facilities for the larger ultimate system passenger capacity. 	Generally underground or elevated with combinations of stairs, elevators and escalators to access platforms varying in length from 100-200m. Spacing is approximately 1 km in built-up portions of corridors to 3 km in less built-up areas. The fully segregated underground or depressed right-of way results in complex, costly stations with long platforms and access elements for large volumes of passengers. In the past platforms have been high-level to provide access at vehicle floor level. Passenger circulation usually requires a concourse with fare-paid zone and often, an extensive stair/escalator system depending on station depth. Feeder bus platforms and park-and-ride facilities are also needed at many stops. 	Station stops are generally spaced at 3-4 km in built-up portions of corridors increasing to 5 km in less built-up areas. The stops are often multi-modal with parking and bus access to collect passengers from local neighbourhoods. The larger vehicles and longer trains imply larger passenger loads which in turn require larger stations to accommodate passenger movement.  
Systems	BRT systems are generally controlled by conventional traffic signals where the vehicles interface with other road vehicles. Voice and data communication is also more commonly provided to increase safety and security.	LRT systems have a signal system to control train operations, provide data and voice communications and enhance safety and security.	A GT systems have additional equipment on the vehicles and along the tracks to achieve computerized automatic train control. In some automated systems all functions are controlled by the remote system including door operation.	Heavy rail must have a signal system to control train operation. Additional systems provide data and voice communications, and enhance safety and security. Some systems (e.g., Vancouver Sky Train) are fully automated.	Commuter rail systems usually have a signal system to control train operation from a control centre, while additional systems provide data and voice communications, and enhance safety and security.
Intelligent Transportation Systems	Contemporary BRT systems usually incorporate an Intelligent Transportation System (ITS) with an automatic vehicle location module that supports transit signal priority at intersections when required and real-time passenger information at stations, on-board and at home through websites.	Contemporary LRT systems also have ITS capabilities to provide transit signal priority at intersections when required and real-time passenger information at stations, on-board and at home.	Contemporary Automated Guideway Transit systems also provide real-time passenger information in stations, on-board and from home.	Contemporary heavy rail systems also provide real-time passenger information in stations, on-board and from home.	Commuter rail systems often provide passenger information in stations, sometimes in real-time and on-board.

Table 5-1: Technology Characteristics (Cont'd.)

	Bus Rapid Transit (BRT)	Light Rail Transit (LRT)	Automated Guideway Transit (AGT)	Heavy Rail Transit (e.g. Subway)	Commuter Rail
Fare Collection	Prepaid fares are required to reduce dwell times at stations and for passenger convenience. Options include fare gates and fare-paid, segregated platforms in stations and proof of payment systems using passes, smart cards or tickets.	Pre-payment of fares is required to reduce dwell times at stations, take advantage of efficiencies of train operation and for passenger convenience. Options include fare gates and fare-paid, segregated platforms in stations and proof of payment systems using passes, smart cards or date and time-validated tickets.	Pre-payment of fares is required to reduce dwell times at stations, take advantage of efficiencies of train operation and for passenger convenience. Options include fare gates and fare-paid, segregated platforms in stations and proof of payment systems using passes, smart cards or date and time-validated tickets.	Fare pre-payment is required to reduce dwell times at stations, take advantage of efficiencies of train operation and for passenger convenience. Options include fare gates and fare-paid, segregated platforms in stations and proof of payment systems using passes, magnetic strip card, smart cards or date and time-validated tickets.	Prepaid fares are beneficial to reduce dwell times at stations, avoid adding conductors to train crew and for passenger convenience. Options can include fare gates and fare-paid, segregated platforms in stations but are mostly proof of payment systems using passes, smart cards or tickets.
System Capacity	Segregated BRT service with station bypass lanes is capable of handling over 12,000 persons per peak hour per direction, depending on the degree of segregation from other traffic and grade separation. The busiest BRT segment in North America, in downtown Ottawa, carries approximately 10,000 passengers per hour in the peak direction during the single peak hour. The practical capacity without overtaking capability at stations is in the 8,000 passenger per hour range. 	LRT systems are capable of carrying up to 18,000 persons per peak hour per direction, depending on the degree of segregation from other traffic and grade separation. Approximately, 10,000 people per hour (peak hour, peak direction) use the busiest light rail segments in North America in downtown Calgary and on the Green Line in downtown Boston. 	A major benefit of the larger initial investment is the ability to expand the capacity of these systems to subway capacity levels by increasing the frequency of the trains under automatic control without major unit operating cost increases. Vancouver's new vehicles comprise a permanently coupled two-car vehicle with an overall length of 34.7 m and a capacity of 250 passengers. With trains consisting of two vehicles operated at 1.5 minutes headways, system capacities around 20,000 passengers per hour per direction are possible. AGT offers significant benefits if the high initial investment can be recovered by carrying large passenger volume growth in the mid to long-term periods of the system life. 	Up to 60,000 per peak hour per direction for a double track line. During the early nineties, the TTC carried over 30,000 passengers per hour on the Yonge line, south of Bloor Street in the peak direction during the peak hour. New York's Lexington Avenue Line carries over 63,000 passengers per hour per direction on a four track running way, two local, two express, with trains comprised of eight 23 metre cars 	As noted above commuter rail technology is usually adopted for long haul inter-regional services primarily to move large volumes of passengers commuting to major employment centres in CBDs. Its use in the Highway 407 corridor is partially compatible with the objectives for rapid transit in the corridor in the role of an east-west feeder line to existing north-south commuter rail corridors. 
Capital Cost	Total costs, including transitways, stations, ITS, vehicles, fare collection system, etc. range from $15m - $30m for a partially segregated transitway with mostly at-grade intersections. Costs can increase to $60m+ per km for fully segregated, grade- separated segments. Implementation costs depend on the volumes to be carried, system complexity, the degree of segregation from general traffic and the type and degree of grade separation (e.g., at grade, below grade or elevated).	Total costs including stations, ITS, vehicles, fare collection system, etc. range from $5m per km for single track diesel lines using former rail rights-of-way to $40m per double track km for partially segregated at-grade, electrified lines with mostly at-grade intersections. Fully segregated, grade separated electrified transitways can cost up to $100m per double track km. Implementation costs depend on volumes to be carried, system complexity, degree of segregation from general traffic and the degree and type of grade separation (e.g., at grade, underground or elevated).	Usually entails significant investment in initial infrastructure and systems but offers an operating cost advantage if passenger demand levels optimize the technologies capacity Implementation costs depend on volumes to be carried, system complexity, and the type of grade separation (e.g., underground or elevated). Typical infrastructure and system costs range from $80 – 120M per double track km.	Total costs, including cost of vehicles, ITS, fare collection system range from $100-$200M+ per double-track km depending on station spacing and opportunity for surface running way. Implementation costs depend on volumes to be carried, system complexity, and the type of grade separation (e.g., subway or elevated).	Total costs including stations, ITS, vehicles, fare collection system, etc. range from $10m per km for single track diesel lines using former rail rights-of-way to $40m per double track km for partially segregated at-grade lines with mostly at-grade intersections. Fully segregated, grade separated systems can cost up to $70m per double track km.

Table 5-2: Evaluation of Rapid Transit Technology Alternatives

RAPID TRANSIT TECHNOLOGY ALTERNATIVES	Bus Rapid Transit (BRT)	Light Rail Transit (LRT)	Automated Guideway Transit (AGT)	Heavy Rail Transit (e.g. Subway technology at-grade)	Commuter Rail
Evaluation Criteria	 BRT technology is defined as the operation of conventional transit vehicles, or purpose built rubber-tired vehicles, or both, on an exclusive or partially exclusive right-of-way to provide a higher capacity and higher quality rapid transit service than conventional bus service, nearer to that of higher speed rail-based systems.	 Light Rail Transit (LRT) technology, in its current form, usually comprises electrically-propelled rail vehicles operating singly or coupled to form short trains operating on a partially or fully segregated right-of-way. This intermediate-capacity rapid transit technology can be based on a range of vehicle and infrastructure characteristics.	 Automated Guideway Transit (AGT) systems such as those in Vancouver, Scarborough and Lille, France with automated, mostly driverless operation require a rail right of way totally separated from other traffic over its entire length. Typically electrically-powered, these systems provide intermediate to high capacity on elevated or underground guideways.	 Heavy rail rapid transit or Subway technology is traditionally adopted for congested, densely-developed urban corridors or to carry large volumes of passengers to major CBDs. Establishing a fully segregated right-of-way allows the use of longer trains at close headways giving a high capacity, high-speed, typically underground system.	 Loco-hauled or DMU-based commuter rail technology is generally used to carry large volumes of passengers to a central work zone on a limited stop fixed schedule. Typically, the operating characteristics require a dedicated right-of-way with standards similar to existing inter-city rail corridors. This limits route opportunities and often wider station spacing.
Transit Service Quality • demand-capacity relationship • user convenience and comfort, • service reliability • operating speed • network connectivity/ transfer issues	BRT is compatible with the projected demand in the corridor (4000 6,000 pass/hour per direction) and can provide the desired level of user convenience, comfort, speed and reliability. In the 407 transit ROW it offers the benefits of network connectivity with three GO Rail lines and a planned northward extension of the both the Yonge and Spadina subway lines. Being bus-based, a significant feature is the opportunity to link major trip-generating nodes off-line such as the Vaughan regional Centre and Pearson Airport without a passenger transfer.	Typically, LRT technology offers greater capacity (up to 15,000 pass/hour) than the projected demand and can provide the desired level of user convenience, comfort, speed and reliability. In the 407 transit ROW it also allows network connectivity with the three GO Rail lines and a planned northward extension of the both the Yonge and Spadina subway lines. However, the necessary line-haul operation requires transfers from feeder services at all stations.	In corridors where peak demand is unlikely to ever exceed 10,000 passengers per hour, the investment for AGT technology (capacity 10,000 – 25,000) cannot be justified despite reduced operating costs achieved by using centralized control for driverless train operation. AGT technology allows the required network connectivity and can provide the desired level of user convenience, comfort, speed and reliability but the necessary line-haul operation requires transfers from feeder services at all stations.	In corridors where peak demand is unikely to ever exceed 10,000 passengers per hour, the capital investment, even for largely surface heavy rail, cannot be justified. Operating cost savings of large capacity train service (20,000-30,000 pass/hour) are not achieved with low ridership levels. Heavy Rail technology can provide the desired level of user convenience, comfort, speed and reliability but the necessary line-haul operation requires transfers from feeder services at all stations.	Commuter rail technology capacity is compatible with projected demand in the corridor (4000 6,000 pass/hour per direction) and can provide the desired level of user convenience, comfort, speed and reliability. In the 407 right-of-way it also allows network connectivity with the three GO Rail lines and a planned northward extension of the both the Yonge and Spadina subway lines. However, the necessary line-haul operation requires transfers from feeder services at all stations.
Planning Considerations • support of Provincial objectives • infrastructure integration issues	BRT technology has good potential to increase transit use, encourage transit-oriented land use and link the 407 right-of-way to the proposed Regional Centres thus reinforcing urban form and development objectives. Also, it can provide inter-regional longer distance express trips. Opportunities for TOD generating walk in ridership are limited but park-and-ride infrastructure can be developed.	In other jurisdictions, LRT technology has been shown to increase transit use and encourage transit-oriented land use. Opportunities for TOD generating walk-in ridership are limited but good park-and-ride infrastructure can be developed. Indirect links to proposed Regional Centres in Vaughan and Markham, partially reinforce urban form and development objectives. The protected ROW to the east and west has geometry that would allow inter-regional longer distance LRT service.	AGT technology, in other jurisdictions has been shown to increase transit use and encourage transit-oriented land use. Opportunities for TOD generating walk-in ridership are limited but good park-and-ride infrastructure can be developed. Indirect links to the proposed Regional Centres in Vaughan and Markham, partially reinforce urban form and development objectives. The protected ROW to the east and west has geometry that would allow inter-regional longer distance LRT service.	In most jurisdictions, Heavy Rail technology is known to increase transit use and encourage transit-oriented land use. Opportunities for TOD generating walk-in ridership are limited but good park-and-ride can be provided. Alignment geometric standards limit planning options and would increase costs. Indirect links to the proposed Regional Centres in Vaughan and Markham, only partially reinforce urban form and development objectives.	In most jurisdictions, commuter rail technology increases transit use for medium to long distance trips to major high density CBD-type destinations. Opportunities for TOD generating walk-in ridership are limited but good park-and-ride can be provided. Alignment geometric standards limit planning options and can increase costs. Indirect links to the proposed Regional Centres in Vaughan and Markham, only partially reinforce urban form and development objectives.
Environmental Compatibility • socio-economic environment • natural environment • reduction of emissions and energy consumption	Since the alignment can be largely at-grade alongside the 407 ETR, BRT technology could be implemented with adequate measures to mitigate most natural and social environmental impacts. These could include measures such as avoidance of sensitive natural features and watercourses, bridge widenings minimizing aquatic habitat effects, urban design treatment of new station areas, traffic infiltration prevention, noise attenuation devices etc. Low emission vehicle technology is becoming more available and proven.	The largely at-grade LRT alignment alongside the 407 ETR, could be implemented with adequate measures to mitigate most natural and social environmental impacts. These could include measures such as avoidance of sensitive natural features and watercourses, bridge widenings minimizing aquatic habitat effects, urban design treatment of new station areas, neighbourhood traffic infiltration prevention, noise attenuation devices etc. Electric propulsion eliminates emissions in the corridor, but requires low or zero emission generating methods.	As the alignment can be largely at-grade alongside the 407 ETR, AGT technology, with a ground level power rail, would require a totally secure ROW. It could be implemented with adequate measures to mitigate most natural and social environmental impacts. These would include measures such as avoiding sensitive natural features and water-courses, bridge widenings minimizing aquatic habitat effects, urban design treatment of new station areas, neighbourhood traffic infiltration prevention, noise attenuation and ROW intrusion detection devices etc. Electric propulsion eliminates emissions in the corridor, but requires low or zero emission generating methods.	Since the alignment can be largely at-grade alongside the 407 ETR, Heavy Rail technology, with a ground level power rail, would require a totally secure ROW. Geometric standards may make implementation mitigating most natural and social environmental impacts difficult. This would require measures such as avoiding, wherever practical, sensitive natural features and water-courses, bridge widenings minimizing aquatic habitat effects, urban design treatment of new station areas, neighbourhood traffic infiltration prevention, noise attenuation and ROW intrusion detection devices etc. Electric propulsion eliminates emissions in the corridor, but requires low or zero emission generating methods.	If geometric standards permit, the largely at-grade alignment alongside the 407 ETR, could be implemented with adequate measures to mitigate most natural and social environmental impacts. These would include measures such as avoiding, wherever practical, sensitive natural features and water-courses, bridge widenings minimizing aquatic habitat effects, urban design treatment of new station areas, neighbourhood traffic infiltration prevention, noise attenuation devices etc. Diesel propelled units will require state-of-the- art low emission engines to be environmentally acceptable
Implementation Considerations • property requirements • capital and operating costs • staging flexibility	BRT options have good planning and staging flexibility and their capital and operating costs are more in line with the size of the potential market for rapid transit service in this corridor. Right-of-way property requirements are marginally greater than those for rail-based systems due to need for runningway shoulders and bypass lanes at stations.	The capital investment and operating cost benefits are more in line with larger initial ridership levels than are projected for rapid transit service in this corridor. Conversion to LRT technology may be justified for longer term demand levels. LRT technology has fairly good planning flexibility and allows a reduced right-of-way width but viable initial operating segments usually exceed 10-12 km.	The proposed development density along the right-of-way does not support east-west trip volumes that would justify the higher capital investment needed for intermediate-high capacity AGT. Although fully grade-separated AGT technology minimizes surface property requirements, the technology does not allow flexibility to stage implementation across the study area without inconvenient transfers along the route..	The high capital investment needed for high capacity, heavy rail technology is not justified by the east-west trip volumes that would be generated by the proposed development density along the ROW. Although the fully grade separated Heavy Rail technology minimizes surface property needs, it does not allow the flexibility to stage implementation across the study area without inconvenient transfers along the route	The moderate capital investment and operating cost benefits are more in line with larger, initial ridership levels than are projected for service in this corridor. Conversion to commuter rail technology may be justified for longer term demand levels. Commuter rail right-of-way property needs are larger than the other rail systems. Also, it has less planning flexibility and does not have the flexibility to stage implementation across the study area without inconvenient transfers along the route.
	PREFERRED TECHNOLOGY	**Protect for LRT**			

objectives was assessed. Elimination of station nodes that did not fully meet the objectives of the 407 Transitway was based on the following considerations:

- A considerable amount of additional travel time would be required to serve these station nodes;
- There would be an excessively high cost associated with developing a grade separated transitway route to these nodes in a non-exclusive ROW situation; and
- There would be associated detrimental environmental and socio-economic effects from developing the transitway route to reach station nodes located outside of the primary Highway 407 Corridor Central Section.

Through the application of the above screening process, the following 11 potential station nodes were identified:

1. Vaughan Metropolitan Centre - Jane Street/Spadina Subway Extension route
2. Keele Street
3. GO Barrie Line corridor
4. Dufferin Street/Centre Street
5. Bathurst Street
6. Richmond Hill Centre/Yonge Street Subway Line extension route/GO Richmond Hill Line
7. Bayview Avenue
8. Leslie Street/Beaver Creek Business Park
9. Woodbine Avenue/Rodick Road/Highway 404/7 Business Park
10. Warden Avenue/Birchmount Road/Markham Centre West
11. Markham Centre/Kennedy Road/GO Stouffville Line

With the development of the 11 potential station nodes listed above, further analysis was undertaken to keep the transitway's primary objective at the forefront of the study approach, along with the use of demand modelling analysis. **Table 5-3** presents the comparison of the above potential station nodes against the project's transportation service and land use objectives.

A fundamental objective of the 407 Transitway is to "offer a faster, safer, reliable and efficient way of moving people". Meeting this objective requires:

- a facility with an alignment that will permit a high operating speed between stations; and,
- an optimum number of stops (stations) located to serve all major transit trip generators, such as regional centres and achieve efficient access to the transitway from all modes of transportation in the corridor, encompassing inter-regional and local transit (rail and bus) and private automobiles through park-and-ride facilities. The resulting station spacing should allow transitway vehicles to achieve the optimum average operating speed (65-70 km/h) including station stops.

Demand modelling analysis of various station location scenarios conducted during the study indicated that a seven station scenario within the central segment of the 407 Transitway would achieve the above objectives. This table further illustrates the justification for the selection of the seven station nodes adopted for the remainder of the Preliminary Design study and used as the basis for evaluation of route options and ultimately, selection of the technically preferred alignment.

Selection of Preferred Station Nodes

Through this comparative evaluation process, the 11 potential station nodes were further reduced as described below.

Each node was assessed in terms of its ability to meet the key transportation and land use objectives for the transitway. **Table 5-3** summarizes the assessment of the eleven potential station nodes. Station nodes that ranked highest in the assessment were short-listed for further development of station facility sites along the alternative transitway routes. The seven short-listed station node locations were:

1. Vaughan Metropolitan Centre and TTC Spadina Line
2. GO Barrie (Concord) (crossing of a major radial transit line)
3. Bathurst Street (to serve Vaughan residential growth area and provide 'park and ride' capacity near the Yonge Station)
4. Richmond Hill-Langstaff Gateway, TTC Yonge Street Subway Station and GO Richmond Hill Line
5. Leslie Street (Beaver Creek Business Park)
6. Woodbine Avenue (to serve Markham Centre West, provide 'park and ride' capacity south of Markham residential growth area and support uniform service distribution along transitway corridor)
7. Markham Centre and GO Stouffville Line.

These preferred station nodes and facility site options within them were then connected with potential route links. **Section 5.4** describes the development of alternative station site and transitway route combinations.

Assessment of Station Site Locations within Nodes

Station sites were initially considered in all four quadrants of each station node. They were then analyzed in terms of the station site generation criteria presented below in **Table 5-4a** and, as a result, quadrants that did not meet those criteria were eliminated from further consideration. As well, as illustrated in **Table 5-4b**, environmental factors criteria were used for the assessment of the station nodes.

Table 5-4a: Station Site Assessment Criteria

Ability to connect with major north-south transportation corridors (i.e. major arterials, GO Transit, TTC Subway lines, 400 series highways, etc.) station location within 200 metres from the major intersections
Accessibility to existing and planned urban centres (i.e. UGC's) station location within 500 metres of an urban centre
Meet minimum facility/functional requirements: – minimum 40 metres width outside of the proposed running way route – minimum 150 metres length – minimum 25,000 m^2 area – delineate area beyond the minimum 25,000 m^2 area that avoids environmental constraints
Avoid environmental constraints, where possible (developed land, hazard land, watercourses, designated natural areas, contaminated sites, etc.)

5.4 Alternative Routes, Alignments & Station Layouts

The purpose of this section is to initially outline the evaluation criteria and process used to arrive at the technically preferred alignment and station alternatives for the 407 Transitway Central Section and describe the alternatives considered through the process. The process comprised several evaluation steps, each progressing to greater levels of analysis and design. Specifically, this section presents the following:

- Evaluation Criteria and Process
  - Routes, Station Sites and Alignment Alternatives
  - Station Layouts
- Evaluation of Alternatives
  - Segment A – From East of Highway 400 to East of Keele Street
  - Segment B – From East of Keele Street to West of Yonge Street
  - Segment C – From West of Yonge Street to West of Bayview Avenue
  - Segment D – From West of Bayview Avenue to East of Leslie Street
  - Segment E – From East of Leslie Street to East of Rodick Road
  - Segment F – From East of Rodick to East of Kennedy

5.4.1 Evaluation Criteria and Process

5.4.1.1 Routes, Station Sites and Alignment Alternatives

As a first step, transitway route alternatives linking the seven short-listed station nodes were developed along the Highway 407 Corridor using the Route Generation Criteria tabulated below:

- Route Generation Criteria (Runningways)
- Ability to connect with a station site;
- Exclusive, grade separated ROW within Highway 407 Corridor
- North side of Highway 407, south side of Highway 407 or one crossing of 407 ETR between station sites;
- Meet minimum geometric design standards:
  - minimum 560 metres radius on running way main lanes
  - minimum 420 metres radius entering and exiting station
  - minimum 300 metres tangent length in the vicinity of stations
  - minimum 100 metres tangent between reverse curves
  - maximum 5% gradient

The routes consisted of 50 metres wide swaths that met the route generation objectives and standards. Station sites were then identified for each station location defined in **Section 5.2**. Typically, routes and station sites were identified on both sides of Highway 407, where feasible. In the second step of the process, alignment alternatives, applying the geometric design standards, were developed for the selected routes within each segment.

Table 5-4b: Preferred Station Nodes – Environmental Objectives and Criteria Considered

Objectives	Criteria	Indicators	Jane Station	GO Barrie (Concord Station)	Bathurst Station	Yonge Station	Leslie Station	Woodbine/Rodick Station	Kennedy Station
A) Minimize adverse effects on the natural environment.	A1) Potential effects on natural heritage features.	A1.1) Number, type and significance of terrestrial and aquatic natural heritage features affected.	**Terrestrial –** None of significance. **Aquatic** – Black Creek and tributary bridged for transitway approaching station	**Terrestrial –** One, young to mid-aged succession, relatively natural vegetation community adjacent to Bartley-Smith Greenway – preservation or compensation required **Aquatic –** West Don River Tributary and West Don River bridged for transitway approaching station.	**Terrestrial –** None of significance. Baker Woods unaffected **Aquatic** - E. Don River tributary bridged for transitway approaching station	**Terrestrial –** None of significance **Aquatic** - Crossing of existing Pomona Mills Creek tributary culvert. – Lowering feasible	**Terrestrial** – none of significance **Aquatic** – German Mills Creek tributary bridged for transitway approaching station	**Terrestrial –** One, north of station. A young to mid-aged succession community with relatively large forest cover and high water table significant for wildlife habitat. - preservation required **Aquatic** – minor Rouge River tributary bridged for transitway approaching station.	**Terrestrial** - None of significance. **Aquatic –** minor Rouge River tributary bridged for transitway approaching station from east.
	A2) Potential effects on geology and hydrogeology.	A2.1) Area of groundwater discharge affected.	15,000 sq. m. – mitigation built into design if necessary	15,000 sq. m. – mitigation built into design if necessary	10,000 sq. m. – mitigation built into design if necessary	30,000 sq. m. - mitigation built into design if necessary	none	None	30,000 sq. m. - mitigation built into design if necessary
		A2.2) Number of sites with issues of potential subsurface environmental concern (i.e. contaminated soils, etc) affected.	None	None	None	None	None	3 - Miller Waste (formerly Direct Waste Systems), Miller Asphalt/Aggregates/Offices/Maintenance Yard, and Town of Markham Works Yard are potential contaminated properties located in the vicinity of the station area.	None
	A3) Potential effects on hydrology.	A3.1) Area of floodplain affected: Transitway approaches Station facilities	Black Creek – 2000 sq. m bridged None	W Don & trib. – 5000 sq. m bridged None	None None	None None	None (Creek floodplain bridged)	None None	None None
B) Minimize adverse effects on the social environment.	B1) Potential effects on socio-economic features.	B1.1) Length of transitway approaches adjacent to residential neighbourhoods and other sensitive land uses.	None	Concord West Community – 200 m Bartley-Smith Greenway – 200m	None	Parkway Belt West – Public Open Space and Buffer Area– 150 m Richmond Hill – Residential – 200 m	Parkway Belt West Plan– Public Open Space and Buffer Area – 600 m	Markham – Hazard Lands – 2 280m	None
		B1.2) Length of the transitway station facilities adjacent to residential neighbourhoods and other sensitive land uses.	None	Concord West Community – 300m W Don River tributary – 150m	None	None	None	None	None
	B2) Potential effects on cultural heritage resources.	B2.1) Number, type, and significance of archaeological sites, built heritage features and cultural landscapes affected.		Adjacent West Don River is considered a Cultural Landscape feature (waterscape). Two built heritage buildings – original appearance considerably altered – evaluation required		C.N.R. Bala Subdivision (GO Richmond Hill Line) as a Cultural Landscape Feature	None	None	None

Figure 5-8 illustrates the selected preferred route from Highway 400 to Kennedy road.

b) Alternative Alignments

Horizontal alignment options were studied in the area between the GO Barrie grade separation and the crossing of Centre Street, as well as in the Bathurst Street area. In the GO Barrie (Concord) station area alignment variations considered aimed to minimize impacts to the West Don River water course and flood plain. **Figure 5-9**, as seen below, illustrates the alignment alternatives through the West Don Lands. In the Bathurst Street area, various alignment options were analyzed with a view to reducing impact to the 407 ETR-Bathurst Street Interchange operation, as well as cost and construction complexity.

Vertical options were analyzed for the required grade separations, in this segment. These comprised the GO Barrie Line, Centre Street, Dufferin Street and Bathurst Street, and are summarized.

GO Barrie Line crossing

Crossing either over or under the GO Barrie line was evaluated. Crossing over would represent less complexity during construction; however, the existing track is on an embankment which would imply elevated station platforms and consequently more inconvenient pedestrian connection to the station ground level facilities, future GO platforms and street level. Also crossing over would have a negative visual impact on the residents west of the GO Line and would require the runningway to be on a costly viaduct east of the station. As a result of this evaluation, an underpass of the GO Barrie Line was selected.

Centre Street crossing

The option of crossing under Centre Street was not adopted due to West Don River flood plain issues west of the crossing. Consequently an alignment crossing over Centre Street was selected.

Dufferin Avenue crossing

Crossing either over or under Dufferin was considered. As with most arterial road crossings of Highway 407, an overpass would imply being two levels (about 11 metres) over existing ground, requiring a long section of costly, elevated runningway, west and east of Dufferin Street. Consequently, an underpass across Dufferin Street was selected.

Bathurst Street crossing

Both overpass and underpass options were evaluated for the Bathurst Street crossing. The key findings of the evaluation in **Table 5-7** below were the following:

- An overpass option would require an elevated station with a climb equivalent to two storeys from the station ground facilities to reach the platforms. An underpass option results in less than half the vertical difference with the station ground facility.
- Passing over Bathurst would also require steeper runningway approach grades on both sides of the station.
- An underpass would necessitate more complex construction staging to cross the 407 ETR ramps and Bathurst Street.
- The visual intrusion and adverse noise impacts are minimized with the underpass option.

Table 5-7 Evaluation of Alternatives for Bathurst Street Grade Separation and Station

OBJECTIVE	GOALS	INDICATORS	Alternative 1 – Transitway under Bathurst Street/Ramps	Alternative 2 – Transitway over Bathurst Street/Ramps
Maximize service quality	Attractiveness of system access for passengers	Length/Height of vertical circulation elements to reach platforms	125m horizontal 6m up + 6m down	125m horizontal 6m up + 7m up
	Effect on transit operations	Transitway grading through grade separation and station	One Grade 3 to 4% Good station approach grades	Three grades 4 to 5% Undesirable, steep station approach grade
Minimize adverse effects on social environment	Minimize traffic disruption during construction	Nature, complexity and duration of temporary traffic accommodation measures required	Underpass construction requires lengthy, temporary diversions of ramps and several lane shifts on Bathurst. Traffic delays will be significant.	Elevated transitway construction will require limited diversion and lane closures. Short-term disruption mainly during girder erection.
	Avoid visual intrusion in sensitive areas	Extent of vistas affected by completed transitway works	At or below grade transitway works will not affect any vistas.	Elevated transitway intrudes on views of Baker Woods from south
	Minimize increase in ambient noise levels	Potential for noise intrusion in adjacent sensitive areas	Increase in ambient noise levels will be minimal and not discernable	Engine noise on climbing grades may intrude during quieter evening periods
Minimize adverse effects on natural environment	Avoid intrusion into ESAs	Extent of intrusion and proximity to ESAs	No intrusion as all works are between highways	No intrusion as all works are between highways
	Minimize effects on watercourse valley lands	Potential for adverse effects and nature of works in valley lands	Approaches and structure for E. Don River crossing are normal height with typical built-in mitigation.	Approaches and structure for E. Don River crossing are above normal height requiring major abutments and embankments with greater potential for adverse effects.
Offer a cost-effective way of moving people	Functional performance at least capital cost	Estimated order-of-magnitude construction and property costs	$85-95 million	$110-120 million
	Long term durability and hence least maintenance costs	Nature of infrastructure maintenance and effect on annual maintenance cost	Underpasses will increase runningway maintenance cost moderately; Station maintenance will be at normal levels.	Overpasses, retained fill and elevated station will increase maintenance costs significantly.
	Efficient, affordable transit operations	Effect of infrastructure configuration on transit operating costs	Transitway profile and station configuration will allow operations at normal cost levels	Minor increase in energy consumption due to steeper transitway profile grades.

5.4.2.4 Segment D – From West of Bayview Avenue to East of Leslie Street

Alternative Routes

In Segment D, four route alternatives, D1 – D4, shown in **Figure 5-15**, were developed and evaluated. Initially, in this process, D3, south of Highway 407, was screened out because the southern route coming from the west in Segment C had already been eliminated.

Alternative D2 was also screened out due to significant disadvantages such as:

- the geometry not allowing transitway operation meeting the desirable design speed standard resulting in travel time penalties;
- a complicated crossing of Highway 407 west of Bayview Avenue crossing;
- proximity to the residential development immediately east of Bayview Avenue;
- the need for removal of a portion of sensitive deciduous forest resulting in a greater adverse affect on the natural environment;
- greater intrusion into the Hydro Corridor.

Alternatives D1 and D4, were carried forward for further detailed analysis and evaluation, in particular, for the determination of the Leslie Station location. This evaluation's key findings are summarized below:

- Both candidate alternatives could incorporate reasonably convenient vehicular access facilities (PPUDO, Park-and-ride, feeder bus transfers) however, in Alternative D4, an access ROW would have to be purchased from an adjacent commercial parking lot remote from a main street to reach a north-side Leslie Station parking area.. Avoiding this access complexity by placing the park-and-ride lot south of Highway 407 with a station on the north (D4) increases the walk distance to transitway platforms for park-and-ride users by 250-300m.
- Although the north-side station location, in Alternative D4, is closer to the centroid of the business park, it remains on the perimeter of the developed mixed-use lands beyond walk-in distance thus still requiring community shuttle bus access from the expanding residential areas to the west. It would also become 300m further from residential areas south of Highway 407 and park-and ride access is more difficult with limited capacity and no ability for expansion due to Highway 407 constraints. Also, significantly more of the northern D4 route is immediately adjacent to existing and future residential areas.
- Over half of the ROW in Alternative D1 is within the previously protected corridor while the D4 alternative would require a new ROW, albeit from ORC land along the north edge of Highway 407.
- Construction costs for Alternative D4 will be almost 50% higher due to the constrained D4 ROW, requiring the transitway to pass over Leslie Street and the station facilities on structure along with a higher cost crossing of the Highway 407/404 interchange further east. Some of this cost premium may be offset by the opportunity cost of D1 station land on the south side.

As a result of the above route evaluation conclusions, Alternative D1 with a south-side station was carried forward. Walk-in access from the business park across the Highway 407 bridge could be enhanced by providing weather protection along the additional 100 metre walking distance over the highway. **Figure 5-16** illustrates the selected preferred route through Segment D.

Alternative Alignments

Between Bayview Avenue and the Highway 407 crossing, two local alignment variations, D1A and D1B were considered, as illustrated in **Figure 5-17**. Alignment D1A has better geometry and a smaller skew angle in the crossing of Highway 407. However, it would have a more significant impact on the future development lands north of Highway 407, mainly due to the need to provide an underpass of the transitway immediately north of the Highway 407 crossing to allow access to the western portion of the lands severed by the transitway. While Alignment D1B avoids severing the lands into two parcels, it will require a more costly, new crossing of German Mills Creek instead of the Highway 7 culvert extension possible with Alignment D1A. Since this higher watercourse crossing cost is offset by avoiding the need for an access bridge under the transitway required in D1A, alignment D1B was carried forward to the vertical alignment analysis.

Vertical alignment alternatives were analysed for the required grade separations at Bayview Avenue and Leslie Street. The results of this analysis are summarized below:

Bayview Avenue Crossing

In the examination of Bayview Avenue, it was concluded the preferred vertical alignment was an underpass for the following reasons: Bayview Avenue is already elevated as it crosses above both Highway 7 and Highway 407 creating an elevation difference that is more favourable to an underpass;

The hydro corridor also passes over the Bayview-Highway 7 and Bayview-Highway 407 intersection restricting the maximum height of a possible structure due to clearance requirements. The hydro clearance requirements do not allow for sufficient clearance of a structure over Bayview Avenue.

Leslie Street Crossing

Alternatives crossing over and under Leslie Street were evaluated. Crossing over Leslie Street represented less complexity during construction. However this would incur a much higher cost for earth works due to the existing elevation difference between Leslie Street and the surrounding ground. Crossing over Leslie would require that the adjacent station be elevated and would consequently be more inconvenient for passenger connection to the station facilities located at ground level; an underpass would result in a slightly depressed station. An overpass alignment results in no conflicts with the tributary located just west of the station; and underpass required extra design and mitigation considerations. Consequently an underpass alignment was considered preferable.

The preferred alignment F3A, shown in green in **Figure 5-25**, meets most of the planning objectives listed above given that the proposed underpass of the GO Line and below-grade station can be integrated with the Markham Centre East road network, including planned new road crossings over the GO Line and area land use plans.

Vertical Alignment alternatives analysis entailed an assessment of the options for the transitway to cross the north-south arterial roads in the segment as well as Highway 407 in transitioning from the south into Markham Centre. The findings of this analysis are outlined below.

Warden Avenue Crossing
Crossing over and under Warden Avenue were considered. As in most road arterial crossings, an overpass would imply being two levels (about 11 metres) over existing ground, representing a long section of costly elevated runningway; additionally impact to Hydro and Markham District Energy would be greater. Consequently it was selected to cross under Warden Avenue.

Birchmount Road Crossing
Crossing over the future Birchmount Road Extension would allow an integrated structure to cross over both, Highway 407 and Birchmount Road, crossing under Birchmount was consequently screened out.

CN Stouffville Line Crossing
The two options discussed above were considered. Although crossing over the track would be less costly and would have less impact during construction, the effects to the developments on either side of the GO track and the much less convenient inter-transit user connection, vertical grade challenges due to the proximity of the station platforms and effects to YMCA, were factors to screened out the option of crossing the CN GO Stouffville Line with an overpass.

Kennedy Avenue Crossing
Crossing over and under Kennedy Road were assessed. Kennedy Road as most north- south arterials cross Highway 407 on an overpass, consequently a transitway overpass like in the case of the other arterials would be very high and would imply a lengthy and costly viaduct on either side of the crossing with a significant visual effect. Crossing Kennedy Road with an underpass minimizes the surface effects to the lands east of Kennedy Road and is allows a favourable vertical alignment on the approach to the station.

c) Alternative Station Layouts

The proximity of the Kennedy Station to the GO Stouffville Line grade separated crossing dictates potential station locations and configurations based on the alignment selected through the Markham Centre lands. For the preferred alignment F3A, **(Figure 5-25)**, passing under the GO Line, the transitway station must be located in a depressed section immediately east of the GO Line right-of-way since a station on the surface would only be possible at the top of a ramped section east of the underpass. This would place the transitway station over 300 metres east of the existing GO Station, a separation considered unacceptable for convenient transfer between GO Rail and 407 Transitway services.

Accepting the depressed configuration required consideration of two potential alternative layouts for feeder bus platforms and ancillary facilities such as PPUDO and bicycle or walk-in access. Both layouts assumed that Viva BRT service and future LRT would link to the station from the provisions made in existing Enterprise Boulevard underpass to the north of the transitway station. The first alternative analyzed comprised a below-grade (depressed) bus terminal with an island configuration accommodating both Viva and local YRT services. The station concourse, PPUDO and park-and-ride would be developed on the surface in a layout integrated with the existing GO station and proposed GO parking structure along the east side of the existing tracks. Vertical circulation elements (stairs, elevators) would link the surface facilities to the transitway and bus platforms below and buses would access the depressed terminal via a ramp in the YMCA Boulevard median proposed by York Region in the approved Viva EA.

A second alternative assessed focussed on reducing the extent of below-grade works by splitting the bus terminal facilities between the depressed and surface levels. In this alternative, Viva bus platforms remain at the lower level to achieve convenient access from the Enterprise Blvd. underpass and enable Viva platforms to be adjacent to the transitway platform allowing across-the- platform passenger transfer in at least one direction. The remaining local bus services, provided by YRT, would be arranged on the surface in a configuration compatible with the proposed ancillary surface facilities and allowing direct vertical transfer to Viva and transitway services below.
An evaluation of the two alternatives led to the latter, split terminal alternative being selected to gain the advantages of less extensive and lower cost sub-surface works and more convenient access to the GO Rail station for local bus services. Also, stacking the two parts of the bus terminal results in shorter transfer distances between bays (directly vertical) and allows location of some layover bays on the surface. The layout and configuration of the split terminal alternative is shown in **Plates 45 and 46** of Section 6.

5.5 Operation and Maintenance Facility Alternatives

An analysis of the potential operations and maintenance facility requirements was conducted for BRT and LRT operations on the 407 Transitway from Hamilton to Highway 35/115 for the year 2031. The purpose was to establish a demand-response operating scenario(s), the resulting vehicle fleet requirements and the property to be protected for the distribution, capacity and desirable location and size of facilities required to maintain the fleet.

5.5.1 BRT Operations

The analysis for BRT operations and maintenance facility requirement was based on the ridership demand forecasts (Planning Stage), assumed route network concepts, and service level projections along the 407 Transitway (from Hamilton to Highway 35/115). The projections of vehicle requirements were based on the route network, estimated route lengths, average operating speeds, running times and service frequencies. The 407 Transitway in this analysis was divided into three sections:

- West – Hamilton to Square One
- Central – Square One to Scarborough Centre
- East – Scarborough Centre to Oshawa Centre and beyond to Highways 35/115

head distances for service start-up and provide off-peak storage during the day. Any significant extension of LRT operation beyond the initial 47 kilometres will require additional satellite storage capability east and west of the Central facility. For an extension to the west, the land protected in the Mississauga Road or Bronte area could fulfil this satellite function, initially at the end of an extension while in the east, the land protected by MTO at the Ajax/Whitby boundary in Durham is similarly positioned to serve both an initial eastward extension from Markham Centre to Whitby and, potentially, an ultimate eastward extension of rail service to the Highway 35/115 corridor.

A conceptual layout of a typical maintenance and storage complex was developed to assess the capacity of MTO's protected land by recognizing the site limits imposed by the Highway 407 ROW and existing Black Creek tributary flood plains. **Figures 5-26 (a)** and **(b)** presents the conceptual layout of a typical maintenance and storage complex.

5.5.3 Description of Site Alternatives

In the 1998 Corridor Protection Study, the MTO identified suitable sites for Operations and Maintenance Facilities along the 407 Transitway Corridor. The largest of these sites, envisioned as the location for a Central Maintenance Facility, is located within this Central Section Study Area in the southeast quadrant of the Highway 400/Highway 407 interchange **(Site 'A')**. This site, approximately 20ha in area, was deemed to be adequate to accommodate both BRT and LRT fleet maintenance and storage requirements simultaneously, a situation that would arise if the Central Section had been converted to LRT while BRT was still operating on the western and eastern sections as well as the 400-Series highways.

The scope of this Preliminary Design Study required an assessment of the suitability of the Highway 400 protected site and any alternative locations for a major, Central Maintenance Facility along the Central Section or near the section limits. This investigation of alternatives has confirmed that the protected site would be able to accommodate both facilities in a reasonable configuration to store and service the anticipated BRT and LRT fleet sizes described above.

In terms of alternative sites, a single site, accommodating the fleets of both technologies, is not available on publicly-owned lands within the Central Section. The only other option considered was separate sites for each technology. This approach yielded a second alternative **(Site 'B')** comprising the Keele Street Station site protected in the Corridor Protection Study and no longer required, combined with purchase of an undeveloped privately-owned site in Markham, east of Woodbine Avenue. The Keele Street site would accommodate a BRT maintenance and storage facility of similar size and configuration as that developed for the protected Highway 400 site. However, the privately-owned land between Woodbine Avenue and Rodick Road south of Highway 407 is a constrained, long and narrow site which would require a light rail vehicle building and storage yard configured specifically to match the site limits. Access from the transitway ROW to the site is also constrained by the Woodbine/Rodick Station location and the alignment vertical curvature.

A third alternative, **Site 'C'** comprises the Keele Street protected land developed as a BRT facility combined with the publicly-owned land in the southwest quadrant of the Highway 407 and Highway 404 interchange. This latter site could be configured as a LRT maintenance and storage facility to fit the shape of the lands on the south side of the transitway ROW as it crosses the protected lands.

The location and extent of the above sites are shown in the exhibits of the runningway alternatives in each of the three segments in which they occur (Segments A.B and E).

5.5.4 Evaluation of Site Alternatives

Table 5-10 summaries the evaluation of the three site alternatives in terms of nine criteria which reflect the key considerations in site selection and highlight important differences as well as the advantages and disadvantages of each alternative. Site 'B' requires acquisition of privately-owned land south of Highway 407 between Woodbine Avenues and Rodick Road, the only surplus Parkway Belt land in the Central Section suitable for a functional LRT facility. Key conclusions which can be drawn from the evaluation are summarized below:

Site 'A' performs well in terms of all site selection criteria offering the benefits of consolidating facilities for both technologies at a single, central location along the corridor and reasonable layout flexibility with capacity for expansion. Being publicly-owned, this site minimizes out-of-pocket land costs for both modes by avoiding the need to acquire and protect private land for future LRT vehicle maintenance and storage. However, the adoption of Site 'A' as the preferred site reduces the opportunity for other, earlier uses on land newly served by the 407 Subway Station on the Spadina Line extension.

Removing the protection of Site 'A' for both facilities will require acceptance of separate BRT and LRT facilities in the future as neither Site 'B' nor 'C' will accommodate both technologies which are likely to be required simultaneously to serve different sectors of the overall corridor. Adopting this approach will allow a reasonably good BRT configuration on the protected Keele Street Station lands but will require some compromises in layout, operational flexibility and long term capacity for LRT on the Woodbine/Rodick private lands of Site 'B'. Also, immediate or future purchase of these privately-owned lands will add to the ultimate project cost.

While Site 'C', with LRT facilities at Highway 404, removes some of these disadvantages, this location is incompatible with existing surrounding land uses and will remove any opportunity for future redevelopment of the prime lands immediately south of Highway 407 opposite the Commerce Valley Business Park to the north. This site is also being protected for a future Highway 404/407 transitway interface.

Considering the criteria overall, Site 'A' is the preferred alternative given the absence of either an alternative single site or combination of separate BRT and LRT sites that meets all criteria.

Table 5-10 Evaluation of Operation and Maintenance Site Alternatives

Selection Criteria	Site 'A' Protected land between Highway 400 and Jane Street for both BRT and LRT Operation and Maintenance Facilities	Site 'B' Protected land for Keele Street Station E. of Keele Street for BRT and private land between Woodbine and Rodick for LRT	Site 'C' Protected land for Keele St. Station E. of Keele Street for BRT and publicly-owned land S. of Highway 407 & W. of Highway 404 in Markham for LRT
Proximity to transitway ROW and 407 Central Section/400 series highway operations centroid	Site is immediately adjacent to transit-way with good access and reasonable proximity to network centroid (close to 400 and 407 highways).	Both sites are immediately adjacent to transitway with good BRT access but constrained LRT access. Site proximity to network centroid is good for BRT and reasonable for future LRT	Both sites are immediately adjacent to transitway with good BRT access and reasonable LRT access. Site proximity to network centroid is good for BRT (close to 404) and reasonable for future LRT
Site size and configuration – (parcel up to 18 hectares required)	Site size and shape offers good flexibility to optimize layout and configuration of facilities	BRT site size/shape allows reasonable flexibility to optimize configuration but long narrow LRT site limits layout flexibility.	Size/shape of both BRT and LRT sites allows reasonable flexibility to optimize configuration but narrow east side of LRT site limits layout flexibility.
Site ownership and acquisition cost	Entire site is publicly-owned and protected by MTO hence project land cost will be minimal. Placing O&M facilities on site A reduces opportunities for other uses	BRT site publicly-owned but LRT site with a single private owner would cost project an estimated $25million. BRT facilities on site B reduce opportunity for other uses.	Both BRT and LRT sites are publicly-owned and protected by MTO hence project land cost will be minimal. O&M facilities on site remove opportunities for other uses being protected at this node.
Site topography (grading and drainage requirements)	Moderate grading and drainage works required.	Moderate grading and drainage works required	Grading and drainage works required on BRT site are moderate but more significant on LRT site.
Compatibility with surrounding neighbourhood, (zoning, land uses & security)	Good – highway, transitway and hydro buffers to neighbouring uses including future commercial TOD integrated with planned Spadina Subway Station	Good at both sites which are surrounded by light industrial uses.	Light industrial uses around BRT site are compatible but existing education/future TOD uses are less compatible. Hydro ROW buffers adjacent residential.
Site access from transitway and road network and surrounding traffic conditions	Good connections possible for both road and rail vehicles. High traffic volume likely on Jane Street in future.	Good connections possible for road vehicles at BRT site and road and rail vehicles at LRT site. High Keele Street and Woodbine Ave. traffic volume in future.	Good connections possible for road vehicles at BRT site and road and rail vehicles at LRT site. Single access to LRT site from Leslie Street could be congested.
Site servicing and utility relocation/ interface requirements	Potentially no difficulty servicing site and no major utility conflicts.	Potentially no difficulty servicing BRT site. LRT storage parallel to Hydro lines may be problematic.	Potentially no difficulty servicing BRT site. LRT storage parallel to Hydro lines may be problematic.
Flexibility for expansion and protection of LRV maintenance and storage capability	Site size is adequate for facilities to serve both technologies simultaneously.	BRT site size is adequate for long term needs but LRT site has limited capacity for expansion to meet long term needs which would be reasonable if satellite storage sites E and W are protected.	BRT site size is adequate for long term needs but limited capacity for expansion on LRT site for long term needs would be reasonable if satellite storage sites E and W are protected.
Environmental conditions and constraints	Black Creek tributary constrains layout flexibility. Stormwater management facilities required. No noise sensitivity	BRT site has no environmental constraints but LRT site requires removal of vegetation and possibly remediation of soil contamination.	Both BRT and LRT sites have no environmental constraints. Minor noise and visual sensitivity.

5.5.5 Preferred Site Layout Alternatives

Selection of the protected site at Highway 400 requires an assessment of layout alternatives to optimize the distribution of the site between BRT and LRT facilities and maximize the opportunity for transit oriented development on remaining land. Constraints influencing the location of the individual facilities and their configuration include the Black Creek tributary splitting the site in a north-south direction, the transitway alignment crossing east to west and the space required for Spadina Subway Station facilities on the east side along Jane Street.

Two alternatives, shown in **Figures 5-26(a)** and **(b)** were developed and compared to establish the optimum layout and most efficient use of the overall site. Alternative A, **Figure 5-26(a)**, retains the transitway alignment in the protected ROW around the northern and western perimeter of the site and locates the BRT and LRT facilities to the south on either side of the Black Creek tributary. In Alternative B, **Figure 5-26(b)**, the transitway alignment is re-aligned southward, improving the geometry and Highway 400 crossing length, and at the same time allowing space to accommodate the BRT facility north of the transitway alignment. Placing the future LRT facility in the extreme northwest corner, west of the tributary, frees up lands adjacent to, and over the subway parking for TOD on the portion of the site closest to the subway station entrance.

The conclusion from the comparison of the alternatives is that the southern alignment, Alternative B with BRT & LRT facilities to the north is preferred in that it:

- consolidates both BRT and LRT facilities on the north side of the transitway alignment more remote from the subway station;
- leaves approximately 2 hectares of surplus land adjacent to and west of, the subway parking to allow TOD with the opportunity for future integration of the subway parking and surface terminal facilities into the development;
- reduces the length of transitway across the Highway 400 ROW and improves the geometry and average speed through the site;
- preserves the flood plain and space for SWM ponds along the Black Creek tributary.

Figure 5-26(a): Conceptual Layout of Typical Maintenance and Storage Complex Alternative A

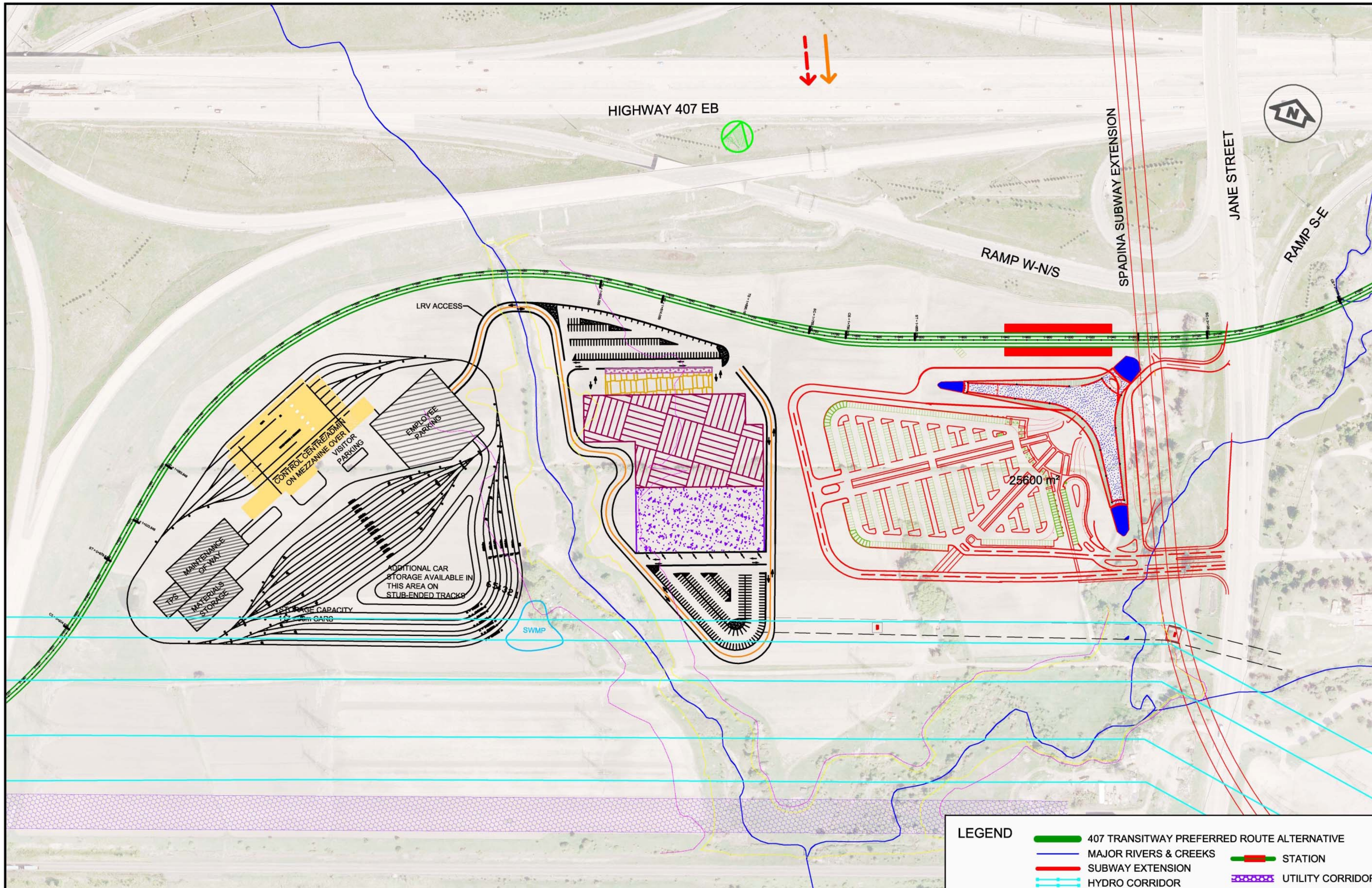


Figure 5-26(b): Conceptual Layout of Typical Maintenance and Storage Complex Alternative B