1. Introduction

This is one in a series of backgrounders that have been produced by Metrolinx to provide further explanation and clarification on the policies and directions of the Regional Transportation Plan (RTP). The RTP is available for downloading at www.metrolinx.com.

From an improvised vanpool to leading edge magnetic levitation trains, a wide variety of transit technologies are in service around the world. Many are in use currently in our transportation system. Several more could be implemented. This backgrounder provides information about different transit technologies considered in the RTP.

Metrolinx wishes to acknowledge the invaluable contribution of IBI Group to the preparation of this backgrounder.

2. General Variables between Technologies

Operational Considerations

1. **Average Speed:** average speed of the service from end to end, including all stops. Low average speeds are appropriate for local trips but cannot make transit competitive with the private automobile over longer distances. The lower the speed, the more vehicles (and drivers) are required to provide the same frequency and capacity.

2. **Station Spacing:** distance between stations. A shorter station spacing will reduce the average walk distance to access transit but will lower the average speed because of the need for more frequent stops.

3. **Grade Separation:** grade separation helps insulate transit traffic from general traffic and can be achieved by routing a line through a tunnel, in an elevated structure, or on the surface with the use of barriers (e.g. at road crossings). Key benefits include greater speed from not stopping at intersections, reduced risk of collision and reduced risk of delay and “bunching” resulting from traffic congestion. Full grade separation allows operation of automated trains.
4. **Headway**: the time between two vehicles or trains arriving at a station. Lower average speeds result in more vehicles required to maintain a desired headway.

5. **Dwell Time**: the time a vehicle stays at the station to allow for boarding and alighting of passengers. Fare collection methods, vehicle configuration, door size and location, floor/platform height and platform congestion all affect the dwell time. Longer dwell times can result in lower average speeds.

6. **Automation**: the use of full grade separation is required for automated trains. Key benefits include: higher capacity; reduced operating costs; increased operating flexibility; greater speed; shorter platforms (or longer trains) since trains can stop much more precisely; possibility to install platform doors (which require perfect alignment), and more space for passengers inside the train.

7. **Capacity**: expressed in passengers per hour in the peak direction (pphpd), this is the number of passengers that can be carried past a point in a corridor in a given hour in the busiest direction.

8. **Reliability**: refers to the incidence of unforeseen delays or deviations from schedule. Reliability is influenced by the number of opportunities for interference, for example at-grade crossings and platform congestion. Tighter headways increase the chance for low reliability.

9. **Power source**: electrically-powered vehicles can be powered from a third rail or overhead wire. Subways are typically powered by a third rail. The use of third-rail technology allows for lower-height tunnels than with overhead sources. However, tracks with a third rail cannot be crossed by vehicular or pedestrian traffic, thus creating a barrier at grade.

### 3. Transit Technologies in the RTP

The RTP contemplates five broad categories of potential transit technologies. Due to the broad nature of these categories, they often overlap with each other. Subsequent to the RTP, recommended alignments and technologies will be developed during the project-level Benefits Case Analysis that Metrolinx will carry out for specific projects in partnership with municipalities and transit agencies.

#### 3.1 Express Rail

Express Rail comprises high-speed trains, typically electric, serving primarily longer-distance regional trips with two-way all-day service. Trains typically run on grade-separated tracks. Some of these may be on existing railway rights-of-way, but dedicated tracks are usually required to eliminate interference with slower traffic (e.g. freight). Express Rail does not currently exist in Canada, but BART in the San Francisco Bay Area is an example. The RER (Réseau Express Régional) network in Paris is another; this is a system made up of former suburban lines linked by new subway sections in the central area. London, England, is planning a similar line called CrossRail. Express Rail differs from Regional Rail in its overall performance – primarily defined as speed and frequency – and the fact that Express Rail is generally electric.

*Average Speed*: Express Rail trains can run at speeds of up to 130 km/h but their average speed ranges between 50 and 80 km/h.

*Frequency*: As low as 5 minutes.
Station Spacing: Stations are generally far apart (2-5 kilometres or more) but possibly less in urban areas.

Capacity: The capacity of Express Rail ranges between 25,000 and 40,000 passengers per hour (in the peak hour, per peak direction).

Overlap: There may be overlap between Express Rail and more conventional Regional Rail if trains operate close to the same average speed, frequency and capacity.

Cost per vehicle\(^1\): An Express Rail trainset costs approximately $30M

Cost per kilometre\(^1\): The first additional track costs approximately $20-50M per km

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Examples

**BART**

Plans for an underwater transit tube to run underneath the San Francisco Bay started as early as 1947. Construction of the Bay Area Rapid Transit (BART) officially began on June 19, 1964.

After eight years of construction, BART opened for passenger service on September 11, 1972.

The BART system is 167 km long and carries nearly 370,000 people daily.

*Photo: Thomas Hawk (flickr)*

**Berlin**

Berlin’s S-Bahn is integrated with the city’s subway system, the U-Bahn, which is mostly underground.

The S-Bahn has 15 lines, 166 stations and a total length of 331 km. Its history dates back to 1924, as a commuter rail link into Berlin. While it originally ran on steam, all lines were electrified by 1929.

*Photo: NeiTech (flickr)*

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\(^1\) Please note that all costs are provided for illustrative purposes only and can vary significantly depending on site conditions and implementation approach.
Tokyo – Yamanote

Tokyo’s circular Yamanote line connects major centres of activity throughout the city.

Trains in the Yamanote line are approximately 200 m long and depart every two to four minutes.

The Yamanote Line moves approximately 3.5 million passengers per day, has 29 stations and is 34.5 km long.

Photo: Nathan Duckworth (flickr)

Paris – Réseau Express Régional

The Réseau Express Régional or RER is a regional rail system that connects at multiple points with the Paris Metro.

RER has 257 stops, and has a total length of 567 km. Its construction took place between the 1960s and 1970s.

Photo: Thomas Lu (flickr)
3.2 Regional Rail

The Regional Rail category includes rail passenger services that operate on standard railway tracks (as noted above, Express Rail differs mainly from Regional Rail in its overall performance). Trains can share tracks with freight and/or intercity trains, or run on their own. Depending on the infrastructure available and the demand, regional train services can operate all day in both directions at various frequencies, as does the GO Transit Lakeshore Line today, or operate in one direction in the morning, returning at night as on several other current GO Transit rail lines. Trains can be pulled by diesel-electric locomotives like current GO Transit trains or by electric locomotives as in New York or Montréal. Railcars can also be self-powered Diesel Multiple Units (DMUs) or Electric Multiple Units (EMUs). The Deux-Montagnes line in Montréal uses EMUs.

**Average Speed:** Trains operate at maximum speeds exceeding 100 km/h, but the typical average speed ranges between 30 and 50 km/h.

**Frequency:** As low as 10 minutes.

**Station Spacing:** Stations are typically about 2-5 kilometres apart, possibly less in urban areas and more in less populated areas.

**Capacity:** The capacity of regional rail ranges between 5,000 and 20,000 passengers per hour (in the peak hour, per peak direction).

**Overlap:** At the higher end of speed and capacity, Regional Rail services may overlap with Express Rail. At the bottom end, regional rail overlaps with Light Rail Transit, especially with tram-trains, which can function as trains outside of built up areas or to take advantage of an existing rail corridor to provide an express service.

**Cost per vehicle**:
- A train car costs approximately $2.0M (2-level)
- A conventional locomotive costs approximately $2.5M
- An electric locomotive costs approximately $4.5M

**Cost per kilometre**:
- A kilometre of standard rail track costs approximately $4.0M (assuming use of existing tracks and right-of-way, and excluding land which can cost up to approx. $200 - $500/m²).
- A kilometre of electrified rail costs approximately $5.0M (includes only wire, catenary structures and substations).

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2 Please note that all costs are provided for illustrative purposes only and can vary significantly depending on site conditions and implementation approach.
Examples

**GO Transit regional rail services – diesel-electric locomotives**

GO Transit began operations in May 1967, making it Canada’s first interregional public transit system. It links Toronto with the surrounding regions of the Greater Toronto and Hamilton Area and carries more than 51 million passengers a year.

Photo: Dave (flickr)

**River Line - New Jersey Transit – Diesel Multiple Units**

New Jersey’s River Line connects the cities of Camden and Trenton following the Delaware River. Between 1830 and 1963 a passenger rail service followed the same route. The line was abandoned for almost 40 years until the River Line began operations in 2004. The River Line is 55 km long and carries approximately 5,500 passengers a day.

Photo: Fußgänger (flickr)

**Deux-Montagnes Line – AMT, Montréal**

Deux-Montagnes is Montréal’s busiest commuter railway carrying more than 31,000 people every day. The 31.1 km line has been in service since 1918. Originally operated by Canadian National Railways, it was transferred to the Agence Métropolitaine de Transport in 1996.

Photo: A. Belaieff
3.3 Subway

Subways are high capacity, heavy rail systems that are fully grade-separated from other traffic and predominantly underground, on fully dedicated tracks. Most subway trains today are operated manually but many new subway lines are now automated.

*Average Speed:* The average speed is 25 to 50 km/h depending on station spacing.

*Frequency:* As low as 90 seconds with automated trains.

*Station Spacing:* Stations are typically about 500 metres to 1 km apart in dense areas and about 2 km apart in less dense areas.

*Capacity:* The capacity of subway ranges between 25,000 and 40,000 passengers per hour (in the peak hour, per peak direction).

*Overlap:* Subways overlap with Express Rail at high speeds, high capacity and wide station spacing. With smaller cars, short station spacing and lower speeds, subway can overlap with Light Rail Transit (LRT) or Automated Guided Transit (AGT).

*Cost per vehicle*\(^3\): A subway car costs approximately $3M ($18M per 6-car train).

*Cost per kilometre*\(^3\): A kilometre of subway costs approximately $250 – 300M (including stations).

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\(^3\) Please note that all costs are provided for illustrative purposes only and can vary significantly depending on site conditions and implementation approach.
Examples

Stockholm

The first portion of the Stockholm Tunnelbanan opened in 1950, with new lines added throughout the 1960s and 1970s.

Today, the Stockholm Tunnelbanan has a total length of 65.7 km, 100 stations and a daily ridership of more than 1 million people.

Photo: Acesee (flickr)

Toronto

The first segment of Toronto's subway system opened in 1954. The line followed Yonge Street from Eglinton Avenue south to Front Street, turning west to Bay Street and ending at Union Station.

The latest system expansion was the Sheppard line in 2002 which added 5.5 km of track. Today, the entire system has 4 lines, 69 stations, a total length of 68.3 km and an average daily ridership of more than 1.2 million people.

Photo: Diego Silverstre (flickr)
3.4 Other Rapid Transit

Other Rapid Transit is a broad category used in the RTP that includes all other transit modes that completely or mostly operate in their own rights-of-way, protected from mixed traffic. Other Rapid Transit includes Bus Rapid Transit (BRT) and Light Rail Transit (LRT) as well as Automated Guided Transit (AGT). It also includes buses operating in mixed traffic on controlled-access expressways that employ congestion management such as tolls, thereby allowing the buses to maintain high average speeds.

- Rapid transit vehicles can be diesel-powered (mostly buses) or electric (LRT, AGT, tram-trains, trolleybuses).
- Rapid Transit services are typically marketed as premium services with high frequencies, upgraded stop or station amenities, express boarding through all doors, and real-time information systems.
- Rapid Transit overlaps with subways at the high end of speed and capacity, and with conventional surface transit at the lower end.
- Automated Guided Transit (AGT), also called Automated Light Rail Transit (ALRT), operates on exclusive rights-of-way, completely protected from traffic, even at intersections. Other forms of Rapid Transit can operate on existing roads, stopping at intersections.
- Light Rail Transit (LRT) uses dedicated tracks, and trains are protected from traffic but typically stop for other traffic at intersections. Tram-trains are special vehicles that can operate on streetcar tracks in urban settings and on conventional rail tracks outside of urban areas. Their application in North America has been limited to date due to safety standards for vehicles operating in mainline rail corridors.
  - LRT generally enjoys a more positive image, better ride quality and a stronger positive impact on urban development (and greater opportunities for value capture) than BRT.
  - Particularly in dense urban areas, LRT can provide a more pedestrian-friendly environment, vehicles produce no emissions along the line and much lower noise.
  - LRT is limited to tracks, requires more transfers than buses and offers less service/routing flexibility.
  - LRT involves longer implementation and requires special facilities and infrastructure (eg. yards).
- Bus Rapid Transit (BRT) is a premium bus service with the characteristics of Rapid Transit outlined above (protection from traffic, premium vehicles, high frequencies, enhanced station amenities, express boarding, information systems). BRT systems generally operate alongside arterial roads or expressways.
  - BRT vehicles can offer transfer-free service with conventional buses using dedicated busways for only part of the trip, and can offer greater routing and service flexibility as a result.
  - BRT typically uses more specialized or larger vehicles than conventional bus services. Articulated buses can carry up to 200 passengers.
  - BRT can be implemented progressively, as ridership builds.
Average Speed: Other Rapid Transit vehicles operate at average speeds of 15-40 km/h (higher for dedicated bus transitways on controlled-access expressways or in mixed traffic on tolled controlled-access expressways).

Frequency: As low as 90 seconds.

Station Spacing: Approximately 500 metres between stations, which can be higher in less populated areas and lower in heavily populated areas.

Capacity: Between 2,000 and 25,000 passengers per hour (in the peak hour, per peak direction).

Cost per vehicle:
- An AGT/ALRT car costs approximately $3 – 3.5M.
- An LRT vehicle costs approximately $3 to $5M per 30m articulated vehicle.
- A 60-foot BRT bus costs approximately $1M per vehicle.

Cost per kilometre:
- A kilometre of AGT/ALRT costs approximately $150M (assuming elevated guideway and including stations).
- A kilometre of LRT track costs approximately $35 – 40M, $150M underground.
- A kilometre of busway costs approximately $25 – 50M.

Examples

Los Angeles – Orange Line Bus Rapid Transit

Starting in October 2005, Los Angeles County Metropolitan Transportation Authority operates a Bus Rapid Transit line known as the Orange Line.

The Orange Line was inspired by the famous Rede Integrada de Transporte in Curitiba, Brazil. The Orange Line is 22.5 km long and carries nearly 27,000 people everyday.

Photo: Jim Ellwanger (flickr)
**Adelaide O-Bahn**

The Adelaide O-Bahn is a guided busway system. These guided buses are steered, at least partly, by dedicated tracks that parallel existing roads.

The Adelaide O-Bahn is the longest and fastest guided busway system in the world. Buses ride on a specially built track as well as on the road. They can travel at a maximum speed of 100 km/hr and have the capacity to carry 18,000 passengers per hour.

*Photo: Brett Moore (flickr)*

**RandstadRail – train function**

The RandstadRail has three lines and runs on converted train and tram tracks.

It services the cities of Rotterdam, The Hague and Zoetermeer, Netherlands, as well as the suburbs that surround them.

The RandstadRail has a total length of 36.7 km.

*Photo: Rienk Mebius (flickr)"

**RandstadRail – tram function**

*Photo: ArthurA (flickr)*
Paris

Paris has a network of 3 tram lines and one tram-train line. The first of these lines, T1, began operations in 2003, followed in 2005 by T2 and in 2006 by T3 and T4.

This modern system is part of a long history of Parisian trams. Since 1855, the Paris tramways have evolved from cars powered by horses, steam and pneumatic engines.

T3 carries 100,000 passengers per day.

Vancouver Millennium Line

The second SkyTrain line, the Millennium Line, opened in 2002. Its total length is 20.3 km, and it has 13 stations.

Both SkyTrain lines are fully automated and run, for the most part, on elevated tracks. The SkyTrain has a total length of 49.5 km, which makes it the longest automated light rapid transit system in the world.

The SkyTrain carries 220,000 people a day.
3.5 Conventional Surface Transit

This category includes all the transit modes that operate in the same lanes as general traffic. These technologies are typically used for local trips or as feeders to the rapid transit network.

3.5.1 Buses

Buses can vary in length. Standard buses are 40 to 45 feet long and carry about 50-60 passengers, but articulated buses can reach 78 feet (24 metres) and carry up to 200 passengers. Buses can be powered by conventional diesel engines, diesel-electric hybrid engines, natural gas or hydrogen. Trolleybuses are powered by electric motors and derive their power from overhead power lines. This category also includes long-distance buses which provide a different seating configuration and luggage storage, as well as jitney services that use smaller buses and provide full or partial on-demand services.

*Average Speed:* Buses operate at average speeds of 10-30 km/h.

*Station Spacing:* Typically about 250 metres apart, but can be further apart in less populated areas. When stops are placed further apart, average speed increases.

*Capacity:* The capacity of conventional buses ranges between 2,000 and 5,000 passengers per hour (in the peak hour, per peak direction).

*Overlap:* In some cases, conventional buses can come close to Rapid Transit such as BRT or LRT when improvements are brought to operations, such as signal priority that allows the operator to extend a green light, or queue jump lanes that allows buses to bypass stopped traffic at an intersection.

*Cost per vehicle*:  
- A standard bus costs approximately $450,000 (diesel) to $650,000 (diesel-electric hybrid)
- An articulated bus costs approximately $750,000 (diesel) to $850,000 (diesel-electric hybrid)
- A double-decker bus costs approximately $800,000 (diesel)
- A suburban highway coach costs approximately $550,000 to $600,000 (diesel), $750,000 to $800,000 (hybrid)
- A 40 ft trolley coach costs approximately $950,000; A 60 ft articulated trolley coach costs approximately $1.2 million

*Cost per kilometre*: < $200,000 (assuming allowances for bus bays and customer amenities)

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5 Please note that all costs are provided for illustrative purposes only and can vary significantly depending on site conditions and implementation approach.
**Examples**

**Articulated 4-axle bus**

Bi-articulated, 4-axle buses are used in Curitiba, Brazil, Hamburg, Germany and Utrecht, Netherlands. Buses carry approximately 170 passengers. They are used mainly on high-frequency routes. The city of Curitiba was the first in the world to use these types of buses.

*Photo: Michiel (flickr)*

**Vancouver – trolleybus**

The trolleybus, or trackless trolley, is an electric bus powered by two overhead wires. Trolleybuses are used in many countries around the world including Argentina, Belarus, Brazil, the Czech Republic, France, Mexico, and Switzerland among others. In Canada, Vancouver and Edmonton have trolleybus systems. Trolleybuses can help reduce energy use, noise and harmful emissions.

*Photo: Alex (flickr)*

**England - Double-decker bus**

The use of double-decker buses in coach services is widespread around the world. Their use as part of the regular transit system, however, is less common. The most famous example of double-decker buses is in London. Some others include Dublin, Ireland; Colombo, Sri Lanka; Hong Kong, and Istanbul, Turkey. In Canada, double-deckers are used in Victoria, while GO Transit introduced 12 double-decker buses in March 2008.

*Photo: Ian Robert (flickr)*
3.5.2 Streetcars

Streetcars include urban rail transit services that operate mostly in mixed-traffic with similar characteristics as conventional buses.

*Average Speed:* Streetcars operate at average speeds of 10-20 km/h.

*Station Spacing:* Typically about 250 metres apart, but can be further apart in less populated areas. When stops are placed further apart, average speed increases.

*Capacity:* Up to 10,000 passengers per hour (in the peak hour, per direction)

*Overlap:* In some cases, with signal priority and turning restrictions, streetcars can provide a level of service similar to LRTs.

*Cost per vehicle*: Approximately $2.5 – 3.0M

*Cost per kilometre*: Approximately $5 – 10M

**Examples**

**Toronto**

Photo: Roger Cullman (flickr)

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6 Please note that all costs are provided for illustrative purposes only and can vary significantly depending on site conditions and implementation approach.
New generation, low-floor streetcars are common forms of transit around the world. The new designs are more accessible for wheelchairs and strollers as thresholds can be as low as 18 cm (7 inches).

Some examples of these new streetcars include: Melbourne, Australia; Geneva, Switzerland; Vienna, Austria; Munich, Germany and others.