5. Preliminary Screening

5.1 Evaluation Criteria

In comparing various alternatives for replacement and expansion of Scarborough RT service, a variety of factors will eventually influence the recommendations that emerge from the study. These include:

1. Capacity
   - Realistic potential
   - Timeliness in relation to needs
2. Level of service
   - Average speed
   - Station/stop spacing
   - Transfers
   - Reliability
   - Accessibility
   - Comfort
3. Demand
   - Projected ridership
   - Estimates of new transit riders
   - Changes in vehicle km of travel by automobile
4. Connectivity and coverage
5. Consistency with land use objectives:
   - Support for growth of the Scarborough City Centre
   - Support for other Official Plan intensification sites
6. Costs
   - Capital investment
   - Operating expenses
7. Cost effectiveness
8. Affordability and timing
9. Disruption of service
   - Interim/temporary requirements
   - Loss of ridership
10. Flexibility
    - Capacity expansion
    - Route extensions
    - Network integration
11. Integration with other transit systems
12. Traffic and community impacts.

Clearly, many of these factors are inter-related. Design capacity, for example, which is often well below maximum capacity, is usually dictated by needs based on ridership forecasts. Ridership, in turn, is influenced by various measures of level of service, connectivity and coverage provided by the system, and integration with other services. In

some cases, ridership is simply limited by available capacity, as is the case with the current Scarborough RT.
Cost factors are similarly inter-related. High capital costs of some alternatives can often (although, not always) be offset against lower (life cycle) operating and maintenance costs per passenger. And the most cost effective alternatives may be the least affordable.

Three additional points should be noted.

First, some criteria can be assessed in quantitative terms (e.g. costs, capacity, and ridership) whereas others that are more qualitative and judgemental (e.g. consistency with land use objectives) cannot.

Second, quantitative criteria are not necessarily more important, or even as important, as qualitative criteria. Justification for the existing Scarborough RT, for example, was based on qualitative judgements related to desirable land use objectives for new growth "nodes" and anti-expressway sentiments that dominated the decision-making scene of the day. Ridership forecasts played only a minor role.

Finally, many of the impacts associated with these criteria are speculative, the most notable of which concern the effect of a specific choice of transit technology (BRT, LRT, RT, or subway) on travel behaviour and ridership. Assumptions related to such factors form the basis of all forecasting methods and can have a very large effect on results.

5.2 Criteria for Preliminary Screening

For purposes of developing a shorter list of Scarborough RT alternatives for more detailed evaluation, only two of the criteria noted above are used as the basis of preliminary screening, namely capacity and level of service.

Support for the land use objectives of the City's Official Plan, in particular, is clearly an important criterion for the final evaluation of alternatives. However, at this point, the purpose of preliminary screening is to rule out alternatives that fail to provide either adequate capacity or level of service.

5.3 Capacity

As noted in the introduction to this report, capacity of the current Scarborough RT service (about 4,000 pphpd) is too low in relation to potential ridership. The latest ridership forecasts for 2021, treated in Chapter 4, as well as previous TTC projections suggest a target capacity requirement for 2021 of about 6,500 pphpd. For, 2031 about 8,000 pphpd appears to be reasonable. Thus, the intention is to eliminate from more detailed consideration any alternative that cannot realistically provide such capacity. Capacity is essentially the first "screen".

Actual capacity is the simple product of service frequency multiplied by the number of passengers per vehicle (in the case of buses) and the number of vehicles per train (in the case of multiple unit operation).

Maximum capacity for any particular technology is dictated by:

- Vehicle size,
- Train size,
- Maximum maintainable frequency, and
- The size of the vehicle fleet.

At present, for example, the capacity of the Scarborough RT is dictated by the number of vehicles available. With a larger vehicle fleet, all other things being equal (e.g. train length), Scarborough RT capacity could be expanded by increasing train frequency from the present 17 trains per hour to 24 trains per hour without construction of any consequence (other than expanded maintenance and storage yards).

The number of vehicles required to provide any stated capacity is determined by round trip time ("cycle" time), as well as an allowance for spares (usually, about 10 to 20 percent).

Cycle time is influenced by a number of factors including:

- Maximum vehicle speed,
- Vehicle acceleration and deceleration (braking) characteristics,
- Station spacing,
- Passenger loading and unloading times at stations and terminals (dwell time), and
- Turnaround time (the time required at terminals to reverse vehicle direction).

The maximum frequency of service depends largely on the type of vehicle or train control system used. The primary function of train control and signalling is to ensure that a train remains sufficiently far behind the preceding train to avoid a collision. It is a matter of safe operation.

On Toronto's subways, a fixed block clearing system is used to control frequency which, in theory, is limited to about 40 trains per hour. Toronto's subways now operate with maximum frequencies of about 28 trains per hour on a sustained basis, largely because the time needed to turn trains back at subway terminals is a little more than two minutes and because overcrowding at the Bloor station often leads to very long station dwell times.

The Scarborough RT uses a moving block (SELTRAC) train control system which permits higher frequencies. With sufficient vehicles, for example, the Scarborough RT is capable of safely handling as many as 60 trains per hour on individual segments of the route. However, as in the case of subways, maximum practical frequency is dictated by the turnaround operation at terminals.

Today, 17 trains per hour are operated on the Scarborough RT. With sufficient vehicles, this frequency could be increased to 24 trains per hour. However, for both the RT and LRT technologies, achieving higher frequencies would require reconfiguration and reconstruction of both the Kennedy and McCowan terminals to permit faster turnaround. (If the route is extended to Malvern, the restrictions at McCowan are eliminated, but a new terminal at Sheppard and Markham would have to be designed for shorter turnaround times.)

In the case of BRT, maximum frequencies are dictated by operator behaviour. Signalling is rarely used to control the flow of vehicles on BRT. Again, maximum frequency depends upon dwell times at stations and turnaround times at terminals. However, depending upon how intermediate stations are designed, every bus need not stop at every station. Thus frequencies of between 60 and 90 buses per hour are theoretically possible provided major new bus terminals are constructed at the Kennedy and the Scarborough Centre stations and passing lanes are provided at intermediate stations. It should also be noted that use of the current right-of-way for BRT is more labour-intensive than any of the multiple unit alternatives.

Various forms of BRT elsewhere (Ottawa and Curitiba, Brazil, for example) actually achieve considerably higher frequency of service. Ottawa's "busway" system (examples of which are shown in Figure 5.1) reaches service levels of between 190 and 200 buses per hour, levels that are also achieved on dedicated lanes within downtown Ottawa (but with much lower average speeds).

Ottawa's BRT handles about 10,000 pphpd. However, Ottawa's facilities are much more extensive than any reserved lane application in the City of Toronto. They also do not focus on a single terminal. In addition, within the downtown area, reserved bus lanes are strictly enforced.

For surface operation where buses or streetcars incur delays due to other traffic and traffic signals, possible frequencies on a reliable basis are, of course, much lower. Probably about 40 buses or 30 streetcars per hour is optimistic for exclusive lanes on major arterials, the type of service now operated on Spadina Avenue and proposed for the improved St. Clair streetcar service.

Figure 5.2 compares capacities for the Scarborough RT corridor applications treated in the preceding chapter in relation to the estimated design capacity of about 8,000 pphpd. "Existing" capacity assumes the current maximum frequency of service (17 trains per hour).

Although the cost and service disruption implications differ for various RT vehicles, the same capacities can be achieved. Similarly, although alternate subway routes can be considered, there are no differences in capacity. For on-street LRT, two-car trains are feasible, thus providing higher capacity than BRT.

These comparisons show that the existing Scarborough RT, surface BRT on surrounding streets, and conversion of the current Scarborough RT guideway to BRT all fail to meet capacity requirements.

Figure 5.1 – Ottawa BRT Stations

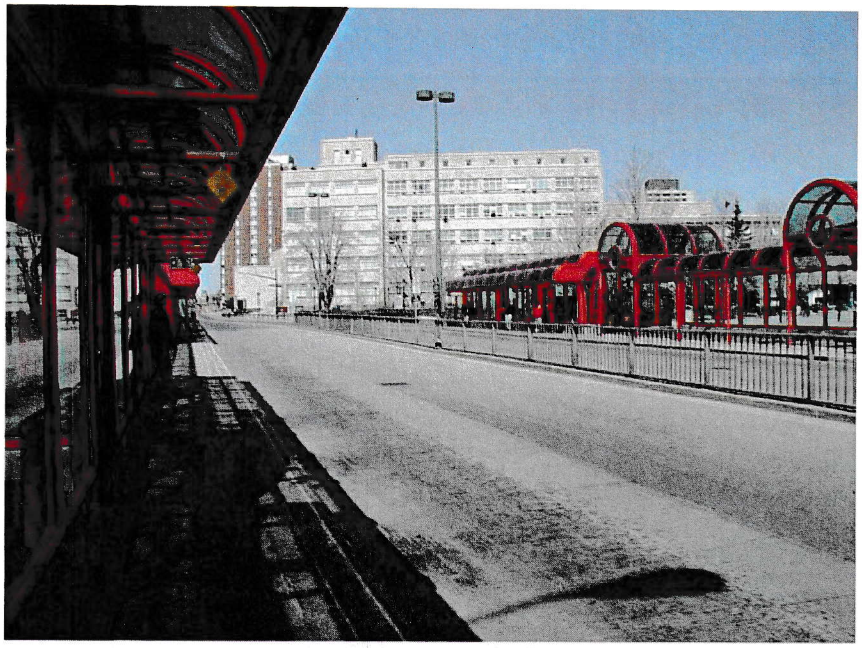
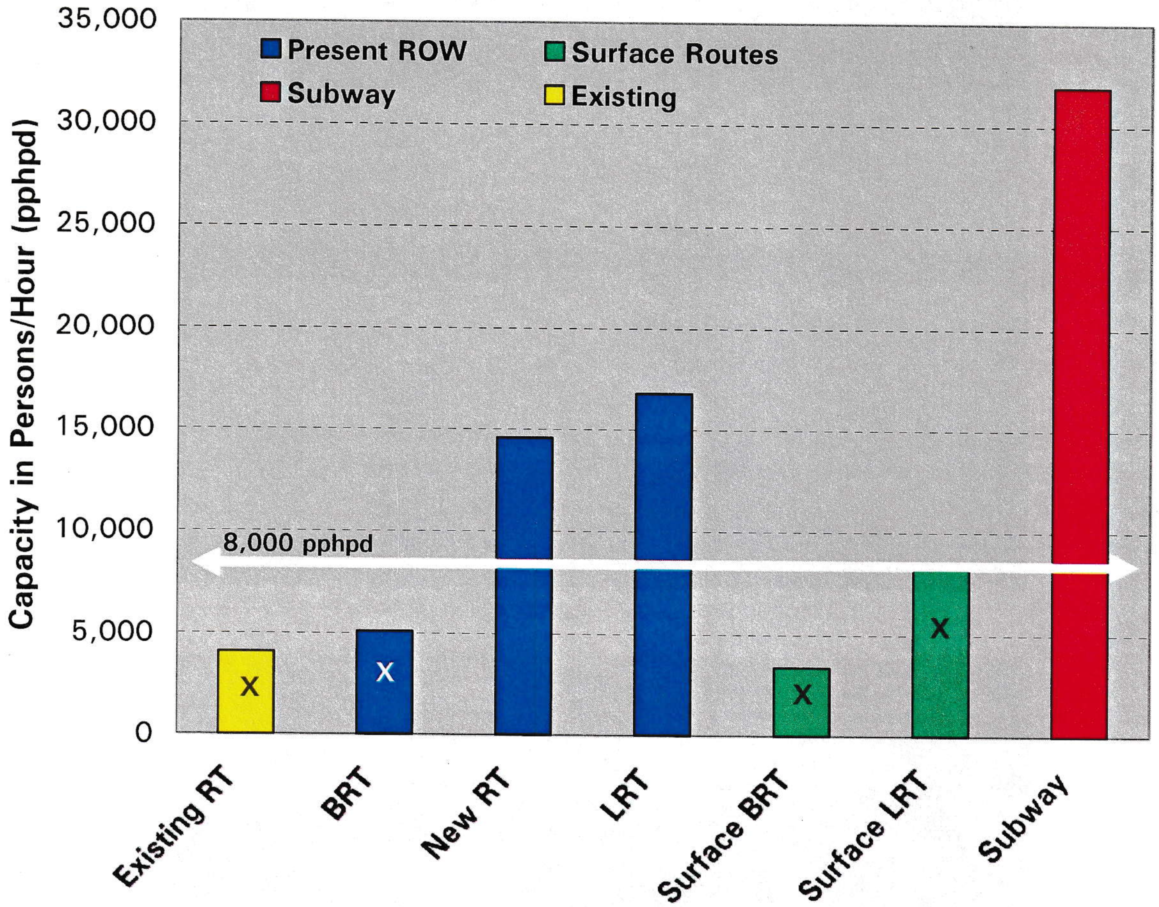


Figure 5.2 – Potential Capacities for Scarborough RT Alternatives



5.4 Level of Service

Level of service has many dimensions, including frequency, reliability, convenience, travel time, comfort, ease of boarding and alighting, transfers, and ride quality. Some of these dimensions conflict with one another. Convenience, for example, is affected by stop spacing. However, with more convenient access, average speeds are lower than with greater station spacing.

For purposes of preliminary screening, however, the operative word in Scarborough RT is "rapid". Thus, the second "screen" is that the alternative must be at least as rapid (and reliable) as the current Scarborough RT. That screen, more or less, rules out any serious consideration of surface BRT or LRT on surrounding streets as an alternative to the level of service now provided by the Scarborough RT.

5.5 Summary of Screening Based on Preliminary Criteria

It appears that the existing RT service, BRT on surrounding streets, and conversion of the Scarborough RT to BRT can reasonably be eliminated from more detailed consideration on the grounds of capacity limitations. LRT on surrounding surface routes can also be ruled out from the standpoint of level of service.

This comparison leaves three main alternatives for more detailed analysis, namely:

- The acquisition of new Mark IIA or Mark II current technology vehicles with appropriate infrastructure modifications,
- Conversion of the Scarborough RT guideway to LRT, and
- Replacement of the current service by an extension of the Bloor-Danforth subway on a new alignment.

Finally, it should be noted that this preliminary screening applies to alternatives for replacing and expanding service on the existing Scarborough RT route between the Kennedy and McCowan stations. Consideration of the proposed extension to Malvern (Markham Road and Sheppard Avenue) would likely involve the same technology as selected for the existing Scarborough RT corridor. However, in the event a subway solution is selected, BRT may be the most relevant extension even though it has been eliminated for the existing Scarborough RT itself.

6. Cost Estimates

6.1 Cost Overview

Cost estimates are comprised of the costs associated with:

1. Construction and re-construction of physical structures including:
    - Elevated guideways,
    - Bridges and tunnels,
    - Intermediate stations,
    - Terminal stations,
    - Buildings, and
    - Vehicle storage areas.

2. Fixed plant comprised of:
    - Track and crossovers,
    - Electrification (3rd rail or overhead wire) and sub-stations,
    - Signals,
    - Station finish and equipment, and
    - Vehicle maintenance equipment.

3. Vehicles (including spare trains)

4. Operation and Maintenance

The first three involve capital investment and are treated as fixed costs over the effective service life of the facility (generally, 25 to 30 years). Operating and maintenance costs vary year by year depending upon the level of service provided in terms of capacity and frequency of service.

For all four components, the choice of vehicle is undoubtedly the major driving force inasmuch as:

- infrastructure and fixed plant investment is dictated by vehicle specifications, train lengths, and the frequency of service required to provide the design capacity (based on ridership forecasts), and
- the number of vehicles to be procured depends upon the design capacity of individual vehicles.

Costs are presented only for the three technology alternatives derived from the preliminary screening process. For RT and LRT technologies on the existing route, a one-way design capacity of about 8,000 passengers per hour is used for capital estimates, a capacity that is likely to handle anticipated ridership well beyond 2031.

For all three options, capital cost estimates for both construction and fixed plant were developed by the Engineering and Construction Branch of the TTC on the basis of:

- revisions and updates of previous work to reflect 2006 conditions,
- new estimates for special work required to convert the existing guideway and right-of-way to accommodate alternative vehicles, train lengths, and minimum headway (the time between successive trains) or frequency, and
- an approximate new alignment for a Scarborough Subway between Kennedy Station and Scarborough Centre.

Key features of the capital cost estimates for each alternative are summarized below.

6.2 Expanded RT Capital Costs

Three main factors influence the costs of construction and fixed plant required to replace existing cars and expand the total fleet of vehicles to provide adequate design capacity.

The first concerns the choice of vehicle. Two vehicles have been considered, namely, one that is similar to the latest vehicles acquired for the Vancouver SkyTrain (denoted as Mark II) and a shorter version (referred to as Mark IIA) that dimensionally, is similar to the existing Mark I Scarborough RT vehicles. Vehicle choice affects both route and yard modifications. As indicated in the schematic diagram of Figure 6.1, for example, the elevated structure known as the "Kennedy curve" (presently a 26 m radius curve) would require reconstruction to accommodate minimum turning radius requirements (about 35 m) of the longer, Mark II vehicles.

Both the Mark II and IIA vehicles are slightly wider than the existing Mark I vehicles. As a result, there *may* be a need to provide for widening of the safety walkway along side the existing track and to make track modifications within the Ellesmere tunnel.

It should be noted that Vancouver's SkyTrain experience indicates that both types of vehicle can be operated on the same route during the transition from the old fleet to the new, expanded fleet, thus allowing for capacity increases before the full fleet of new replacement vehicles is acquired.

The second factor relates to maximum train length which affects modifications to existing stations and terminals, including platform lengthening, as well as modifications to storage yards, maintenance facilities, and the train control system. Existing station platforms are adequate for 4-car Mark IIA trains or 3-car Mark II trains. Using longer and/or more frequent trains, of course, leads to a larger fleet of vehicles and associated increases in storage facilities (yards).

Finally, the existing terminal at Kennedy Station is another important consideration. Originally constructed as an LRT terminal with a turnaround loop, variations in terminal modifications that range from lengthening the existing single track terminal to relocation and construction of an entirely new, central platform, double track terminal affect costs of construction, possible train frequency, and ease of transfer from the passenger's perspective, as well as the need for reconstruction of the Kennedy curve. These options are shown schematically in Figure 6.2.

Figure 6.1 – The Existing RT Route Alignment

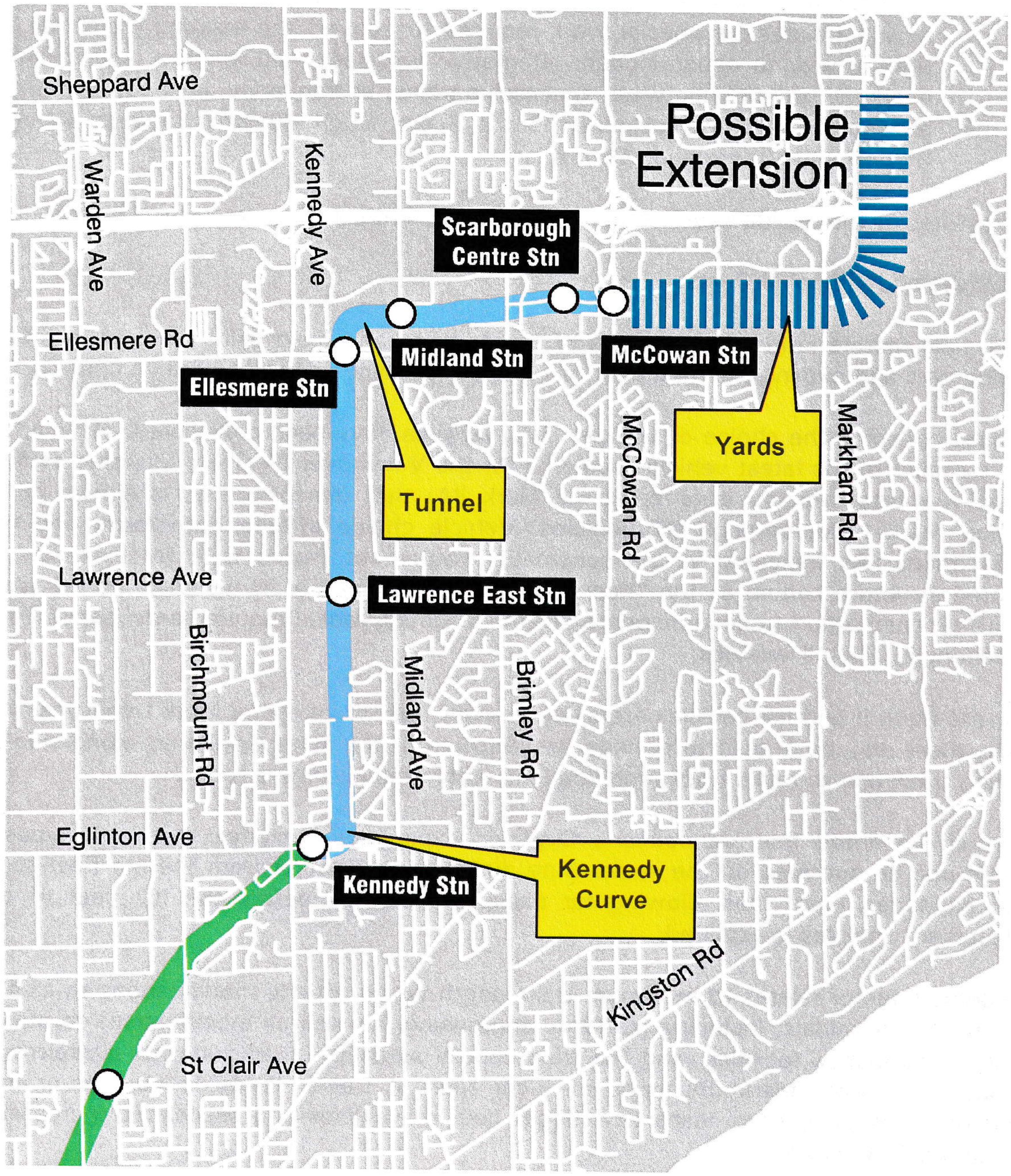
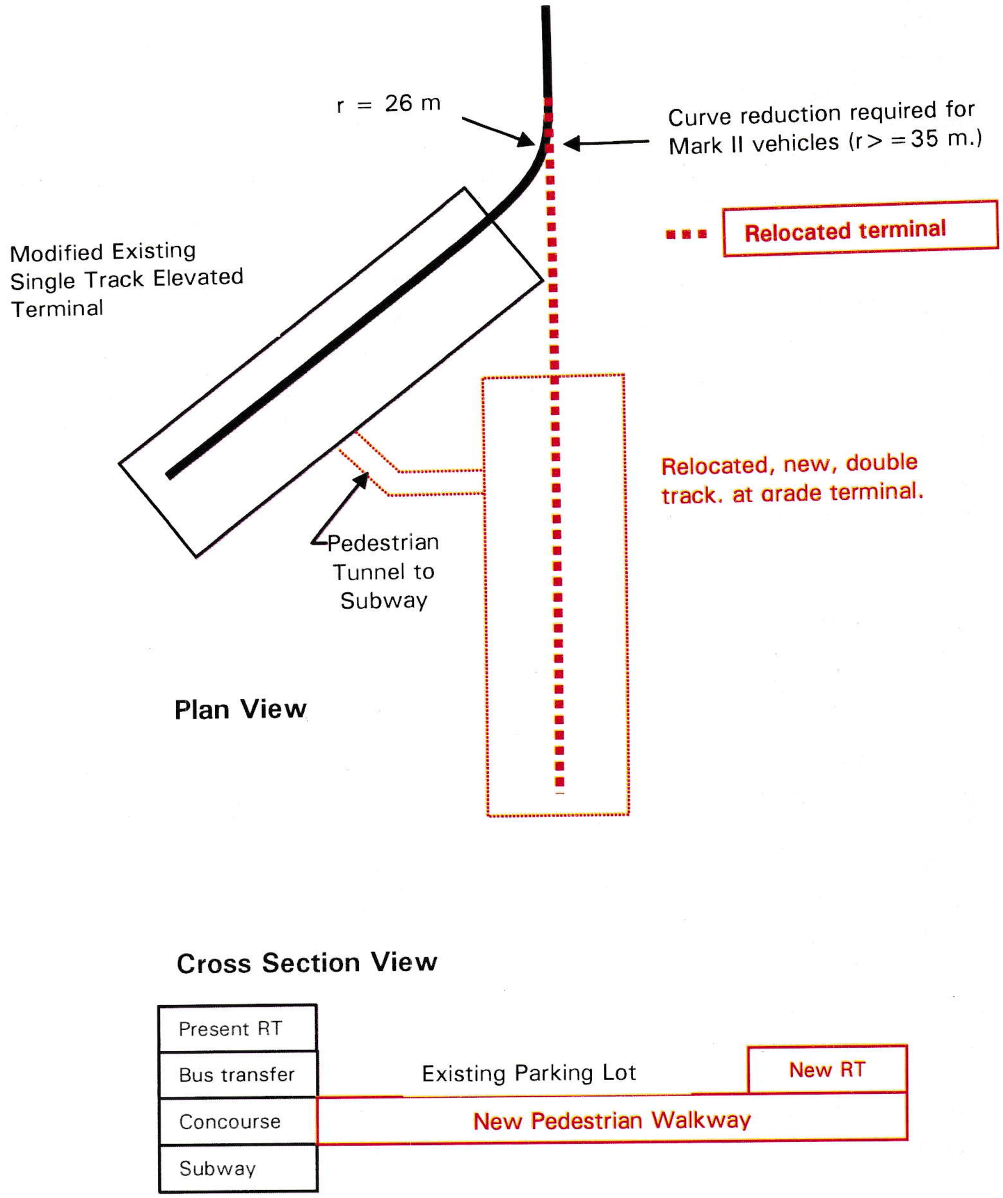


Figure 6.2 – Schematic Diagram of Kennedy Station Alternatives



Relocation of the Kennedy Station to provide a double track, centre platform terminal also offers potential for improving the transfer between the subway and the RT by eliminating at least one (if the new terminal is constructed on the surface) or two levels (if the new terminal is constructed below grade and connects directly with the Kennedy Station platform of the Bloor-Danforth subway). The latter option requires study and analysis that is beyond the scope of this study.

To summarize construction requirements,

- The combination of Mark II cars and the existing, lengthened Kennedy Station, requires reducing the curvature of the Kennedy curve from 26m to 35m,
- With a relocated Kennedy Station, the need to reduce curvature is eliminated for Mark II vehicles,
- Both the Mark II and Mark IIA cars may require widening of the safety walkway used by maintenance crews and changes to track alignment within Ellesmere tunnel,
- Operating more than four Mark IIA vehicles or more than three Mark II vehicles requires lengthening platforms at five of the six existing stations,
- The need for reconfiguring and expanding storage yards, as well as modification of major vehicle maintenance facilities, increases with frequency of service or the operation of longer trains and, correspondingly, increases in the size of the vehicle fleet, and
- Regardless of the vehicle selected, an allowance is included for improved sound barriers at various locations along the route (also applicable to LRT options).

These features are incorporated in the capital cost estimates summarized in Table 6.1. For a design capacity of about 8,000 pphpd in 2031, total capital investment including vehicles is shown for two cases, one using the rebuilt, existing Kennedy Station, the other, based on a new relocated Kennedy Station.

Using infrastructure costs for the estimated 2031 design capacity appears to be reasonable from the standpoint of providing long term flexibility for capacity increases, one of the weaknesses of the existing Scarborough RT facility. By contrast, procurement of vehicles can likely be staged more easily on the basis of required capacity. Should the RT technology be selected for implementation, of course, optimization of the timing of construction and vehicle procurement would be treated in a more detailed analysis.

Table 6.1 shows that in each case, the selection of Mark II cars results in the lowest total construction and vehicle capital investment. Since Mark II cars would also provide additional benefits associated with newer technology, the Mark II vehicle option has been carried forward into the final evaluation. Note also that the combination of Mark II vehicles and a new, relocated Kennedy Station involves the least disruption to service (about eight months).

Table 6.1 – Scarborough RT Capital Cost Estimates for 2031 Design Capacity

Item	Units	Existing RT Route			
		Mark IIA Cars		Mark II Cars	
Cars per Train	#	4	6	3	4
Design Load per Car	passengers	55	55	78	78
Route Length	km	7.2	7.2	7.2	7.2
Vehicle Length	metres	12.3	12.3	16.7	16.7
Train Length	metres	49.1	73.7	50.1	66.8
Stations & Terminals	#	6	6	6	6
Vehicle Unit Cost	$M	4.1	4.1	4.1	4.1
Cycle Time	minutes	21	21	21	21
Modified Existing Kennedy Terminal					
Service Disruption	months	8		15	
2031 Design Capacity	pphpd	*	7,900	*	8,000
Vehicles required	#	*	66	*	44
Construction Cost	$M(2006)	*	191	*	173
Vehicle Costs	$M(2006)	*	271	*	180
Total Capital Costs	**$M(2006)**	*	**462**	*	**353**
Relocated New Kennedy Terminal					
Service Disruption	months	8		8	
2031 Design Capacity	pphpd	7,900	7,900	8,000	8,000
cars	#	60	66	42	44
Construction Cost	$M(2006)	177	256	185	241
Vehicle Costs	$M(2006)	246	271	172	180
Total Capital Costs	**$M(2006)**	**423**	**527**	**357**	**421**

*Does not provide adequate capacity

6.3 Capital Costs for Conversion of the Existing Route to LRT

As in the case of the RT alternative, vehicle characteristics, train length, and service headway dictate construction requirements and associated cost estimates for construction.

In order to achieve economies of scale in vehicle manufacturing and allow for integrated operation with other streetcar and possibly new LRT services, cost estimates are based on the acquisition of light rail vehicles (LRVs) that are similar, in most respects, to articulated replacement streetcars now being considered by the TTC.

Dimensions, aside from length, are approximately equivalent to the articulated streetcars now used by the TTC. In length they are assumed to be 28 metres in contrast to the 23 metre length of the TTC's current ALRVs. Although estimates have been prepared both for 2-car and 3-car LRT trains, for operation "on-street" in mixed traffic or in segregated LRT lanes beyond the present Scarborough RT corridor, probably only the 2-car trains should be considered.

Four main factors affect cost estimates for conversion of the RT to an LRT service.

First, although LRVs have less stringent curvature limitations than Mark II RT vehicles with the result that curve reduction would not be required on the Kennedy curve, major reconstruction of the 160 m tunnel between Ellesmere Station and Midland Station on the present route would be required because of greater vehicle height.

Second, replacement LRVs will be designed for "low floor" loading. As a result, platform height of the existing Scarborough RT stations would be lowered in three stations and the track structure itself would be raised in three stations where the existing platforms are integral components of the station structural design.

Third, the elevated portions of the existing RT require strengthening to accommodate the higher axle loads of the longer and heavier LRVs.

Fourth, the gauge, or distance between the rails, on the RT is different than that used by the TTC streetcars. While LRVs could be ordered with either gauge, for the sake of inter-operability, it would be advantageous to modify the existing gauge on the RT (including the RT yard) to the current streetcar gauge

It should be noted that although reconstruction of the tunnel, rebuilding of some stations and terminals, strengthening of the elevated guideway and changes to gauge, all lead to higher construction costs than in the case of the RT alternative, vehicle costs are considerably lower.

As shown in Table 6.2, the lowest capital cost alternative for 2-car LRT trains involves modifications to the existing Kennedy Station. However, there is little or no room for improving the passenger transfer process. Service disruption during construction is estimated to be three years.

6.4 Subway Capital Costs

The existing alignment of the Bloor-Danforth subway in combination with a number of right-of-way and design issues led to the conclusion that, from the standpoint of engineering and technical feasibility, an entirely new alignment could be constructed more efficiently than a route that retains some segments of the current Scarborough RT. The orientation of the existing Bloor-Danforth subway track at Kennedy Station, as well as limitations on available right-of-way, are the main impediments.

Setting aside matters related to decision-making, timing, and funding, a new alignment is assumed to have few, if any, construction impacts that would disrupt the present RT service (except for possible short term construction impacts at Scarborough Centre). However, it should be emphasized that Scarborough RT service would be suspended between 2015 and the opening date of Scarborough subway service.

Table 6.2 – LRT Capital Costs

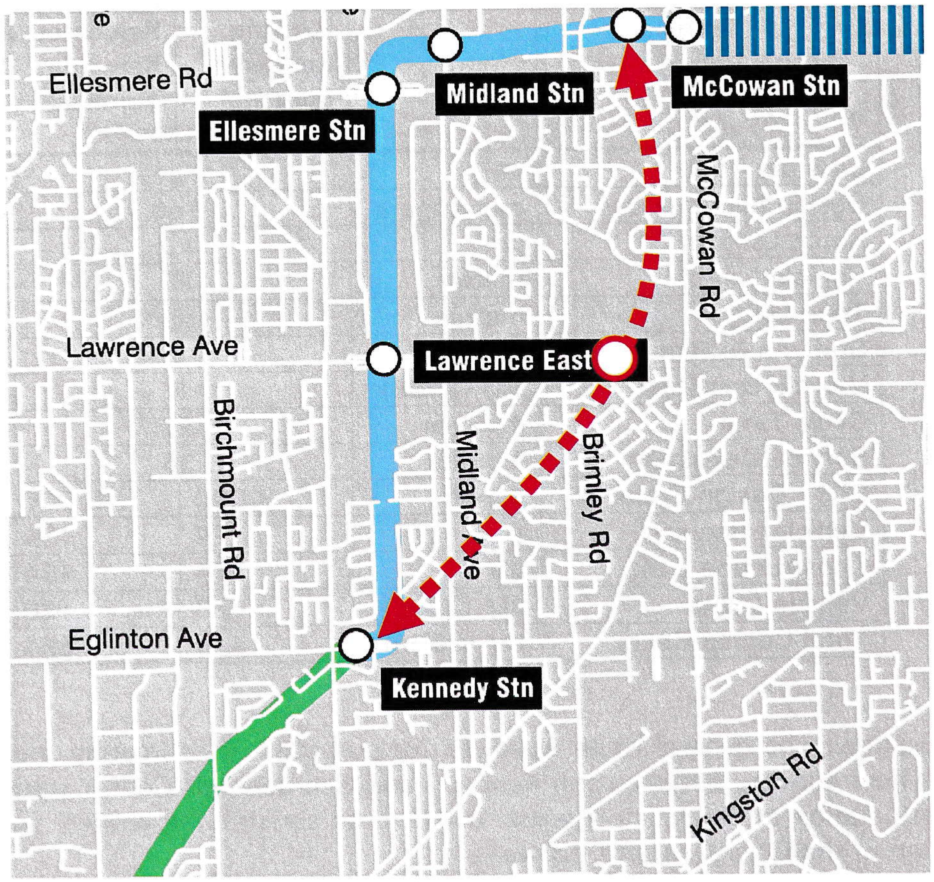
Item	Units	Existing Kennedy Terminal Location	Relocated Kennedy Terminal
Cars per Train	#	2	
Design Load per car	passengers	140	
Route Length	km	7.2	
Vehicle Length	metres	28	
Train Length	metres	56	
Stations & Terminals	#	6	
Vehicle Unit Cost	$M (2006)	5	
Cycle Time	minutes	21	
Service Disruption	months	36	
2031 Design Capacity	pphpd	8,000	8,000
Vehicles Required	#	24	24
Construction Cost	$M	374	434
Vehicle Costs	$M (2006)	120	120
Total Capital Costs	**$M (2006)**	**494**	**554**

Figure 6.3 shows the general route assumed for purposes of estimating the construction costs of a new subway between the Kennedy and Scarborough Centre stations with one intermediate station at Lawrence Avenue. It would be constructed entirely underground as an extension of the Bloor-Danforth subway.

Estimated costs of the subway alternative, excluding property acquisition and any relocation of major underground utilities, are approximately $1.2 billion, comprised as follows:

Item	2006 $M
Construction	1,120
Vehicles	100
Total	1,220

Figure 6.3 – Possible Subway Corridor



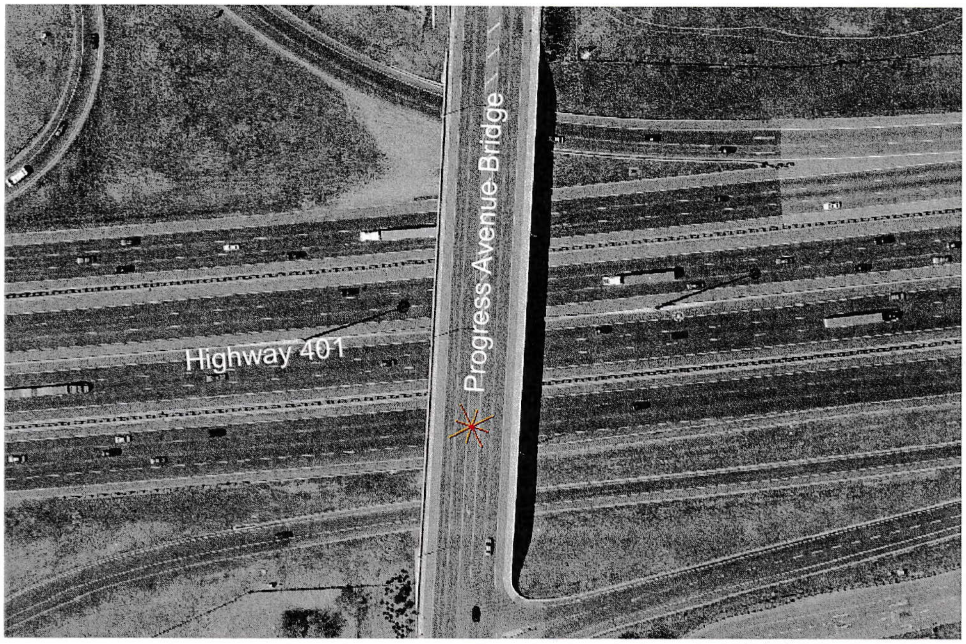
6.5 The Malvern Extension

Estimates for construction of a Scarborough RT extension, either as RT or LRT are based on an update of the costs previously estimated in the 1992 environmental assessment. Presently estimated at about $500 million for either RT or LRT technology, both options are based on using a completely dedicated right-of-way and guideway.

Though necessary in the case of RT, there are opportunities for reducing the degree of right-of-way exclusivity and associated costs for the LRT alternative. LRT costs could undoubtedly be reduced by introducing more "on-street" operation in dedicated lanes provided, of course, that design features ensure adequate reliability for integration with new LRT service in the existing Scarborough RT corridor.

A new bridge over Highway 401 is one of major cost elements associated with the Malvern extension. This cost could be reduced by incorporating the transit crossing into an existing bridge. Making use of the existing Progress Avenue bridge (shown in Figure 6.4), for example, would reduce the estimated RT or LRT extension costs significantly and is certainly consistent with the transit priority initiatives embodied in the Official Plan.

Figure 6.4 – Existing Highway 401 Bridge on Progress Avenue



6.6 Costs of Operation

Costs of operation include the costs of conducting transportation (such as labour and energy), maintenance of structures, stations, and fixed plant, as well as the costs of vehicle maintenance, supervisory, and administration costs. Using recent annual operating cost data, unit costs of operation have been developed that are dependent upon:

- Route length,
- Number of stations,
- Size of the vehicle fleet,
- Vehicle-kilometres of operation, and
- Train hours of operation.

These unit costs of operation have been applied to the 2031 design capacities and subsequently expanded to reflect the ratio of annual car-kilometres and train-hours to peak period measures.

6.7 Summary of Costs

Figure 6.5 summarizes costs for the RT, LRT, and Subway alternatives. Capital costs shown are for the lowest RT capital cost derived from Table 6.1, for two-car LRT trains derived from Table 6.2, and for the subway. In the case of RT and LRT, the capital costs are those associated with a design capacity of approximately 8,000 pphpd (the 2031 estimate). All capital costs are shown to the nearest $10 million.

Figure 6.5 – Comparative Capital Costs for 2031 Design Capacity

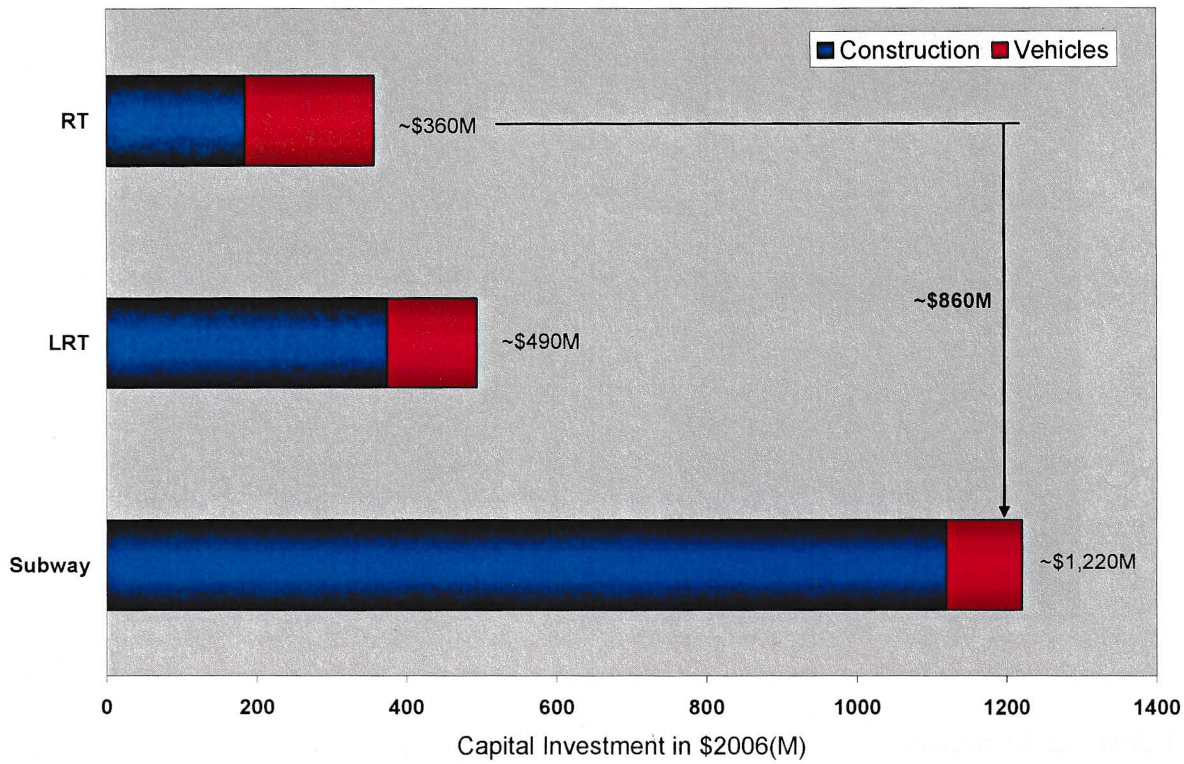


Table 6.3 compares total annual costs for the 2031 design capacity. Infrastructure costs are amortized (or annualized) at an interest rate of five percent for an assumed service life of 25 years for RT and LRT and 30 years for subway.

Table 6.3 – Comparative 2031 Annual Costs in 2006$

Item	Units	RT	LRT	Subway
Trains		3 car Mark II	2 car LRV	6 car Subway
Kennedy Station		New, relocated	Existing, modified	Existing (no SRT)
2031 Capacity	pphpd	8,000	8,000	exceeded
Capital Costs	$M(2006)	360	490	1,220
Annual Capital	$M(2006)	25	35	79
Annual Operating	$M(2006)	18	17	10
Total Annual	$M(2006)	**43**	**52**	**89**