

# Mode succession in a public transit corridor

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## Abstract

There are many transit modes, technologies and operating strategies to apply within developing transit corridors. The selection of mode will have a significant impact on the level of service, capital and operating costs, energy use, environmental impacts and transit market development.

Additionally, in developing communities this is not a static decision, indeed over decades there could be several mode changes as the market within the corridor grows and matures. The appropriate transit response over time may cover a range of services: e.g. regular mainline bus, express bus, Bus Rapid Transit (BRT), Busways, Light Rail Transit (LRT) & Metro.

Our paper will examine the appropriate decision factors and planning considerations that would lead to optimum mode selection decisions in developing corridors. The paper will examine the transit market in developing corridors in terms of changing trip densities and corridor volumes and the appropriate mode response. Factors that impact the decision may include system capacity, access, travel time, the schedule, reliability, customer experience factors, energy use, environmental impacts, capital and operating costs, etc.

We will propose methodologies for optimizing mode selection and design as a corridor evolves, and selection of an optimum series of modes and transition points for a corridor over a long period of time.

*Keywords: transit modes, transit corridors, mode selection, transit decision criteria, capacity, travel time.*

## 1 Introduction

A public transit corridor in an urban environment may be viewed as a linear or curvilinear concentration of land use activity in which significant travel takes



place via public transit. There is a symbiotic relationship between the land use concentration along a corridor and the transit infrastructure and services provided. This relationship evolves over a long period of time. Concentrations of appropriate land use and an urban form which encourages pedestrian activity will provide the necessary base for the provision of public transit. Equally important is the provision of permanent transit services that evolve over time in service intensity and mode in response to changes in passenger demand as the corridor intensifies and lengthens over time.

This evolutionary relationship requires close monitoring and planning, as much can go wrong over the passage of several decades. Issues may arise with the location or lack of public transit right of way, the environmental impact of a specific mode, the inefficient location of terminals and stations, insufficient passenger capacity, slow or inconsistent travel times, and poor feeder bus, pedestrian or park and ride access.

There is significant peer reviewed literature on the design and optimization of transit service in a given corridor, for example Vuchic [1], Chang and Schonfeld [2], Liu and Wirasinghe [3], Wirasinghe [4], Hurdle and Wirasinghe [5]. The relationship between rail line location within a corridor and land-use has been explored in Wirasinghe et al. [6] and, Wirasinghe and Seneviratne [7]. They showed that there are optimal termini locations for a rail line within a corridor at a given time, and that future land use changes within the corridor beyond the termini call for line extensions which can be pre-calculated. Issues related to selection of the transit technology given the demand characteristics is discussed in Parajuli and Wirasinghe [8]. A generic study of the evolution of transit services within a corridor via mode changes over time is not directly discussed in the peer reviewed literature.

In this paper we discuss the criteria and conditions under which transit services in a corridor could be considered for transition from one mode to another. It is noted that certain mode choices can block the transition into a mode which is more efficient or provides a better level of service, and that good planning can avoid the intermediate modes that will cause such problems. For example, under certain conditions it is better to evolve directly from bus rapid transit (BRT) offered on street to LRT on exclusive right of way, without using an intermediate bus-way on the same right of way as the evolution from a bus-way to LRT would be problematic due to service disruptions during the construction.

Finally, we will describe the development of transit services and the evolution of transit modes over the last 40 years in a prominent corridor in Calgary, Alberta, Canada.

## 2 Mode transition considerations

Two of the key criteria to consider, but not the only ones, in planning for mode transition, are system capacity and travel time.



Figures 1 and 2 illustrate the min/max capacity and speed of various modes in ascending order. This information is illustrative only as there is great variability in system capacities and speeds [9–13].

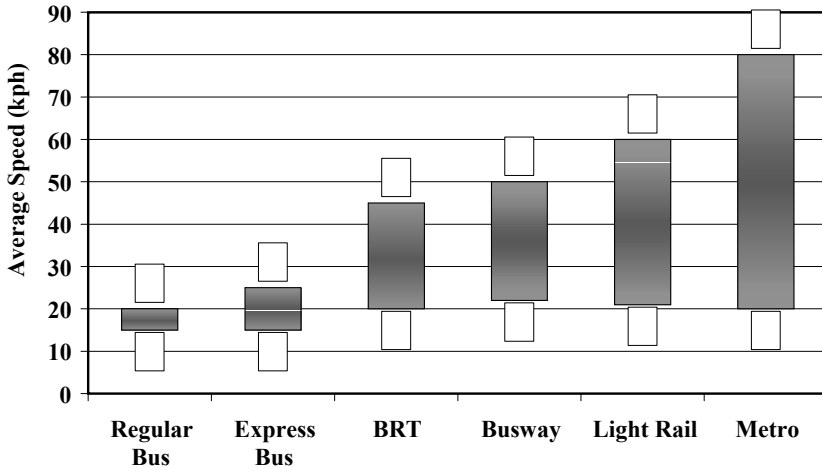


Figure 1: Speed ranges by mode.

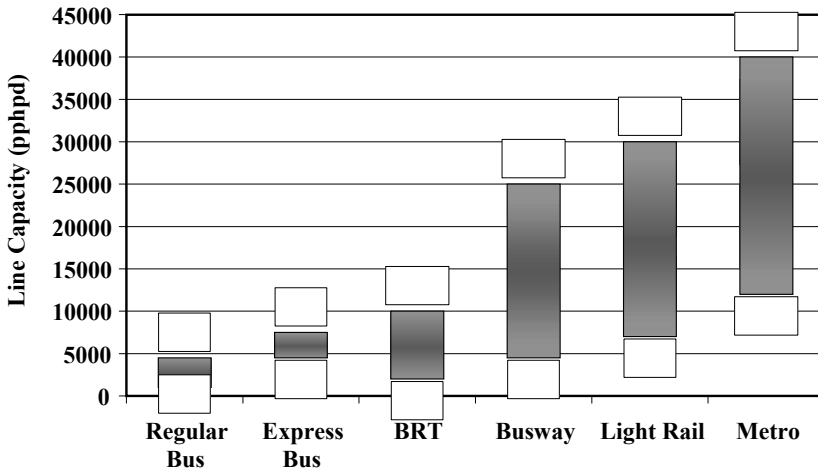


Figure 2: Line capacity by mode.



In Figure 3, the capacity of transit modes are arranged in ascending order from main line bus to metro. The capacity values are shown in the Y-Axis and boundary lines drawn across from left to right. The X-Axis indicates the flow of time over decades during which modal changes may take place. The increase in demand (maximum load per hour in the corridor) for transit over the decades is shown as an exponentially increasing function of time measured in decades.

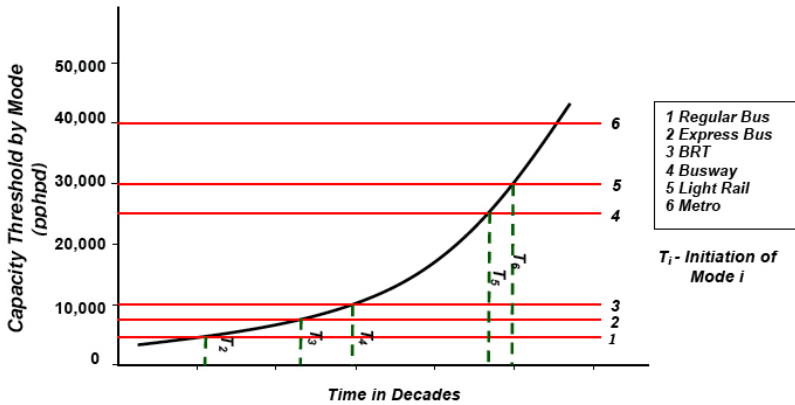


Figure 3: Matching line capacity to demand over decades.

The points at which the demand curve crosses the modal capacity boundaries are the times at which modal change should be considered. The development of such curves for a specific corridor and transit service offering would allow logical planning for the required modal changes.

Travel time in a corridor is another key criterion to consider in modal transition analysis. Corridor lengths can increase over time as development extends beyond existing corridor boundaries. As well, increased traffic congestion on major roads may result in slower and less reliable transit service. Further, the actual transit service in existence at any time may only cover a portion of a corridor. As the corridor lengthens, the overall travel time also increases. In Figure 4, we illustrate the travel time increase in a corridor with travel time in the Y-Axis and time in decades in the X-Axis. Each curve stylistically illustrates the change in travel time for a mode as the corridor length increases over time. The length of the corridor is not shown. The horizontal line indicates the maximum acceptable travel time. The crossing point of the line with a particular modal curve indicates the points at which the modal change should occur, and the new reduced travel time via the new mode.

Clearly there are other issues such as capital cost, operating costs, environmental impact that must be considered in modal transition in addition to other level of service parameters such as access modes, schedule and level of comfort.

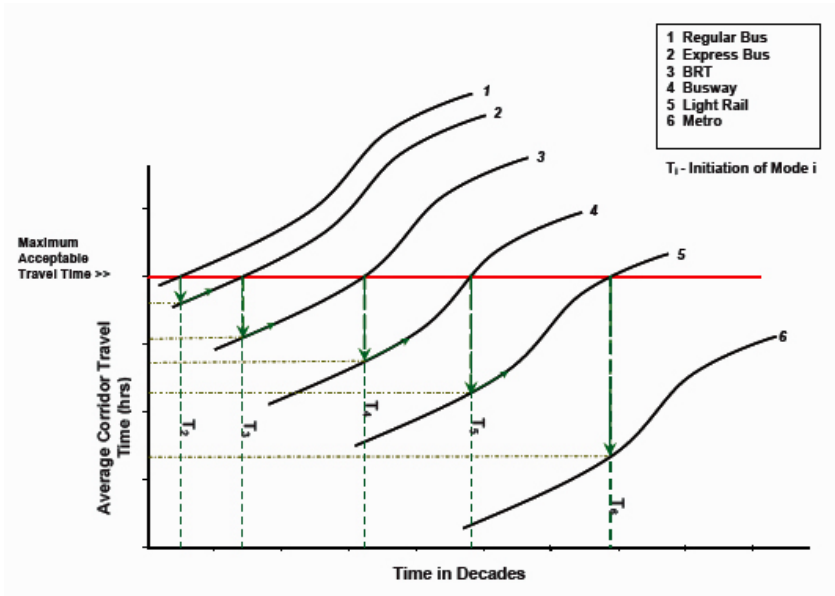


Figure 4: Matching acceptable maximum travel time in a corridor to modal travel time increases over decades.

### 3 Performance measures framework

Creating an effective quantitative description of public transit services within a corridor is a challenging exercise. For the purpose of this work a rudimentary framework was developed. The framework is based upon a supply and demand model. While public transit systems are not generally thought of as competitive systems, the model allows measures to be grouped into logical categories.

The performance framework contains four sets of measures; Supply Characteristics; Demand Characteristics; System Performance Indicators; and Other Influences.

Figure 5 shows the performance measure framework and how the categories fit together.

#### 3.1 Supply characteristics

Supply characteristics describe the overall functionality of the transit system. The measures will provide enough sensitivity to delineate between mode strategies (Bus, BRT, LRT, Metro).

- **Corridor capacity** – How many passengers can be accommodated by the mode and service supplied in the corridor. This characteristic will be a combination of number of routes, frequency and vehicle capacity. (measured in passengers / hour/direction);

- **Travel speed** – The combination of vehicles and infrastructure will generate a range of travel speeds. (measured in kph);
- **Comfort / accessibility** – A bundle of subjective attributes that describe the relative comfort of passengers. Attributes include stop and vehicle amenities (e.g. temperature controlled, ride quality, type of seating, access to information, ease of fare payment, access, security, cleanliness, etc.) (subjective measure - Utilitarian / Enhanced / Superior);
- **On-time performance** – Schedule adherence will measure the reliability and consistency of service. (% of service within defined on time window).

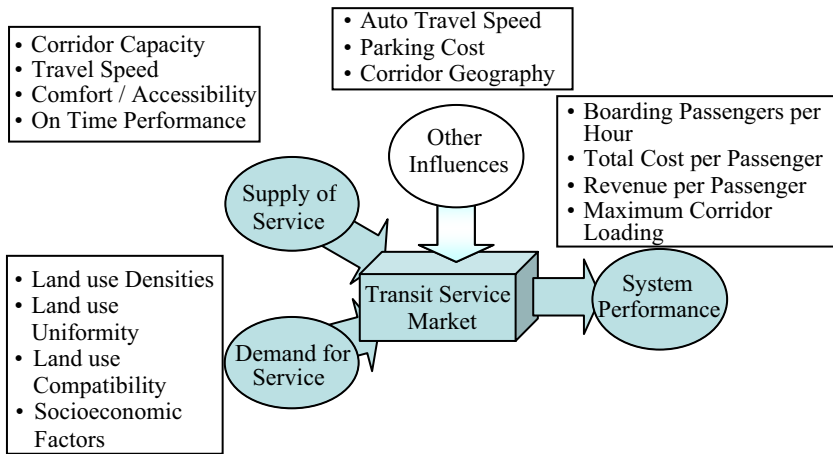


Figure 5: Performance measure framework.

### 3.2 Demand characteristics

These characteristics will provide information on the intensity and pattern of demand along the corridor. Land use measures are used to provide a proxy of transport demand. Three different criteria are included which, when examined in combination, should provide a basic description of travel demand and provide insight into mode selection.

- **Land use densities** – The density of the built environment is directly related to trip generation along the corridor. For example, Balanced (100 jph / 100 pph), Job Heavy (150 jph / 50 pph), and Population Heavy (50 jph / 150 pph). (100 jph = 3000 sq m of development, 100 pph = 20 units per hectare). (measured in jobs and/or persons per hectare);
- **Land use uniformity** – This characteristic seeks to describe the corridor in terms of the pattern of development along the corridor. This measure will also reflect major intensities of trip generation along the corridor. (subjective measures: even / nodal / peaked);

- **Land use balance** – A measure of the balance of trip origins and destinations along the corridor. For example, weak trip attraction may exist if one end of a corridor with strong trip attraction at the opposite end resulting in uneven directional flows and poor vehicle utilization. (subjective measure: unbalanced / neutral / balanced).

### 3.3 Other influences

Other factors may be at play in the transit market.

- **Auto travel speed** – Speed and consistency of auto travel;
- **Auto parking** – Parking location, cost and availability;
- **Socioeconomic factors** – Income and age profile, travel, disabilities, etc.

### 3.4 System performance indicators

These indicators will help describe how efficient and effective the system is in responding to both the corridor and transit trip demand.

- **Boarding passengers per hour** – Provides a measure of equipment or system utilization and service effectiveness;
- **Cost per passenger** – Provides a measure of the economic performance of the system;
- **Revenue per passenger** – Measures fare strategy effectiveness and when combined with the cost per passenger will provide an overall measure of financial efficiency;
- **Maximum corridor loading** – The loading profile along a corridor will provide indications when service or mode capacities are being reached and when mode change may be required;
- **Corridor ridership** – Overall corridor ridership provides a measure of mode effectiveness and may indicate when mode change is warranted;
- **Modal split** – Indicates the relative effectiveness of the current mode and may provide guidance for mode change;
- **Emissions** – System or per passenger emissions may provide guidance on mode selection or the timing of change.

## 4 Mode succession example – Calgary South LRT Corridor

Calgary, Alberta, Canada is a city of one million people. It has developed around a strong central downtown core with residential development spreading in a crescent to the north, west and south around the core and industrial development to the east. Calgary has a one hundred year history of successful transit services evolving in pace with community growth. The transit services have evolved from the implementation of street cars in 1909, buses in 1930, electric trolley buses in 1950 and LRT in 1981. Each mode change was based on a review of the criteria described above and consideration of evolving transit vehicle and system technologies [16, 17].

The evolution of bus, trolley coach and LRT services in major transportation corridors has seen Calgary's transit system develop into a model for North



American cities and support the development of a downtown that continues to be the heart of Calgary's economy. Transit ridership is high by North American standards and continues to grow despite Calgary having a relatively high level of auto ownership. Planning is currently in progress to develop a transportation system and land use to accommodate a doubling of urban population for the next 60 years. Appropriate high quality transit services and the development of a supportive land use and urban form are seen as key to building a sustainable city that optimizes mobility, social, financial and environmental objectives.

The following information provides a summary of the evolution of transit modes in Calgary's south (MacLeod Trail) corridor (shown in Figure 5).

A 1958 study reported that Calgary's transit network consisted of several radial trolley coach and bus routes serving the downtown plus cross-town and local feeder bus routes [14]. The transit system served 29 percent of downtown travel during peak periods. In order to attract a higher share of travel and avoid costly road construction, the report recommended providing transit service with higher capacity, faster travel speed and a radial routing to reduce transfers. The study also identified future need for dedicated transit roadways or elevated bus lanes in the downtown since bus volumes were approaching 70 buses per hour on some streets.

In 1967, an extensive transportation study provided the foundation for the future development of Calgary's transportation network with a significant transit system focus [15]. The study recognized the challenges presented by Calgary's land use patterns with low density residential development growing outward from the downtown towards the north, south and west. Industrial and commercial development was spreading to the southeast and northeast. The downtown was projected to continue to provide a significant concentration of Calgary's employment but that it would decline in importance over time.

The 1967 study recommended a future "interim rapid transit network" based on travel forecasts for Calgary's developing transit corridors as shown in Figure 6.

#### **4.1 Blue arrow bus express**

Based on a continuation of this land use pattern, travel forecasts predicted significant concentrations of trips originating in the south corridor travelling either to the downtown or to business areas within or adjacent to the south, MacLeod Trail corridor.

An "interim rapid transit" service would use express buses supported by feeder buses and park and ride to develop the transit market within the south corridor.

In 1972, Calgary Transit began operating the first phase of the "interim rapid transit" service within the south and northwest corridors as envisioned by the 1967 Calgary Transportation Study. This bus service was designed to build ridership within the south corridor and bridge the gap between existing conventional bus services and an eventual rapid transit service. The new "Blue Arrow" bus service had the following features:





- Local community routing with close stop spacing combined with limited stop “line-haul” express type service along the major corridor.
- New 52 passenger diesel buses with two-way radios for better service coordination.
- Buses and bus stops with distinctive colours, new passenger shelters.
- Park and ride and kiss and ride facilities at major stations.
- Frequent peak and off peak service,
- Reserved bus lanes (MacLeod Trail in the south downtown)

The service was highly successful with 6,200 weekday passengers and peak hour peak direction ridership of 2,000. Twenty five percent of Blue Arrow riders previously made their trip via auto.

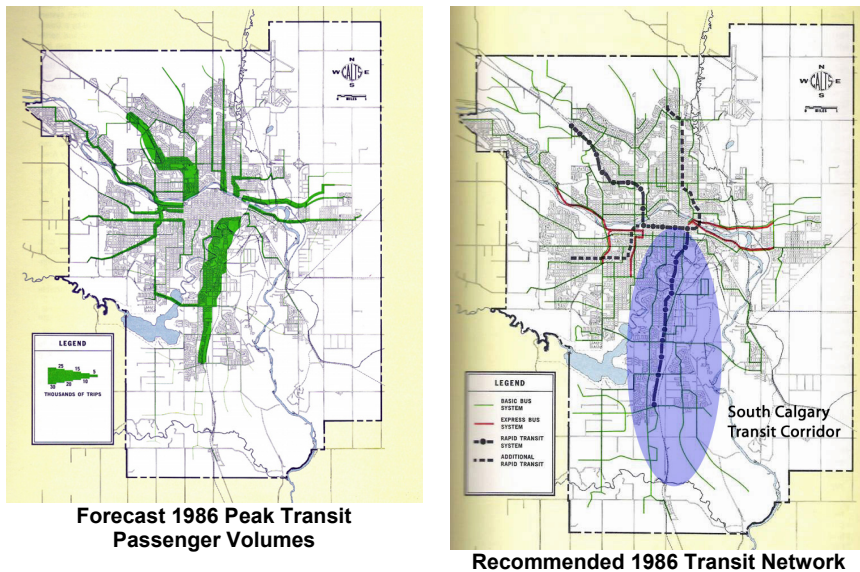


Figure 6: South (MacLeod Trail) corridor.

## 4.2 Light rail transit

Following the success of the Blue Arrow Bus Express system in 1972 work commenced on the next generation of transit services in the south corridor. Rather than define transit technology the initial studies described the desirable characteristics of an intermediate capacity system.

- Flexibility to operate on an exclusive right of way either elevated, at grade or underground;
- Ability to serve high concentrations of peak travel;
- Station spacing that achieved a balance between service and travel speed;
- Electric vehicles with rapid acceleration and fewer emissions.

Additionally, it was determined that such a system had the ability to:

- Defer significant costs associated with road construction;
- Increase travel by transit;
- Attract a more compact transit supportive land development at station locations.

Three options were examined – bus lanes on existing roadways, an exclusive bus roadway (busway), Light Rail Transit (LRT). LRT was selected based on the following analysis:

- The right of way for bus lanes was not available on existing roads;
- Busway operating and capital costs were only 8% less than LRT and were seen as a short term alternative given the projected city growth rates;
- A bus based system would have a significant environmental impact within the confined downtown street network;
- LRT required less land and a rail right of way was readily available;
- LRT had higher speed, better passenger comfort, greater service reliability, lower noise impacts on adjacent communities and a lower environmental impact;
- LRT capacity could be increased more readily than a bus system;
- LRT had a greater potential to influence a transit supportive land use.

In 1981, Calgary Transit commenced operation of a 12 kilometre LRT service in the South corridor to the downtown. The line is located primarily within a portion of an active freight rail right of way that bisects the residential and industrial areas within the South corridor. The location and availability of this right of way was indeed extremely fortunate since it provided the ideal location for the LRT line. Most of the LRT alignment is at-grade with short tunnel and elevated sections to bypass major transportation and geographic barriers. Most of the 7 suburban stations feature feeder bus terminals and park and ride lots with an initial supply of nearly 3,000 parking stalls. Within the downtown, the CTrain, as it became known, operates along a 2 kilometre long transit-only roadway with 10 platforms spaced about every three city blocks. The system has full signal priority at road crossings outside of the downtown and operates with traffic signal progression in the downtown.

Initially, three-car trains, each with a capacity of about 600 passengers operated every 5 minutes during peak periods. Combinations of one, two and three car trains operated every 15 minutes in off-peak times. Initially, Calgary's new LRT met its operating projections attracting 42,000 daily trips. About 20 percent of LRT passengers previously made their trip via auto. Average walking distance to LRT stations was well in excess of the typical 400 metres for bus service.

Despite economic recessions in the early 1980s and 90s, LRT ridership continued to grow. The success of South LRT fostered the construction of the northeast line 1985 and the Northwest line in 1987. The system has been gradually expanded so that today the CTrain system consists of 37 stations and 44 kilometres of track. Daily boardings are approaching 300,000 and about half of Calgary Transit customers make some portion of their journey via LRT. Calgary's LRT system is the most successful in North America serving the

highest ridership in total and certainly on a per capita basis. Clearly the decision to implement LRT has proven to have been the right one for Calgary.

Table 1: South corridor ridership and demographic history.

	Peak Period / Peak Direction at Downtown	All Day Downtown Trips In & Out	South Corridor Total Daily Passengers	South Corridor Population	Downtown Employment
1964	n/a	4,000	6,000	45,100	40,000
1973	4,000	8,000	10,000	130,000	50,000
1982	7,000	28,300	42,000	137,000	82,000
1990	8,000	30,000	44,000	168,000	92,000
2000	13,000	38,200	54,500	190,000	103,000
2008	17,600	61,500	82,000	230,000	120,000

Peak Period = 6 to 9 am, 3 to 6 pm

## 5 Conclusion

Over a period of forty years Calgary has followed a phased development strategy for transit services in the south (MacLeod Trail) corridor. Service evolved from conventional mainline bus to bus express service with some service aspects that emulated a rapid transit service including limited stop spacing, park and ride and transit signal priority. The latest development phase has LRT serving the corridor.

It is noted that system capacity, speed, reliability and the passenger experience are basic attributes used to describe a transit mode. The system capital and operating costs in total or per passenger are always discussed. How well a mode serves the land uses, urban form and intensity of development within a corridor and how a specific mode may influence change in the corridor also enters into the discussion.

At each stage in the evolution of the corridor staff, elected officials and community members have engaged in a dialogue regarding the appropriateness of the current mode, possible future modes and the process and criteria to be used to select a future transit mode to serve the corridor. It is remarkable that the description and emphasis of decision criteria may have changed over time, however, the core system attributes which individuals find important to understand and judge the appropriateness of a transit mode have been constant.

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