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Ottawa's Transitway: From Busway to Light Rail

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Abstract

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Ottawa's Transitway is a well-known implementation of bus rapid transit (BRT). Its main feature is the use of busways or bus-only roadways that separate buses from all other traffic, often by grade separation, to allow buses to maintain reliable rapid transit service. The busways were originally conceived of as technology-neutral transitways and were designed to allow conversion to a rail-based technology should the need arise.

In recent years, the downtown portion of Ottawa's rapid transit system has become congested due to capacity constraints at stations arising from the throughput of upwards of 180 buses per hour in the peak hour, or one bus every 20 seconds. With dwell times exceeding this, the result is the long queues of buses frequently seen in downtown Ottawa.

Establishing a light rail line through downtown Ottawa would address the capacity issue, lower operating costs and improve the local environment. Converting the Transitway outside downtown Ottawa would avoid the need for large bus-rail transfer terminals and further lower operating costs.

While convertibility to rail has been designed into Ottawa's transitways, no consideration was given to undertaking it without shutting down rapid transit service. This Master's Degree Project proposes a solution to the conversion problem by employing the use of interim single track rail infrastructure during conversion.

Key Words: Ottawa, Transitway, Busway, Bus Rapid Transit, BRT, Light Rail, LRT, Conversion, Rapid Transit, Transportation Infrastructure.

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for their support during the time I was carrying out this endeavour.

This project is dedicated to the long-suffering transit users of Ottawa, who deserve the real credit for Ottawa's transit successes but receive none and nonetheless hold out hope that it will some day improve.

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Chapter 1

Rapid Transit in Ottawa

1.1 Introduction

In the late 1970s, Canada's three "second tier" cities, Calgary and Edmonton in Alberta and Ottawa, the nation's capital, embarked on planning for the establishment of rapid transit systems. At the time there were two relatively new rapid transit solutions available to such cities. One was light rail, which was a successor to earlier streetcar and tram systems and the other was bus rapid transit (BRT), a key component of which is the busway, a road dedicated to the exclusive use by buses. The two Alberta cities each opted for light rail as their rapid transit solution, with Edmonton creating a small system centred on a downtown subway and Calgary creating a fairly broad system using a surface transit mall downtown. In stark contrast, Ottawa proceeded with a BRT system (subsequently termed "the Transitway") and concentrated on building busways outside the downtown while leaving the downtown comparatively untouched.

Though Ottawa chose to implement a bus rapid transit system, its 'transitways' (as the busways were termed) were designed to light rail standards in terms of such things as structural loadings and curves so that at some point in the future they could be converted to light rail if there was a need to do so. Ottawa is arguably at this point now. However, while Ottawa's transitways and other busways modelled on them have been designed to accommodate light rail requirements little consideration has been given as to how a conversion might actually take place, especially a conversion that does not significantly disrupt rapid transit service.

1.2 Background

Until the early 2000s, the issue of how to carry out a conversion of the Transitway was of little interest since the bus rapid transit system seemed to be working fairly well and a study from the late 1980s had proposed the building of massive twin bus tunnels under Ottawa's downtown, which seemed to offer the prospect of solving the sole significant problem in the system: the increasing bus congestion downtown. But since then a twisting tale of events has now brought the issue of converting the Transitway into prominence.

1.2.1 Transitway built

By the mid 1990s, the first phases of the Transitway programme were complete and a functioning BRT system was in place, though significant gaps where no busways were in place still remained to be filled. However, during the 1990s a recession hit Ottawa particularly hard because it was combined with employment reductions in Ottawa's major employer, the federal government. During this period ridership either stagnated or declined and even once the local economy began to pick up again there was little in the way of ridership gains because the employment growth was led by the information and technology sector, which was mainly located in suburban office parks poorly served by transit in Ottawa's western suburb of Kanata. With transit capital funding no longer available from the Province of Ontario and with stagnating ridership, there was little in the way of either means or justification for further Transitway expansion in the late 1990s.

1.2.2 Light rail pilot project: the O-Train

As an inexpensive alternative to transitway construction, it was proposed to make use of the lightly or unused railways that crisscross Ottawa. By happy coincidence, many of these railways run past or near major activity centres, such as Kanata's technology sector office parks, the international airport, Carleton university, and at least two "suburban" federal office complexes. A pilot light rail project was proposed for one of these corridors, running roughly north-south along a lightly-used CPR line. To save on both capital costs and time, it would use diesel-powered light rail vehicles (also known as diesel multiple units, or DMUs) rather than the electric vehicles and associated overhead infrastructure that are more typical. To satisfy federal safety regulations, freight service along the line would be limited to times when the light rail service was not running, such as at night. At its north end, about a kilometre west of Ottawa's downtown, the O-Train, as the pilot project was to be called, would interchange with the West Transitway. Along the line were stops serving Carleton University and two federal office complexes, with its southern end interchanging with the Southeast Transitway. The O-Train proved to be quite successful but despite that success it was not expanded along the other lightly-used railway lines in the region. The focus turned instead to extending, double-tracking and electrifying the existing north-south O-Train service, which would allow the service to go into downtown Ottawa without transferring to buses on the Transitway.

1.2.3 Amalgamation and the Rapid Transit Expansion Study (RTES)

Following the amalgamation of the former Regional Municipality of Ottawa-Carleton and its constituent municipalities into the new City of Ottawa in 2001, a study on the expansion of rapid transit service, the Rapid Transit Expansion Study (RTES), was carried out as one of the new City's first undertakings and was used to develop the City's new Transportation Master Plan (TMP). In general, it recommended retaining BRT on the Transitway (and against conversion to light rail) as the spine of the transit system with further outward extensions of the bus transitways, but it also recommended introducing electric light rail on several new transit corridors. One of those corridors was the existing O-Train line.

1.2.4 North-South Light Rail Transit project

The North-South Light Rail Transit project (NSLRT) was to be the first of the electric light rail projects and would have replaced the existing O-Train diesel light rail service. At first glance, there was much to commend the project: it would have extended light rail service to Ottawa's airport and would have been integrated with the land use planning for a new suburb in Ottawa's south, bringing transit service to a new development early on. It would also have brought light rail into downtown Ottawa, unlike the O-Train that terminates a kilometre west of downtown. But there were numerous flaws with it as well.

In downtown Ottawa the NSLRT would have been installed into the same lanes that the buses of the Transitway use but leaving 70% of the buses still operating. This was because the eastern terminus of the project was at the University of Ottawa and not the major hub of Hurdman Station, a decision that precluded the option to remove all buses from downtown Ottawa and use only trains downtown instead. Rather than twinning and then upgrading the existing track for electrification with the O-Train still running, it was instead decided to shut the O-Train down for three years and employ "shuttle buses" on much longer routes. Much of the O-Train route parallels the Southeast Transitway, a fact that already leads to some duplication of capacity, a duplication that would only increase if the trains were to head directly downtown. Since reusing this portion of the O-Train line would require the construction of multiple large grade separation structures, there was an obvious opportunity (Hunter, 2007) to convert the parallel Southeast Transitway to electric light rail instead and avoid such construction, but this opportunity to save both time and money as well as keep O-Train service running was passed up. Within the new suburb the project was to pass, Riverside South, the route to be taken by the NSLRT was surprisingly indirect considering that there was not yet anything there to work around.

Besides the area-specific flaws, there were overall flaws as well. The plans for the project revealed that there would only be single-car trains running with the possibility of lengthening them to two-car trains in the future. The ability to run longer three-, four-, and five-car trains (as Calgary plans for) in the future was effectively precluded. The ridership estimates were desultory and for some residents of the suburb of Barrhaven to which the project had been extended, trip times would have been longer by train than by bus. Finally, though it is arguably commendable to extend transit service to a developing suburb as it develops rather than after the fact, in the specific context of Ottawa it would do so without the transit service faced by the majority of existing (and potential) users being improved first, including in the congested downtown that would likely have been made worse still by the project.

NSLRT cancelled following election

Not surprisingly, opposition mounted to the project, including from many of the same transit advocates who had helped bring the O-Train to Ottawa in the first place. Since the project was dependent on both provincial and federal financial contributions, local senior government ministers became involved, whether by choice or not. John Baird, the then federal Treasury Board President, decided that federal funds would be withheld pending a vote on the project by the incoming City Council, since a municipal election was underway at the time in late 2006. The municipal election resulted in a new mayor who was opposed to the project and when Council reconsidered the project it voted to cancel it.

1.2.5 Mayor's Task Force on Transportation

In the aftermath of the cancellation of the NSLRT project, the mayor struck a small task force in early 2007 to study transportation and in particular transit issues in the Ottawa area. The task force's report, Moving Ottawa, recommended an incremental approach to improving and expanding rapid transit. At the centre of the recommended network was a rail tunnel beneath downtown Ottawa. To minimize construction costs and delays, the use of bimode diesel-electric rail vehicles was also recommended so that they could be used on existing rail corridors but still be suitable for electric operation in the downtown tunnel. Once an initial network was established on existing rail corridors, the Transitway would be converted to electric light rail and the existing rail corridors would also be electrified as demand and finances permit.

1.2.6 2008 Transportation Master Plan update

As part of the regular update of Ottawa's Transportation Master Plan (TMP), in March 2008 four new rapid transit network options were presented to the public. Of these four, two called for the partial conversion of the Transitway to light rail. The public consultation with its thousands of responses revealed that there was virtually no support in continuing to base the spine of the transit system on buses. In the following month, the fourth option, consisting of some conversion of the Transitway and electrification of the O-Train corridor, was recommended as the preferred transit network. As a slightly modified version of this option was adopted by City of Ottawa Council on 28 May 2008, the issue of how the city might go about undertaking the conversion becomes one of genuine interest.

1.3 The Conversion Problem

Since Ottawa's Transitway (and the busway systems of other cities modelled on it) was designed to accommodate light rail, the physical act of converting it from a busway to a light railway does not, in and of itself, pose any great challenge and would not warrant a project of this scope. Conversion would be a simple matter of taking up the asphalt road surface and replacing it with tracks, installing poles and overhead wiring for electric traction power, installing signalling systems, and, finally, modifying the stations as needed. However, the foregoing is premised on one crucial assumption: that there cease to be any buses operating while the conversion is carried out. In other words, rapid transit service (in that corridor) would effectively cease for the duration of the conversion. Obviously, this would be unacceptable in most cases and the apparent lack of an obvious solution that maintains rapid transit service while converting a busway to light rail is certainly a factor that has prevented any busway-to-light rail conversions from having taken place. The basic problem is that while busways have been designed to accommodate light rail requirements, little consideration has been given during their design, construction or operation as to how a conversion might actually take place without the cessation of rapid transit service.

While no city has yet converted a busway system to light rail Ottawa is a likely candidate city to begin undertaking such a conversion because of the maturity of the system, the strain it is currently under, and public pressure. Ottawa may therefore be the first city to face the issues that conversion will bring about, which is why Ottawa makes a good candidate for examining those issues.

1.3.1 Purpose

The purpose of this project is twofold; one, to investigate, explore and assess the issues surrounding the conversion of busway systems to light rail using Ottawa as the test case and two, to propose policy and design solutions that might be employed to facilitate such a conversion, for Ottawa in particular but also for other cities with busways or considering establishing them.

1.3.2 Objectives

The objectives of this project flow from the purpose, but are more narrowly focused on Ottawa. They are:

(1) To determine the issues of busway-to-light rail conversion in Ottawa

(2) To propose design solutions to those issues for Ottawa

1.4 Methodology

The approach for this project was based on a case study and was largely qualitative but with some quantitative elements.

A literature review was used to inform an analysis of BRT and busways that included theory, operations, implementations, and issues. This analysis was used to provide a gauge against which to assess the success of Ottawa's Transitway. Journal articles and books are the main sources to be reviewed.

An archival (document/record) review was conducted to determine key aspects of Ottawa's Transitway, including current data, history, design and construction. These key aspects were used in conjunction with the foregoing gauge to assess the success of Ottawa's Transitway. Ottawa-area transportation and master plans were amongst the documents reviewed.

Key informant interviews (Table 1.1) formed a key part of the project, as they not only helped provide insight into the history, political context, design and construction of Ottawa's Transitway but they also provided crucial insight into the issues surrounding conversion of the Transitway to light rail. Key informants were a then-City of Ottawa transit planner, Peter Steacy, and a City councillor, Gord Hunter. Mr. Steacy had been one the senior transit officials with the City of Ottawa concerned with the Rapid Transit Expansion Study of 2003 and was therefore well-positioned to speak on transit-related issues. Councillor Hunter is a long-time councillor and was familiar with the political context of the original rapid transit studies of the late 1970s/early 1980s and the decisions that have since followed. Other individuals, many associated with the transportation advocacy group Transport 2000, upon learning of the subject of the project in conversation provided comments and suggestions.

An analysis of the information gathered was conducted to identify the issues of converting Ottawa's Transitway to light rail and to provide an understanding of them from which options for undertaking the conversion were informed.

Following his interview, Peter Steacy of the City of Ottawa provided a copy of the Transitway Design Manual for reference purposes. Based on both the interview and the content of the design manual it became clear that while Ottawa's transitways had been designed to accommodate a conversion to light rail, no consideration had been given during their design or subsequent operation as to how this could be accomplished without shutting down rapid transit service during the conversion. It also indicated that further interviews with Transitway designers - i.e. the authors of the Transitway Design Manual itself - would not prove to be fruitful in yielding hoped-for cost-effective and minimally-disruptive options for conversion. This judgement was later proved to be correct when, in April 2008, an appendix on transitway conversion appeared in the supporting documentation to the City's update of its Transportation Master Plan. This documentation was prepared for the City by an engineering consultant that includes many former City of Ottawa/RMOC Transitway planners and engineers. The method of conversion proposed in that appendix called for the shutting down of rapid transit service in at least one direction (DTS, 2008, p. H1) and did not consider the possibility of trying to maintain it in both directions throughout the conversion. This is all the more striking because the other key informant, Councillor Hunter, provided a workable suggestion to maintain two-way rapid transit service based on the typical roadway construction practice of using a flagman system around short sections of construction.

At this point in the project after the initial interviews, it became clear that rather than attempt to carry on pursuing avenues of inquiry that would likely prove fruitless, a change of strategy was called for. Since the ultimate aim of the project is to create a rail system, a better understanding of railway operations was in order to ascertain if other opportunities might present themselves. In other words, consider the “conversion to” aspect as well as the “conversion from” aspect. After some background familiarization with railway operations and construction generally, a fuller appreciation of the operation of Ottawa’s existing light rail system, the O-Train, was gained. It became apparent at this point that the conversion problem is less an issue of construction - which is fairly straightforward in a prepared right-of-way - or engineering (the engineering already having been largely done at the time of original construction) than it is an issue of project management (sequencing, maintaining operations) and the application of some creative thought to the problem. That appreciation of railway operations and the nature of the problem, combined with the information already gathered on the Transitway from other sources, was used to develop the conversion techniques presented in Chapter 5 through a process of logical deduction. Those conversion techniques were presented to a knowledgeable audience on railway matters, the Bytown Railway Society, on 6 May 2008 and the feedback was used to refine and clarify the techniques.

1.4.1 Limitations

The limitations of the methodology used in this project concern the unavoidable fact that it is a theoretical exercise aimed at solving a real-world issue. The practical application “on the ground” may be quite different than envisioned here. The background research found no known conversions from busway to light rail (see section 5.2) so there is no prior experience to build on; at the end of the day the only known method of converting a busway to light rail is to shut the busway down to service and convert it while it is closed. That is always an option and a fallback position, but the purpose of this project is to explore other options.

Name	Position	Organization	Location	Date
Gord Hunter	Councillor Ward 9 - Knoxdale-Merivale	City of Ottawa	City Hall, Ottawa	30 May 2007
Peter Steacy	Program Manager Department of Planning, Transit and the Environment	City of Ottawa	City Hall, Ottawa	18 June 2007

Table 1.1: List of key informant interviews

1.5 Terminology: what is "Light Rail"?

A glossary of terms is included in this project, but a special note on light rail is in order to avoid reader confusion.

The term "light rail" is a rather ambiguous one as it refers to many different types of urban rail-based transit systems short of "heavy rail" metros or subways on separated exclusive rights-of-way and commuter rail systems operating on the same tracks as interurban passenger services and freight. Light rail can encompass mixed-traffic streetcar systems, semi-exclusive tramways and exclusive (or mainly exclusive) urban railways. This last is similar to a metro system but it lacks the full grade separation and complete exclusivity of true metro systems. Terms such as light rail metro, light metro, rapid light rail [transit] (RLRT) or light rail rapid transit (LRRT) could all be used to refer to such a system, an obvious example of which is Calgary's CTrain. In this work, light rail (and related terms such as light rail transit or LRT) will refer to this last form of light rail for both simplicity and practicality: if Ottawa's Transitway were to be converted to a rail-based system, it would end up looking very much like Calgary's CTrain system if no additional measures were taken to turn it into a full metro system.

For the purposes of this project, light rail's characteristics are summarized as follows:

- operating mainly in exclusive right-of-way with limited semi-exclusive right-of-way in high density urban areas (i.e. only other vehicles are buses, which should be few in number)
- grade-separation and/or transit pre-emption with only limited use of transit priority measures
- multi-unit trainsets for high passenger:operator ratios (at least two cars/carriages per trainset)

- stops on average every 1 - 2 kilometres, except in very high density downtown environments
- relatively high operating speeds - i.e. comparable to busways

It should be noted that the range of vehicles that may employed on such a system is quite broad and may include vehicles that are found on tramways and onstreet light rail, but there is an emphasis on vehicles designed for higher speeds so vehicles designed for streetcar service may not be appropriate. Diesel light rail is included in the definition as well since the current busways operate diesel buses to which diesel light rail vehicles such as Ottawa's O-Train are quite capable of providing similar service.

With a working definition of the objective of conversion established - light rail - this project begins with an overview of the what is to be converted - busways and bus rapid transit (BRT) systems - in the next chapter.

1.6 Chapter descriptions

- **Chapter 1:** Introduction to the project, including problem identification and methodology, and a background description of rapid transit in Ottawa.
- **Chapter 2:** Description of bus rapid transit (BRT).
- **Chapter 3:** Evaluation of Ottawa's Transitway, including the case for its conversion to light rail.
- **Chapter 4:** Discussion of the issues to be considered when converting a busway to light rail.
- **Chapter 5:** Conversion solutions, comprising both techniques for converting a section of transitway and strategies for the entire conversion.
- **Chapter 6:** Recommendations for the design of new bus transitways and accompanying policies as well as a discussion of the convertibility of 'convertible' busways.

Chapter 2

Bus Rapid Transit (BRT)

2.1 Introduction

This chapter will present a broad overview of Bus Rapid Transit (BRT) for the purpose of providing an understanding of the nature of bus rapid transit, what distinguishes it from regular bus services and why cities might implement it. The characteristics of BRT will be identified and BRT's advantages and disadvantages will be examined. The chapter will conclude with a brief discussion of the convertability of BRT to light rail.

2.2 What is Bus Rapid Transit?

2.2.1 Definition

Bus Rapid Transit (BRT), as the name implies, is a form of rapid transit based on the use of buses and supportive infrastructure and management. How rapid it is depends on the characteristics of its implementation. In practice, BRT can range from little more than a branding exercise to quite sophisticated systems with near light-rail-like features involving distributed electrical power systems and fixed guideways. In their report on BRT case studies in the United States and elsewhere, the Washington-based Transportation Research Board defined bus rapid transit as

> [...] a flexible, rubber-tired rapid-transit mode that combines stations, vehicles, services, running ways, and Intelligent Transportation System (ITS) elements into an integrated system with a strong positive identity that evokes a unique image. BRT applications are designed to be appropriate to the market they

> serve and their physical surroundings, and they can be incrementally implemented in a variety of environments. In brief, BRT is an integrated system of facilities, services, and amenities that collectively improves the speed, reliability, and identity of bus transit (2003a, p. 1).

McCormick Rankin was less wordy in defining bus rapid transit in a report they prepared on BRT in Canada for the Canadian Urban Transit Association:

> Bus Rapid Transit is a rubber-tired rapid transit service that combines stations, vehicles, running ways, a flexible operating plan, and technology into a high quality, customer focused service that is frequent, fast, reliable, comfortable and cost efficient (2004, p. 16).

With a reasonable definition of Bus Rapid Transit established, the theory behind it can now be explored.

2.2.2 Theory

Bus Rapid Transit is a means to try to solve one of the biggest problems with regular bus transit: the poor service that often results from buses operating in regular traffic. Buses operating in regular traffic tend to get stuck in regular traffic congestion. This has a detrimental effect on ridership as the average prospective user would just as soon be in his own car stuck in traffic as being in a bus stuck in traffic. Furthermore, taking the bus entails walking to and from the bus stop at each end as well as waiting for the bus in the first place, which of course may be stuck in traffic, leading to an even longer wait. These problems are compounded if transfers are required to complete the journey.

Commuter rail, underground systems and light rail do not generally suffer from the service problems caused by on-road traffic congestion because they operate, either entirely or for the most part, in their own rights-of-way. Rail-based systems, however, have high initial infrastructure and capital costs and the task of assembling the necessary rights-of-way for an entire line or network at one go can be difficult, time consuming and/or expensive. Many cities may also lack the economic and population base to support such an undertaking, though the particular circumstances of a city have to be taken into account as even relatively small European cities such as Karlsruhe, Germany, have successfully created new LRT systems by leveraging existing rail infrastructure (Cervero, 1998, p. 359).

Bus Rapid Transit, it is claimed, can help cities resolve this conundrum by combining aspects of metro and light rail systems, such as an exclusive right-of-way or running way, with those of a bus system, such as the vehicles, lower construction costs and the flexibility of operation and routing of buses. The aim is to provide a quality of service that is equivalent to that of light rail (in particular) but at far less cost (TRB, 2003a, p. 1).

2.3 BRT characteristics

The characteristics of Bus Rapid Transit were listed in the definitions presented earlier, but they will be elaborated upon in this section. McCormick Rankin (2004, p. 16) identified six characteristics of a BRT system. These are:

- Running Ways;
- Stations;
- Vehicles;
- Operating Plan;
- Fare Collection; and,
- Intelligent Transportation Systems (ITS).

2.3.1 Running Ways

Running ways are simply the lane on which a bus operates in a BRT system. It may be a dedicated busway, a bus lane, an HOV (High Occupancy Vehicle) lane or, in certain circumstances, a regular lane in mixed traffic (ibid, p. 17).

Busways

A busway is, essentially, a road for the exclusive use by buses (ibid, p. 17). The road is often in a separate right-of-way, sometimes grade-separated as in Ottawa, but it may also be located in the median of a major road, such as is found in Vancouver (Rendek, 2002, p. 84) or Curitiba (Cervero, 1997, p. 272). Another form of busway is a fixed guideway for buses. Once a bus (usually equipped with side-mounted guidewheels) enters the guideway the bus driver need only control the speed of the bus - the steering is controlled by the guideway. Adelaide's O-Bahn is an example of such a system (ibid, p. 364).

The terms ‘busway’ and ‘bus rapid transit’ are sometimes confused or used interchangeably but they are in fact distinct terms and concepts, the former being a running way and the latter a whole transit service. This confusion arises because busways are one of the most visible features of most BRT systems, so it is easy to equate a busway with BRT, and vice versa.

Bus lanes and High Occupancy Vehicle lanes

Most BRT systems include, or have included at some point in their history, bus lanes and/or high occupancy vehicle (HOV) lanes. These lanes are simply lanes on regular roads in which regular traffic is not supposed to operate. The curb lane is usually used but centre lanes are common as well, particularly if they are reversible. Bus lanes are for the exclusive use of buses whilst HOV lanes may be used by other vehicles with multiple passengers (usually three or more) and taxis. Cyclists often are also permitted to use HOV lanes.

Mixed Traffic

In some circumstances buses in a BRT system may operate in mixed traffic so long as the traffic is free-flowing enough not to cause delays. This is usually done to save money during construction but the planning will allow for separation of buses from traffic should congestion later become a problem.

2.3.2 Stations

Stations are one of the features of a BRT system that distinguishes it from a regular, mixed traffic bus system. BRT stations serve much the same functions as stations on a rail or metro service do; they are nodes in the BRT system between surrounding land uses and feeder services that offer a reasonably comfortable and secure location to access the BRT service and interchange with feeder services. In some BRT systems, such as Ottawa’s, they also provide an access point for feeder services to enter and leave the BRT running way, usually a busway. Stations may also provide a number of other functions common to rail stations, such as bicycle racks, park and rides, drop-off points, information boards and ticket machines, amongst others (McCormick Rankin, 2004, p. 18).

As with light rail stations, BRT stations are typically placed further apart than regular bus stops. Distances between stations generally vary between 600m and 2000m (TRB, 2003a, p. 4). Similarly to light rail, integration with adjacent land uses is feasible.

2.3.3 Vehicles

BRT systems usually employ standard buses in their early years but as time passes the use of more specialized vehicles becomes more common, in particular the use of articulated buses. Transit authorities also tend to deploy their newest conventional buses, now with standard features such as low-floors and wide doors, to the BRT system first so as to speed up boarding and alighting as much as possible.

So as to distinguish BRT from buses of the regular on-road bus system, some transit authorities employ unique buses with different designs, signage and colour schemes (McCormick Rankin, 2004, p. 19). Such buses may employ different technologies for propulsion and noise reduction (ibid, p. 19).

2.3.4 Operating Plan

An operating plan describes how a BRT system is used. The specific nature of an operating plan can vary significantly from city to city as the operating plan depends on the nature of the BRT system in place. However, the following services are fairly common.

Trunk Services

Light rail-like trunk services/routes operate on BRT services that employ busways. These routes are typically high frequency (5 minutes or less at peak periods, 10 minutes or less at non-peak periods) and the use of high-capacity vehicles such as articulated buses is common (ibid, p. 19). The trunk services are the services most closely associated with BRT and are the services that are the focus of special signage and colour schemes. If a BRT system uses specialized technology, such as guideways or electric propulsion, it will be first and foremost on a trunk service. BRT systems that have multiple busways radiating out from a central busway, such as Ottawa, may have more than one trunk service serving the central portions of the system.

Arterial and Feeder Services

Supplementing trunk services are arterial and feeder bus services (ibid, p. 19). Arterial services are main routes that generally travel along arterial roads. In some cities, articulated buses may be used for these routes. In a BRT system, arterial routes will intersect with busways at stations and may even travel along the busway. Feeder services travel through residential neighbourhoods and their winding routes can often intersect with multiple BRT stations. Feeder services do not generally travel along busways, though there are exceptions.

Express Services

Peak direction express services are a form of service that benefits enormously from busways in a BRT system. In the morning peak period, they travel on a winding route through a residential neighbourhood and then head to the nearest BRT station in the same manner as a feeder route. However, instead of dropping off all the passengers at the station, the bus turns onto the busway to head to the city centre, bypassing most intermediate stations on the way. The same route follows the same pattern but in the opposite direction in the evening. This type of service offers rapid, transferless service for users (Cervero, 1997, p. 249). Another type of express service is the counterflow express service, which, in the morning period, travels outwards along a busway before leaving it to head to a suburban employment node such as an office park or medical complex (McCormick Rankin, 2004, p. 20).

2.3.5 Fare Collection

Onboard collection of fares is one of the largest sources of delay in a bus system (ibid, p. 21). Such delays would impair the ability of a BRT system to be 'rapid' so reducing or even eliminating the need for onboard collection of fares is imperative. The use of monthly passes and tickets or tokens is a fairly common means of achieving this, as is allowing multi-door boarding to monthly passholders (ibid, p. 21). Curitiba's bus stations allow for fare payment prior to boarding (Cervero, 1997, p. 288).

2.3.6 Intelligent Transportation Systems (ITS)

Combined computer and communications technologies that enhance the convenience, safety and reliability of BRT, such as automated vehicle location and traffic signal priority, are collectively known as intelligent transportation systems (McCormick Rankin, 2004, p. 22). For example, traffic signal priority increases the speed and reliability of BRT by reducing the time that buses spend waiting at traffic signals (TRB, 2003a, p. 5) whilst automated vehicle location systems can be used to provide passengers with real time service information or enable the transit authority to monitor and control schedules and service (McCormick Rankin, 2004, p. 22).

2.4 Advantages and disadvantages of busways and BRT

2.4.1 Advantages of BRT

Compared to regular, on-street bus service, bus rapid transit offers a number of advantages. BRT is faster, more reliable and operating costs are lower (higher speeds result in the same bus covering more distance in a given time period). It may also hold a wider appeal than a regular bus service, particularly if efforts are taken to distinguish it from regular service in some way. BRT systems that make use of busways may also have an impact on adjacent land use (Cervero, 1998, p. 252) that one would not expect from a regular bus service, though it is unlikely that bus lanes on a regular road, even if part of a BRT system, would have any land use effects.

One of BRT's principal advantages is its flexibility, which has a number of aspects, including vehicle selection and system construction.

A BRT system generally does not require specialized vehicles; it can employ existing buses initially and acquire more specialized vehicles as time goes on and finances and ridership permit. This keeps down vehicle acquisition and operator training costs.

The implementation of a BRT system can be staggered or phased in. Bus or HOV lanes may be employed initially and then transition to busways as construction schedules, finances and ridership permit. A busway can be built in a leap-frog fashion so as to focus resources towards the construction of busway segments that bypass areas of high roadway congestion while continuing to use roadways (with bus lanes or without) where traffic congestion is less serious (ibid, p. 244). In other words, the system does not need to be constructed either in whole or linearly, but can be assembled in response to localized needs. A related advantage is the relative ease of responding to new growth. Expansions of the busway in new directions to exploit new destination opportunities may be possible (ibid, p. 245) and new routes or modifications to existing routes are almost always possible. A prime example of the routing flexibility of BRT is that of transferless express routes, which collect passengers in a residential neighbourhood in the same manner as a feeder service but takes them to the central business district with few, if any, stops.

Because the system does not need to be built-out in full, BRT can save on the costs of construction compared to a light rail system serving the same corridor. Or, for the same amount of funding, a more extensive transit system can be established. BRT also has lower implementation costs than light rail systems because it does not require electrical power infrastructure (e.g. overhead wires or third rails, substations, etc.), it can use regular roadway building techniques and new, specialized storage and maintenance facilities are not required (McCormick Rankin, 2004, p. 23). Some BRT systems do make use of distributed (i.e. overhead) power systems and electrically-powered buses (trolley buses) but these need not be installed initially.

2.4.2 Disadvantages of BRT

Given the broad range of implementations that fall under the moniker of "BRT", it is possible that some services that are called "BRT" may in fact be little more than a branding exercise of what is essentially a regular arterial route and may do little to foster increases in transit use. That being said, BRT has few, if any, disadvantages compared to regular bus service besides higher capital costs, but it does have a number of significant disadvantages compared to light rail.

Compared to light rail, BRT may not attract as many choice riders. Choice riders are transit riders who choose to take transit rather than the personal automobile. Choice riders may choose to commute by transit to avoid being caught in traffic congestion or because transit use allows for a more productive use of their time for reading or work (TRB, 2003b, p. 1-1). Indeed, there is recent evidence to suggest that new light rail operations attract far more riders than forecast (LRN, 2001b); Ottawa's O-Train pilot project, for example, was estimated to carry 5100 passengers per day (Ottawa, 2002) but the actual number in 2005 was in excess of 10,000 passengers per day (Transport 2000, 2005, 1), with unsubstantiated reports of 12,000 or more in 2006. This underestimating may be the consequence of using a bus-based estimation formula for ridership in a rail corridor, which is based on an assumption that buses and trains attract riders equally (LRN, 2001b).

In heavily-used corridors, BRT is more expensive to operate than a comparable light rail service. With light rail, multiple vehicles can be coupled together into trains requiring only one operator instead of the multiple drivers that would be required in a bus-based service (LRN, 2001a). With operator wages comprising the largest operating cost category, the savings of a rail-based system can be significant. Ongoing capital costs of BRT may also be higher than light rail as road maintenance tends to be higher than that of rail and buses wear out sooner and thus require replacement more often than railcars (LRN, 2006).

In densely built-up corridors requiring many structures for grade separation, busway construction costs may approach and even exceed light rail construction costs. This is because buses are unguided and therefore require more right-of-way width to ensure safe operation. The extra structural (and often excavation) width - as much as 60% extra - is costly to build and may be more disruptive to construct as well. Station building costs can be higher for BRT too. Since most buses, unlike rail vehicles, have doors only on one side, stations with two platforms are usually required for BRT where light rail could operate with a single, central platform. Where space is at a premium, and even where it is not, this raises the cost of BRT compared to light rail.

BRT has a lower maximum capacity than light rail; to even approach light rail capacity requires that BRT be made very rail-like with fixed guideways and the like, which tends to be costly and remove some of the advantages of BRT, such as flexibility of service routing. Ottawa's Transitway is often claimed to have a capacity of 10,000 passengers per hour per direction (Cervero, 1998, p. 247), but this volume has never been achieved. As of 2005, Ottawa's Transitway was carrying 6500 passengers westwards out of the downtown and 8500 eastwards at the peak afternoon hour (Ottawa, 2005b). Given the congestion already present, it is highly unlikely that 10,000 passengers per direction could be moved in one hour. By contrast, a three-car train with a capacity of 200 passengers per railcar running every 4 minutes can move 9000 passengers per hour. Since 2 minute intervals or less are possible and trains can be four, five or even six cars long, much greater volumes are achieveable with light rail.

Pollution, especially localized air pollution, is much more of a concern with BRT based on the use of existing diesel-powered buses than is the case with LRT because most implementations of LRT use electricity for power. Even compared to diesel-powered light rail systems, current buses tend to pollute more on a per passenger basis. Where cleaner sources of electrical power can be found (e.g. wind power for Calgary's CTrain), then LRT can be considerably less polluting overall than BRT. Additionally, in winter climates BRT will require road salting to remain operational, something that is not true for LRT.

Finally, transit-supportive land use changes along BRT may be slower in coming than along an LRT line as the sense of permanence required for developers to invest may not be present except with the more extensive (and therefore more costly) busway-based BRT systems. Moreover, stations may be constructed as an afterthought or long after the construction of the destination and suffer from poor integration with destinations (e.g. passengers end up having to walk across parking lots).

2.4.3 Advantages and Disadvantages: Summary

As a means of establishing a rapid transit system from scratch, bus rapid transit is an incremental, affordable and versatile option to achieving that goal. For small to medium-sized cities, as well as along moderately-used corridors in larger cities, BRT may be all that is ever needed. In larger cities, however, as build-out proceeds and ridership grows, the inherent constraints and costs of a transit system based on buses alone along heavily-used corridors become apparent. In those situations, conversion to light rail becomes an increasingly attractive prospect.

2.5 Convertability and Upgradeability to Light Rail

Given the limitations of bus rapid transit, many cities have devoted extra resources to the design and construction of busways to enable their future conversion to light rail (Parsons Brinckerhoff, 2005, p. 3), including Ottawa (Cervero, 1998, p. 248), when demand warrants it. It should be noted that not all forms of BRT would be suitable for conversion to light rail; only those systems that use busways would be suitable (Parsons Brinckerhoff, 2005, p. 1).

Busways where future conversion to light rail is anticipated would need to incorporate a number of elements into their design and construction to facilitate that conversion. The consultants of Parsons Brinckerhoff (2005) identified the following critical elements in their study of BRT to LRT convertability for the Seattle-area transit authority, Sound Transit (p.3):

- Horizontal geometry (alignment)

- Vertical geometry (grades and clearances)
- Cross sectional width
- Structural elements (including loading, pavement and stray current protection)
- Utility accommodation (both relocation, new services and drainage)

In Ottawa, the Transitway was designed with provisions for vertical clearances (e.g. station walkways and bridges), structural loadings and geometry (ibid, p. 5) as well as in the design of the stations to allow for long platforms. These and other issues related to the conversion and convertability of busways to light rail will be explored in greater detail in chapters three and four.

By devoting extra resources to enable future conversion of busways to light rail, there may be a trade-off between future convertibility and present catchment area since theoretically a larger busway network could be purchased for the cost of those extra resources. However, since BRT systems draw in buses from large distances anyway, the likelihood of a significant change in catchment area is minimal. To the extent that there is an effect, it will be felt mainly in operations where the savings (from switching from an on-street bus system to a busway system) might not be as high as they could have been. Moreover, the extra resources devoted to enable future conversion are minimal anyway:

- Busway geometries (horizontal and vertical) are designed are to highway standards so are all well within light rail capabilities, including vertical clearances - especially if double-decker buses are provided for
- Cross section is not generally an issue in practice since bus and light rail vehicle requirements are similar; indeed light rail can have narrow requirements
- Structural elements are less of an issue than one might expect; for example overpasses have to accommodate weight of construction vehicles
- Utility accommodation is a planning issue when choosing to locate the utilities

2.6 Summary

This chapter provides an understanding of what is meant by the term ‘bus rapid transit’ and why it has become such a popular option amongst cities establishing or expanding their mass transit systems. Those reasons include its ease of implementation and expansion, the ability to use existing rolling stock without additional employee training, capital cost savings compared to light rail and operating cost savings compared to regular bus systems. As part of a long term plan to increase transit usage, BRT can further this goal by providing a service that is more attractive to potential users than regular bus service and may even induce transit-supportive land use changes along its route that further increase ridership. A particularly appealing aspect of BRT is that it can be phased in or implemented in stages; it represents a spectrum solution rather than the “all or nothing” solution of a rail system. Another appealing aspect of BRT, and one that has been incorporated into some BRT systems like the Transitway in Ottawa, is the possibility of eventual conversion to light rail when BRT can no longer handle the volumes asked of it. This chapter sets the stage for furthering the exploration of issues into converting a busway-based BRT system to light rail.

The next chapter will examine Ottawa’s Transitway and bus rapid transit system, its current ridership and its place in Ottawa’s transportation system as well as providing a greater understanding of the strains it is currently under. It will also examine what elements were incorporated into its design to ease future conversion to light rail.

Chapter 3

The Transitway: An Evaluation of Ottawa's Bus Rapid Transit System

3.1 Introduction

Anyone who spends more than a few weeks in Ottawa will soon hear about "the Transitway". The Transitway, an implementation of bus rapid transit (BRT), is Ottawa's transit backbone, and, indeed, its transportation backbone as it carries more people every weekday than the 6-8 lanes of the Queensway (TRB, 2003, p. 17), Ottawa's major east-west freeway. This chapter will examine Ottawa's Transitway, beginning with an examination of its origins and context and the planning policies that brought it into existence. Notable features and innovations of Ottawa's Transitway will also be looked at before considering how successful it has been as an implementation of busway-based BRT (i.e. ridership, volumes, integration of stations with adjacent land uses, land-use intensification in the vicinity of stations) as well as providing a greater understanding of the strains it is currently under, including the causes of those strains.

3.2 Origins and Context of Ottawa's Transitway

3.2.1 Post-war Gréber Plan

Following the Second World War, Prime Minister MacKenzie King invited French planner and architect Jacques Gréber to draw up a plan for the capital (Gordon, 2001). His landmark 1950 plan, the *Plan for the National Capital*, commonly known as "The Gréber Plan", was the result. Besides tearing down the temporary wartime offices to make way for new national buildings, the main components of interest in the plan were (Gordon, 2001):

- removal of all railways and railyards from the urban core and dispersal to outer areas as well as taking up streetcar tracks
- creation of a network of parkways, expressways and freeways along with bridges
- dispersal of federal offices to other parts of the city (including across the Ottawa River in Hull)
- creation of a greenbelt to contain the urban area and to reserve land for future uses, such as the airport

Gréber's plan focussed on moving people by automobile; what public transit there was would thenceforth be by bus as the streetcar tracks were to be taken up. The plan and its implementation by the National Capital Commission (NCC), a federally mandated and funded agency created for that purpose, would dominate planning activities in the Ottawa area for the next two decades.

The Greenbelt failed to contain sprawl, partly because the Queensway punctured it in both the east and west and partly because the surrounding townships had no desire to follow the recommendations of Ottawa or the NCC to establish more distant and contained satellite cities (ibid). Some of the townships had territory on both sides of the Greenbelt and saw no particular reason to treat land outside the Greenbelt any differently than land within it. By the late 1960s, the growth pressures of the ever-expanding federal government and the animosity between the townships and the city had created a situation that was spinning out of control. The Province of Ontario stepped in to resolve it.

3.2.2 1974 RMOC Official Plan: Transit First

In 1969, the Province of Ontario created a new regional government in the Ottawa area out of the County of Carleton, which surrounded the city of Ottawa, and Ottawa itself. The former county's townships and the City of Ottawa (as well as a few 'villages' and another small city) were placed on an equal footing as lower-tier municipalities within the new upper-tier municipality, the Regional Municipality of Ottawa-Carleton (RMOC) (Wikipedia:RMOC).

The RMOC's council was initially appointed by the councils of the lower-tier municipalities, which gave it a separation from the voter and also a fair degree of independence, even from the municipalities. The RMOC was responsible for services that would most efficiently be delivered on a regional basis such as trunk sewers and water mains, transportation planning (public transit and arterial roads) and regional planning (ibid).

With a scale incorporating the entirety of the Ontario side of the National Capital Region and with regional powers to match, the RMOC set about taking control of regional planning from the NCC, which, by this point, had largely run out of things to do from the Gréber Plan. This marked a sea change in the Ottawa area and its effect in unifying the municipalities behind the RMOC cannot be underestimated.

Besides a general displeasure with the NCC, the one thing that all the municipalities (and residents) were in agreement upon was that traffic congestion was becoming a serious issue and that this would have to be addressed in the first regional plan (Fullerton, 2005). The RMOC sought considerable public input during the formation of its first regional plan (ibid). This was in stark contrast to the NCC, which until quite recently never did.

A surprising consensus soon crystallized that regarded transit as the only viable solution to the growing congestion problems caused by large numbers of suburban workers commuting to downtown. Surprising because even the suburban townships and their automobile-dependent residents all shared the same view as the inner area urban dwellers. Arguably, the OPEC crisis that struck during this period with its rising oil prices helped contribute to this view of transit as the way to go (ibid).

RMOC planning staff considered various scenarios for future urban growth and concluded that a model of continued core employment growth combined with transit-serviceable corridors of suburban development beyond the Greenbelt was best. The satellite communities would be connected to the urban core and each other via a rapid transit network but physically separated from one another by farmland or open space (ibid). This was the model that formed the basis of the RMOC's 1974 Official Plan, but only in a broad conceptual form (Figure 3.1). The specifics of the nature of the future rapid transit network would have to wait.

What was notable and unique about the 1974 Official Plan was its emphasis on transit: transit projects would be given priority over roadway construction and expansion (ibid).

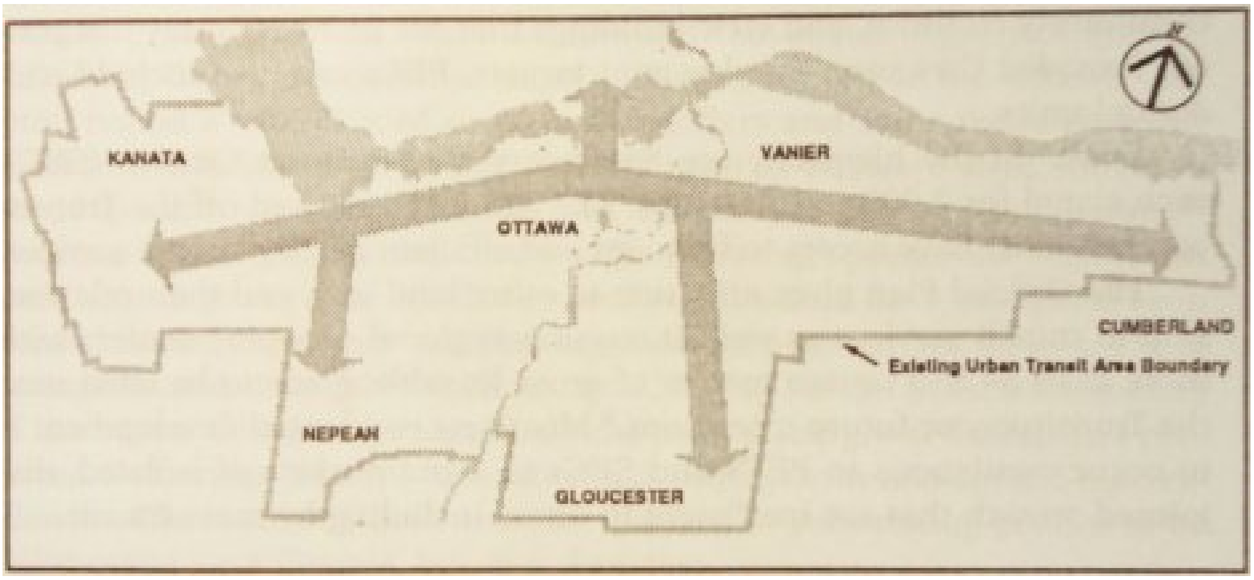

Figure 3.1: The Rapid Transit Concept of the 1974 Official Plan.
Source: Regional Municipality of Ottawa, *Rapid Transit Appraisal Study* (Ottawa: RMOC, 1976) in Cervero, "Busways and the Hybrid Metropolis: Ottawa", *The Transit Metropolis: A Global Study*, p. 241.

3.3 Why did Ottawa go with BRT and not Light Rail?

The RMOC Official Plan of 1974 had established that a rapid transit network would be created in the Ottawa area, but it did not mention what form that network would take. Subsequent studies were commissioned and eventually determined that Ottawa's rapid transit network would be bus-based, or what is known as Bus Rapid Transit (BRT).

3.3.1 Ottawa chooses Bus Rapid Transit

The Regional Municipality of Ottawa-Carleton had a unique problem that was the result of one of the region's defining land uses: the Greenbelt. It had to bring commuters from the low population, low density suburbs beyond the Greenbelt, as well as from low-to-medium density suburbs within the Greenbelt, to the downtown core. The strong central area employment, courtesy of the federal government, was an element in Ottawa's favour.

When the RMOC deliberated on the form of rapid transit technology to use, it considered the entire transit system and not just the rapid component (Gault, 1996, p. 2). In this process, it evaluated the following factors: capital and operating costs, level of service, staging flexibility, and environmental impact. The RMOC concluded that, at that time, the region was not supportive of light rail, in part because of longer travelling distances created by the Greenbelt, and that bus rapid transit offered the best match to Ottawa's urban form. As Gault, of the then Ottawa-Carleton Regional Transit Commission, explains (1996, p. 3):

> The passenger demand over most of the corridors varies quite significantly from the downtown. With a rail system, the opportunity to short turn trains is almost non-existent so that[1], except in the central area, the train capacity exceeds the demand. In the case of the busway, the use of many different bus routes produces much greater opportunities to adjust the overall system capacity to more nearly match the demand.

It was found at the time that the capital and operating costs of a busway-based bus rapid transit system were some 20% lower than those of a light rail system (Gault, 1996, p. 2). The lower capital costs are not surprising, but the lower operating costs are. One would expect bus rapid transit to have higher operating costs because of a higher driver to vehicle ratio (Martinelli, 1996, p. 194). The operating costs were lower because of the closer demand/capacity relationship that Gault mentioned and because of more potential for interlining of bus routes (ibid, p.3), a method of scheduling that allows for a bus to make a revenue trip on one route and then deadheading to the start of a different route rather than deadheading back to make another trip on the initial route (Koffman, 1993, p. 3). In contrast, a rail system presents fewer opportunities to interline feeder bus routes because the number of routes at any given station is limited (Gault, 1996, p. 3).

There were other advantages as well; express buses were compatible with low-density residential land uses and the break created by the Greenbelt. An 'outside-in' approach to busway construction could be adopted that would be able to maximize busway mileage with the available funding and deal with the downtown later (ibid), which would allow the Transitway to extend into new town centres early on, rather than later (ibid). New sections of the Transitway could also be brought online and put into use as soon as built rather than having to establish a continuous route (ibid, p. 4). Such an approach would also allow for the use of existing vehicles.

Taken together, these factors explain the decision to construct the Transitway as a busway.

[1] Short turning trains can be accomplished using a crossover and a siding or turnout; the corresponding busway infrastructure is a turn off, which requires a ramp where the busway is grade separated.

3.4 Planning Policies

From the policies they advanced, it is evident that the RMOC's planners recognized the need to link transportation and land use policies. As mentioned, the 1974 Official Plan called for the development of a multi-centred urban structure in which downtown Ottawa would remain the dominant commercial, employment and cultural centre but orbited by a hierarchy of primary and secondary nodes (Cervero, 1998, p. 241) or 'town centres'.

These town centres would be linked to the downtown and each other by the Transitway, and, crucially, its development would take precedence over road widening and construction (Cervero, 1998, p. 243), also referred to as the "transit first" policy (Gault, 1996, p. 2). The stations in suburban town centres were to be built as the new town centres are formed (ibid, p. 4). However, outside the town centres market-driven development would be permitted, including "low-density spread" (Cervero, 1998, p. 241).

A number of transit-oriented policies were adopted by the RMOC. One called for increases in employment near Transitway stations: 40% of jobs were to be within 400m of one (it was 32% in 1996)(ibid) within a hierarchy of Primary Employment Centres (PECs, 5000+ jobs) and Secondary Employment Centres (SECs, 2000-5000 jobs) (ibid, p. 242). Another required that regional shopping centres with more than 34,840 square metres of gross leasable space be sited near the Transitway or future extension thereof (ibid, p. 242).

In new subdivisions, collector roads were to be designed to allow efficient transit circulation and bus stops and shelters were to be conveniently located (ibid, p. 245). There were also guidelines to encourage the siting of retail centres, seniors' residences and the densest land uses near transit lines with single-family residences and parks further away (ibid, p. 245). Recognizing the importance of ensuring that office workers did not need to drive off-site at lunch to access restaurants, banks and other services, mixed-use development was encouraged at SECs (ibid, p. 245).

To discourage automobile use, parking policies were also introduced or revamped. In a spirit of cooperation, the federal government began eliminating free parking for its employees after the Transitway opened, which reduced the number of downtown parking spaces by 15% between 1975 and 1984, even as office space nearly doubled (ibid, p. 246). Another policy reduced the number of required parking stalls at retail centres for each bus bay that was integrated into the retail centre (ibid, p. 246).

Finally, the RMOC encouraged employers to stagger working hours to distribute commutes over a wider time frame (Fullerton, 2005), thus allowing the bus fleet to carry more commuters. The federal government also cooperated in this regard (Cervero, 1998, p. 246), and eventually extended the staggered hours policy to all its offices and not just those downtown (Fullerton, 2005).

3.5 The Transitway

3.5.1 The Transitway today

Within the Greenbelt, the Transitway network is 31 kilometres in length; almost 26 km of that is in the form of busways and another 2 km are bus-only lanes downtown. The remaining 3 km or so are on the NCC's mixed-traffic Ottawa River Parkway (Cervero, 1998, p. 246). There are another 3 kilometres of busway cutting across the Greenbelt to the southern suburb of Barrhaven and 1 km of busway heading west to Kanata before the busway ends and becomes bus-only lanes along the Queensway for 8 km through the Greenbelt. In the east of the city heading towards Orleans, again cutting through the Greenbelt, are another 11 kilometres of bus-only lanes along the Queensway, for a total Transitway network of about 54 kilometres (Figure 3.2).

3.5.2 Notable features and innovations of the Transitway system

Ottawa's Transitway is the exemplar for bus rapid transit because it exemplifies one of the main advantages of BRT: flexibility, both in construction and in operations.

Rapid transit systems are typically built from the core outwards, but not the Transitway. As recognized in the early studies, the RMOC adopted an 'outside-in' approach to constructing the Transitway (Gault, 1996, p. 3). The creation of a separate and exclusive right-of-way in the core, which would likely have been quite costly, was left for later. Instead, the available funding was in effect leveraged to create an extensive network outside the core (ibid). Additionally, individual segments were brought into operation as soon as they were ready (Cervero, 1998, p. 245), with buses continuing to use regular roads in the meantime. For example, the so-called Scott Street trench segment took longer to

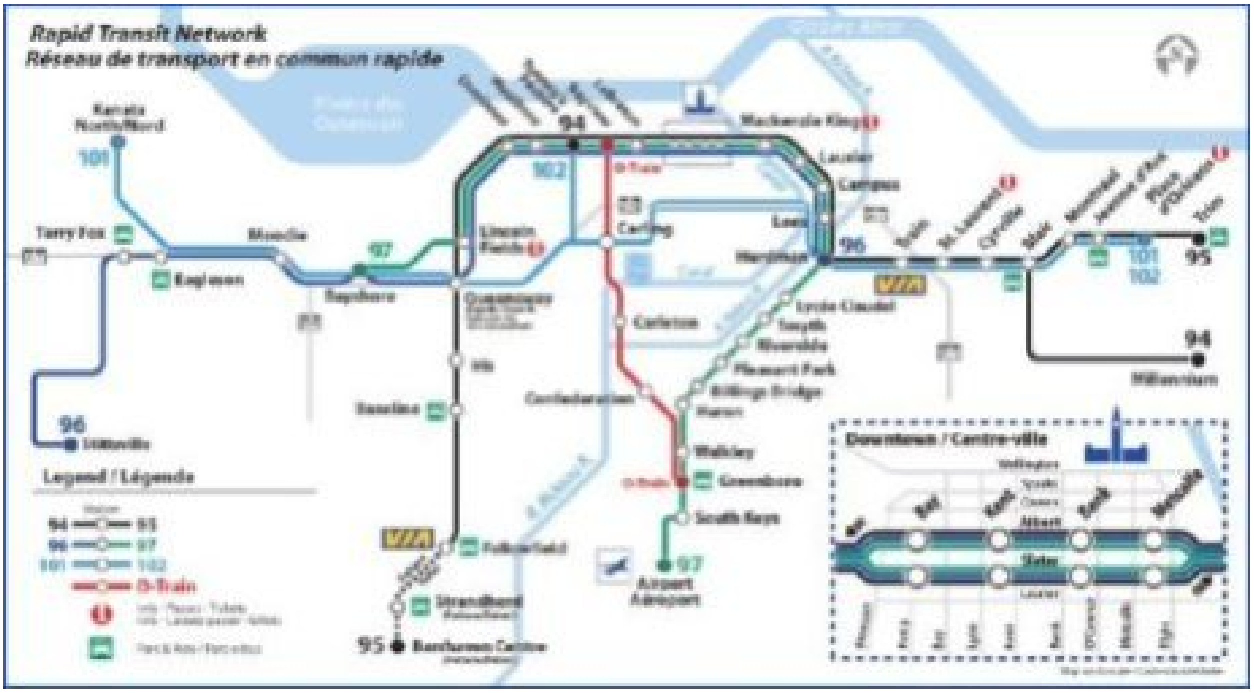

Figure 3.2: System map of Ottawa's Rapid Transit Network, the Transitway.
Source: OC Transpo
<http://www.octranspo.com/mapscheds/Transitway/Rapid_Transit%20_Map.pdf>

complete than the Baseline to Lincoln Fields segment further out, yet the latter was in use while the former was still under construction; buses continued to use contraflow lanes on the Ottawa River Parkway to travel to the downtown.[2] Indeed, to this day, the Transitway continues to operate along a few kilometres of the Ottawa River Parkway as the traffic on it is not heavy enough to impede bus flows. This is an illustrative example of both the flexibility of BRT in the staging of construction and in its operation.

The outer segments also helped establish momentum and provide visibility (and therefore political support) for the Transitway project. By 1996, the 31 kilometre network had been largely completed at an estimated cost of about $440M (Gault, 1996, p. 7) or at an average cost per kilometre of $14M, which includes the average station cost of $4.5M (ibid). A fully built-out light rail network would undoubtedly have cost more (20% to 30% more) and it could not have been put into operation nearly as quickly.

As a busway, existing regular buses were used initially as there was no need to wait

[2] The Baseline - Lincoln Fields segment was completed in 1983 and my family moved into a Westboro neighbourhood in 1984 adjacent to the trench while it was being blasted out, and both the author and his father and can recall seeing buses travelling contraflow on the Parkway.

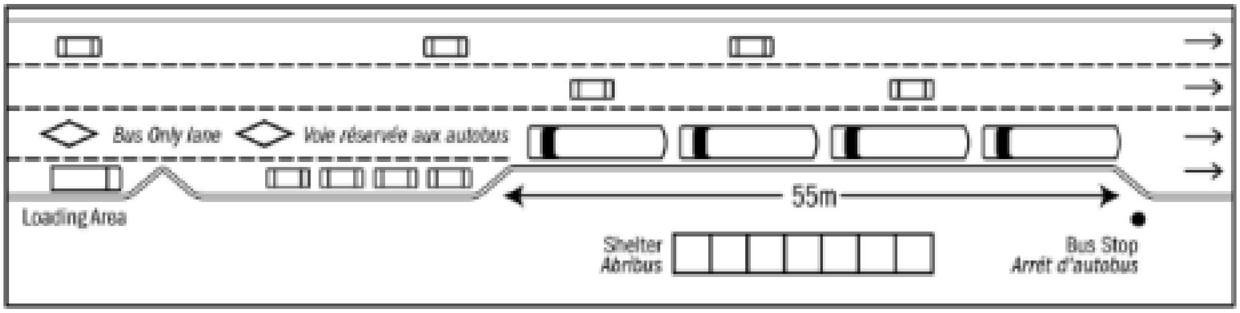

Figure 3.3: Diagram of Ottawa's innovative downtown 'fast acting lanes'.
Source: Transportation Research Board, *Ottawa BRT Case Study*, 2003, p. 36

for specialized vehicles to put busway sections into use. Dedicated articulated buses for the main Transitway route (the 95) were acquired early on and gave that route a distinctive appearance, but that was not necessary for the functioning of the system. Even after the articulated buses were acquired, regular buses continued to use the Transitway in the guise of peak-hour routes and some regular, all-day routes.

A prime example of the routing flexibility of BRT is that of transferless express routes, which collect passengers in a residential neighbourhood in the same manner as a feeder service but take them to the central business district with few, if any, stops. In a light rail system, passengers would have to transfer from a local bus to the train at a station, but because of the design of the Transitway's stations buses can drive onto the Transitway to head downtown. Moreover, every Transitway station outside the downtown is equipped with passing lanes, so express or peak-hour buses can drive past other buses that may be stopped at a station.

Even though the downtown was not the primary focus of attention, operations there are still critical to the functioning of the system as a whole. The chosen solution was bus lanes, but not the regular curb bus lanes found elsewhere. The Transitway travels through downtown on two one-way streets (Albert westbound and Slater eastbound) that are each four lanes wide. Buses operate in a 'fast acting lane' (Figure 3.3) that is the second lane out from the curb (Gault, 1996, p. 6). Platforms are constructed by extending the sidewalk out into the curb lane, thus providing more room for shelters and passengers (Cervero, 1998, p. 248) without blocking the sidewalk for pedestrians. Between platforms (which are typically two blocks apart), the curb lane is used for necessary urban functions like loading zones, short-term parking, access to laneways and underground parking, and as right-turn lanes at intersections. While there is some unavoidable crossing of the bus lanes by other vehicles, this innovation largely eliminates the potential for conflict between buses and stationary vehicles that is the bane of bus operations on most other urban streets.

A few other features of the Transitway are also worth mentioning; many stations are grade-separated to separate local buses from Transitway buses. Such stations are equipped with elevators for accessibility (Gault, 1996, p. 4). Another innovation is the use of metalling on the curbs at the platforms/sidewalk of Transitway stations. This allows buses to get much closer to the platform to aid in boarding and alighting than would be possible with concrete curbs, where there is a much greater risk of the bus driving up onto the platform. During the summer, most of the articulated buses that travel along the Transitway have been equipped with bicycle racks. These allow for commuters who work further from the Transitway to have a ready form of transport to their final destination. Many cyclists who use this service also use it only in the morning, and cycle home in the afternoon[3].

When considered as a whole, it becomes clear that the RMOC took a pragmatic approach to building up a rapid transit system in the form of BRT. As the Transportation Research Board notes in their Ottawa case study (p. 7):

> One of the more striking features of BRT transit planning in Ottawa has been the emphasis on coverage of the system, rather than investing heavily in short sections of mass transit in the more congested central area.

This coverage has no doubt contributed to Ottawa's high transit ridership, covered in the next section.

3.6 Success and Failures of Ottawa's Transitway

3.6.1 Transit ridership

Ottawa's commuter transit ridership at 20.1% (based on 2001 census data) rivals that of Toronto (22.4%) and Montreal (21.7%), both of which are far larger in population and have subway systems. It also comes in far higher than the slightly more populous Calgary (13.2%) and the much more populous Vancouver (11.5%)(Ottawa, 2004). When including Gatineau, which does not yet have a rapid transit system, Ottawa-Gatineau's number

[3]Based on personal usage and that of other cyclists. The advantage of taking the bus in the morning is that there is no need to shower or change when arriving at work (even with a five-minute ride from the station); for the afternoon ride home one would typically change at work and shower at home.

falls, but to a still respectable 18.5% (ibid), with a population slightly larger than Calgary's. Within Ottawa itself, one third of commuters leaving the eastern suburb of Orleans do so by bus (Drolet, 2006, p. C4).

There was an average of 346,800 boardings on OC Transpo's buses (the City-owned transit agency) every day in 2005, with over 200,000 of the trips from those boardings taking place in part on the Transitway (OC Transpo, 2006). Peak hourly volume is claimed to be 10,000 riders per direction per hour in 175 buses (ibid).

The ridership numbers speak for themselves: the Transitway, with its breadth of coverage and in concert with the policies mentioned previously (parking, flex hours, employment node location), has helped Ottawa attain its enviable ridership levels, especially compared to other Canadian cities.

3.6.2 Savings

Not only has the Transitway helped bolster Ottawa's transit ridership numbers, it is also responsible for considerable savings. In 1996, it was estimated that without the Transitway OC Transpo would have required 150 more buses to carry the same number of passengers. The capital cost of those buses would have been $45M and their annual operating cost (again, in 1996) would have been $25M (Gault, 1996, p. 4), which assumes that the ridership would have been as high in the absence of the Transitway. For the Transitway's users, there are no doubt time savings because of it.

There are other implicit savings as well: every kilometre of the Transitway carries up to ten times the number of people as a kilometre of the regional (arterial) road system (Gault, 1996, p. 3). Five freeway lanes per direction would be required to carry 10,000 by automobile (Cervero, 1998, p. 247), which considering the Queensway has at most four lanes per direction as it passes south of the downtown core of the city, says quite a bit. The financial cost of constructing all that extra road capacity - including all the expropriations that would be required - would be considerably more than the $440M that was spent on the Transitway (Gault, 1996, p. 7). There is also the environmental and land savings to be considered from not building extra roads, and the social dislocation that was avoided as well.

3.6.3 Transit Oriented Development

A question of interest to planners, urban designers and developers is whether a busway can spur the sort of transit oriented development usually associated with light rail and metro systems. Ottawa's Transitway provides some evidence that it does.

The two best examples of such development are the St. Laurent Shopping Centre on the Eastern Transitway and the Riverside Hospital on the Southeastern Transitway. An expansion of the St. Laurent Shopping Centre happened to coincide with the construction of the Eastern Transitway, allowing for a physical integration of the station and the shopping centre (Cervero, 1998, p. 253). One of the region's largest, if not the largest shopping centre, a third of the customers arrive on the Transitway (TRB, 2003, p. 17). The story is similar at the Riverside Hospital, which was slated for expansion at the time of Transitway construction. A new wing was built right over the Transitway and its station, allowing unparallelled access to the hospital for staff, visitors and patients (Cervero, 1998, p. 253). In both cases, co-operation between the RMOC's planners and the owners of the facilities enabled these developments.

The shopping centres Place d'Orléans in the east and Bayshore in the west now also incorporate some form of transit integration. The owners of the would-be Gloucester Centre were convinced to build it to front onto Blair Station and provide a covered link to the station rather than siting it on the other side of the site across a vast parking lot (Cervero, 1998, p. 255). The Rideau Centre in downtown Ottawa is located adjacent to the Transitway, resulting in some 60% or more of its customers arriving by transit (TRB, 2003, p. 17). Billings Bridge Plaza is also directly linked to Billings Bridge Station and has since seen some expansion. The plaza near Baseline Station has seen much expansion in recent years, though its location adjacent to Algonquin College must also be taken into account. That said, many of the students attending Algonquin College arrive via the Transitway. The new Transitway stations in the suburbs of Barrhaven and Kanata are located in the middle of retail areas, but these appear to be of the "big box power centre" variety and not the more pedestrian-oriented shopping centres found elsewhere in Ottawa, both on and off the Transitway.

A few Transitway stations have become employment nodes. Blair Station has seen the most growth in employment (Cervero, 1998, p. 255), whilst St. Laurent, Cyrville and Baseline stations have also seen employment growth (ibid, p. 253), and, in the case of the latter, medical-dental facilities as well. Tunney's Pasture Station, located at the existing federal office complex, has seen the construction of the mixed-use Holland Cross, a project that may not have taken place without the Transitway (ibid, p. 255).

The gentrifying neighbourhoods of Westboro around Westboro Station have been the subject of some of the greatest amount of residential intensification in the city. Where once there were abandonned fields and yards, there are now townhouses and the 32 storey Metropole condominium tower. Other condominium developments are taking place within Westboro Village itself, as has much pedestrian-oriented mainstreet retail development, including the new location of Ottawa's M.E.C. outlet.

Given the foregoing, it would appear that the Transitway has had the desired effect on development, but that would not be entirely accurate. As mentioned, the presence of the Transitway, even at an early stage, has not prevented the growth of power centres with their dispersed big-box stores and acres of asphalt. Many of the aforementionned employment nodes, whilst in the vicinity of a Transitway station, are not oriented towards them (i.e. pedestrian linkages, building orientation) or integrated with them. At a wider level, the Transitway was also unable to prevent the growth of suburban office parks, particularly in Kanata. The Kanata North Business Park, the centre of much of the region's technology sector boom in the late 1990s, is not on the Transitway or a planned extension thereof, nor is it conducive to transit service with its medium height towers surrounded by asphalt. Given it was built-out long after 1974, a right-of-way for a future Transitway extension could have been incorporated and buildings built accordingly. It seems likely that an automobile-biased mindset on the part of the former suburban townships, developers and major private sector employers, especially in the technology sector, contributed to this and other similar planning failures.

As the Transportation Research Board observed, employment has not occurred around Transitway stations as much as was called for and has instead grown more rapidly in areas and in ways harder to serve by transit (2003, p. 15). The same trend also appears to be taking hold with retail, leaving residential as the only land use still increasing substantially around Transitway stations - an ironic twist as it was envisaged that residential uses would occur further away to allow for employment and retail (destinations rather than origins) to concentrate around them.

3.6.4 Victim of its own success

The Transitway was developed on an 'outside-in' basis, a method that allowed for rapid growth of the system. But it has also meant that the downtown core, even with the 'fast-acting lanes', has become congested with buses at peak hours, particularly in the afternoon period. The essential problem is one of too many passengers with too many routes and buses to choose from - there are over 80 routes travelling through the downtown at peak periods (Gray, 2005, p. D1).

To the observer and participant alike, the scene on Albert and Slater streets at 17:00 is one of pandemonium. The platforms can generally support only four stopped buses, but that is enough to cause problems. Passengers do not know which end of a platform to wait at since there is no way of knowing where a particular bus is going to be able to stop. When a group of buses does come to a stop, passengers who guessed wrong can be seen hurriedly heading up and down the platform to get to their bus. Some passengers will actually head further up the street beyond the beginning of the platform and attempt to board their bus as if it was a streetcar of old. Most drivers will oblige and open the door, but sometimes the queue starts moving and they are left there still waiting for a passenger to board. Other passengers do not bother putting in that kind of effort; they simply set up shop at the bottom end of the platform (i.e. west end for westbound buses) and wait for their bus there and flag it down when it comes past, even if it had already stopped at the other end of the platform. If a stop is located at a traffic signal, the signal might turn red, thus stopping the bus's progress for awhile. The light will also provide an opportunity for yet more passengers to arrive, some of them racing across the street in its dying seconds to board that very bus, delaying its departure yet again.

There is no obvious solution to this problem that also retains the express buses travelling through the core. A toll plaza-like collection of platforms would be required with strict scheduling to keep everything moving, but there is clearly not enough space for such an arrangement. In recognition of the problems being faced in the downtown, OC Transpo in 2004 (Figure 3.6.4) acted to remove a few of the eastbound afternoon peak-hour routes from the downtown. Those passengers were told to board any other bus and transfer at Hurdman station, a major hub in the Transitway. But this was just the start; in March 2005, OC Transpo announced a major shift in how it conducts bus operations.

Ottawa would largely abandon the express bus system by 2009 and move to a hub-and-

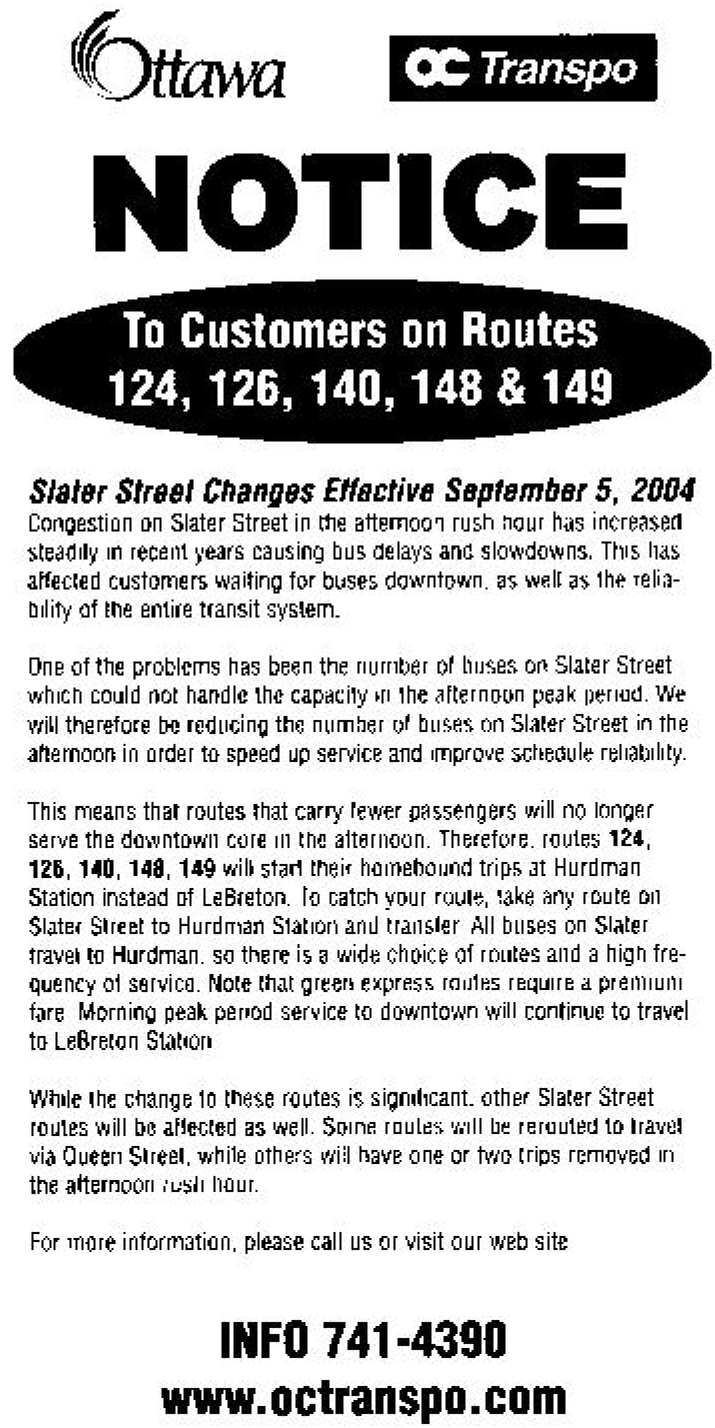

Figure 3.4: System overloaded: OC Transpo poster from 200 advising of removal of routes from the downtown and that affected passengers take any bus and transfer at Hurdman Station.
Source: Friends of the O-Train, <http://www.friendsoftheotrain.org/?q=node/16>

spoke system on the Transitway. Feeder routes and transfers would become the norm and only a small number of routes using articulated buses would go through the downtown (Gray, 2005, p. D1). With the express bus system destined to disappear, one of the major advantages of a bus-based rapid transit system would go with it: transferless service from the suburbs.

3.6.5 Trade-offs of the BRT-based Transitway

Though there were advantages to Ottawa choosing a bus rapid transit system, by doing so it had to give up some of the benefits that would have come with a light rail system.

As part of its capital acquisitions, OC Transpo purchased numerous articulated buses in the 1980s to increase the capacity and productivity of the Transitway. As of the early 2000s, these buses had all been replaced. By contrast, Calgary's original CTrain vehicles are still operating. Serious rusting is widely suspected to be the cause of the buses' demise. This would not be surprising considering how filthy the buses' windows get in the winter, so much so that it is often impossible to see what stop the bus is at. If that level of debris gets up to the windows, one can only imagine how much gets into the undercarriage. The capital saved in constructing a busway may in fact be eaten up in replacing the rolling stock more often. Winter service disruption is also less likely with a light rail system than a bus system, even in a city like Ottawa that has turned snow clearing into a religious observance. Ottawa's pilot diesel light rail project, the O-Train, has a reliability rate of 99%, compared to 70% for the entire system (Transport Canada, 2005). Moreover, because of the interlining of routes, delays will tend to cascade through the system.

On the Transitway trunk routes, operating expenses for buses exceed those of light rail[4]. With increasingly scarce labour becoming a concern, it is likely that uneconomic practices such as paying for four drivers to drive four articulated buses when one driver could be driving a three-car train will become untenable.

Stations on a light rail system can be designed to take advantage of the fact that light rail vehicles have doors on both sides. Indeed, the stations on a light rail system - especially one with the newer low-floor vehicles - are more amenable to integrating with adjacent land uses and buildings because there is not an issue with fumes. The localized

[4]The 2008 update of the Transportation Master Plan gives an indication of this through the difference in savings between options with more or less LRT compared to BRT

pollution issue downtown is one of the biggest sources of complaints about Ottawa's BRT system; having dozens of buses idling for much of their time downtown does nothing for local air quality and no doubt wastes untold volumes of fuel every year.

Finally, despite all the efforts to brand the Transitway and emphasize its rapid nature, it may still suffer from an image problem in attracting choice riders because it is bus-based. By contrast, the O-Train has exceeded ridership forecasts by a considerable margin; from a forecast of 5,000-6,400 riders per day it is now carrying in excess of 9,000 (Transport Canada, 2005), and some estimates have placed it as high as 12,000. After one comfortable trip on the O-Train compared to the high-speed jostling of a bus ride it is not hard to see that rail has more appeal.

3.7 Conclusion

3.7.1 Was BRT the right choice for Ottawa?

The unique way in which the Transitway was constructed and sections brought into immediate operation regardless of the status of the rest of the system, its breadth of coverage for the available funding and Ottawa's far flung suburbs, its role in Ottawa achieving the highest transit ridership of a North American city in its population class are all compelling reasons why the BRT-based Transitway was the right choice for Ottawa at the time, although some corridors were in fact more amenable to light rail than to busway (Chapter 6 includes a discussion on this point). To have achieved what was achieved by the Transitway with light rail alone in Ottawa at the time would have been more costly and could not have been done nearly as soon. However, that was the past and the very success of Ottawa's transit model is now causing problems that a BRT system may not be able to handle.

3.7.2 The case for conversion in Ottawa: BRT hits the wall

The main operational advantage of BRT is the ability to use express buses as a way of increasing transit ridership. However, as the number of express routes and buses increases through the core of the system, pressure increases to switch to a hub and spoke system to avoid system breakdown. A busway could possibly handle the oft-mentioned 10,000 riders and 200 buses per hour but the stations themselves cannot handle that number of buses (one, on average, every 18 seconds) nor the number of different routes that are required to make a BRT system acceptable. Once the switch occurs and the BRT system is characterized by intensively used trunk routes on a hub and spoke system, the operational logic of remaining as a BRT system disappears as it would be more efficient to operate as a light rail system.

With the success of O-Train pilot project, memories of a long-ago promise to convert the Transitway to light rail when required are being reignited and questions are being asked as to how that might be accomplished. The next chapter examines the issues that such questions raise.

Chapter 4

Busway to Light Rail Conversion Issues

Issues that would have to be considered when converting Ottawa's bus-based Transitway to light rail and will be explored in this chapter include design elements, conversion alternatives, ridership impacts, disruption of service, cost and timing of conversion. A literature search revealed a paucity of existing literature on these issues as they relate to busway to light rail conversion, though some issues have been discussed in other contexts. However, the documentation review revealed that some of the issues not covered in the existing literature have been touched upon before in municipal government, transit agency and other institutional reports, though often not to the extent here, and still some issues never at all. Whilst many of the specifics of the topics covered here are particular to Ottawa, the issued raised could apply more generally to any busway-based bus rapid transit systems (BRT) designed and built along the same lines as Ottawa's transitways.

Given the ongoing debates with respect to the choice between light rail and BRT in the theoretical and practical fields, the fact that so little has been researched and published concerning the issues surrounding the conversion of busways to light rail systems is intriguing. It is often mentioned in the literature, especially on the part of those writing favourably about bus rapid transit, that busways such as Ottawa's Transitway have been designed to allow conversion to light rail, yet this chapter shows that such conversions would entail the consideration of issues that would make conversions to light rail more difficult than is suggested by the fact that the systems had been designed to allow for them. In other words, just because a BRT system and its busways were designed to allow conversion to light rail does not mean that conversion is a simple, straight forward process. The silence on these issues on the part of those advocating light rail transit solutions is therefore intriguing because these extra conversion considerations would tend to strengthen the case for light rail in the first instance if it is envisioned that new or planned transit systems will ultimately exceed the capacity of a BRT system.

4.1 Design elements built into Ottawa's transitways

The Ottawa-Carleton Rapid Transit Development Program, which was published in an eight volume series in the late 1970s and early 1980s, called for the transitways to be built with convertibility in mind: "planning and design standards should be adopted to allow conversion to a higher capacity technology" (DeLeuw, 1978v1, p. 5).

Both the city councillor (Gord Hunter) and the planner (Peter Steacy) interviewed for this project confirmed that the transitways were designed and built to light rail standards in terms of vertical clearances for underpasses, loadings for bridges, turn radii, grades and so on. The stations were also designed to allow for extra length of platforms for LRT. This was further corroborated in the 2003 Rapid Transit Expansion Study's (RTES) Transitway Conversion Discussion Paper: "The alignment characteristics in terms of horizontal and vertical curvature of the existing transitway are based on 80 km/h design speed and are compatible with requirements for LRT," (RTES-D, 2003, p. 1). The paper states therefore that conversion is "feasible from a technical and operational perspective" (ibid).

Figure 4.1: Westboro Station shows to advantage many of the design standards built into Ottawa's transitways, including vertical clearances and separate platforms for trunk services and local services (at grade, outside of picture). Photo by author, Dec. 2006.

The stations on the Transitway are for the most part inline, an example of which, Westboro Station, is shown in Figure 4.1. These stations feature a four lane cross section with sideloading platforms along with a centre passing lane in each direction. The inline stations for the most part have separate platforms off the transitway for use by local feeder buses or other buses not using the Transitway. This feature means that these stations are already equipped to handle both light rail vehicles (LRV) on the line portion and buses on the

Figure 4.2: Hurdman Station, an example of an island station. The buses on the nearside platform have crossed the path of the buses on the farside to access the station, and will do so again (where the bus from the left is entering the frame) when leaving. The inset is a satellite image of Hurdman Station showing the path-crossing to advantage. The camera position and perspective of the main photograph are marked in red. Photo by author, July 2007; inset via GoogleEarth (probable date late winter/early spring 2007).

offline portion of the station in a post-conversion environment.

There are a few stations on the Transitway that are islands and are not inline; to use them at present buses from at least one direction must cross the other direction of travel. These stations are found at hubs in the system such as Hurdman (shown in Figure 4.2) and at present and former terminuses (such as Terry Fox and Baseline, respectively). LRT could in most cases use these stations in an inline centreloading configuration but that would require the construction of new feeder bus platforms. Alternatively, the existing island stations could continue as feeder bus platforms and a new, dedicated LRT platform constructed. The latter option would be less disruptive and probably less costly, but in practice it would depend on the characteristics and orientation of each individual existing station.

4.2 Conversion alternatives

Before discussing some of the other issues that conversion will bring about (ridership impacts, costs, etc.), one first has to have an understanding of the nature of the conversion itself. One of the first questions to be faced when considering a conversion of a busway to light rail is whether to carry out a conversion that results in a light rail-only facility or one that results in a hybrid or dual-use (light rail and busway) facility. The topic is relevant because the type of conversion decided upon affects the cost of conversion and the amount of disruption it creates. It also drives station layouts, which in turn can affect the cost and amount of disruption as well. Another question to be considered is the power source of the light rail vehicles themselves, a choice that can affect the cost of conversion as well as the amount of time it takes. This section provides an examination of both of these considerations.

4.2.1 Hybrid transitways

A hybrid transitway can take on two forms, both of which have been proposed at one time or another as possible ways of converting Ottawa's Transitway. They are depicted in Figure 4.3. The first form (what will be termed "type 1" for simplicity) features a two-lane cross section where each lane contains rails embedded in a roadway, which would probably be constructed out of concrete. The second form ("type 2") is a four-lane cross section. The outer lanes would be for running buses with the inner "lanes" for light rail (somewhat similar to Calgary's CTrain where it runs in road medians).

Type 1

The type 1 hybrid transitway requires no widening of the existing transitway right-of-way but it would require the use of prodigious amounts of concrete for the combined road surface. Operationally, buses and LRVs would be operating in the same space, and possibly at speeds in excess of 80km/h. All vehicles would have to be operating based on driver line-of-sight rather than signalling because typical LRT headways would be inappropriate for bus operations. The LRVs would also likely be subject to the corrosive effects of road salting in the winter, thus reducing their operational lifetimes, though it is conceivable that a combination of heated running way and ploughs fitted to the LRVs could eliminate this requirement. The duration of disruption during rebuilding to a type 1 is likely to be greater than with a complete conversion and the cost would also be quite high (see s. 4.5.1) but it would allow for the conversion to proceed piecemeal in short stretches at a time (including in multiple locations), thus minimizing the extent of ongoing disruption.

Type 2

The type 2 hybrid transitway would require a widening of the existing transitway right-of-way. This aspect opens up the possibly of significantly reducing disruption because the new outside bus lanes could be constructed first and work on the rail portion would commence only once those were in place. It would also effectively more than double the capacity of the transitway since the capacity of the busway would be largely unaffected -

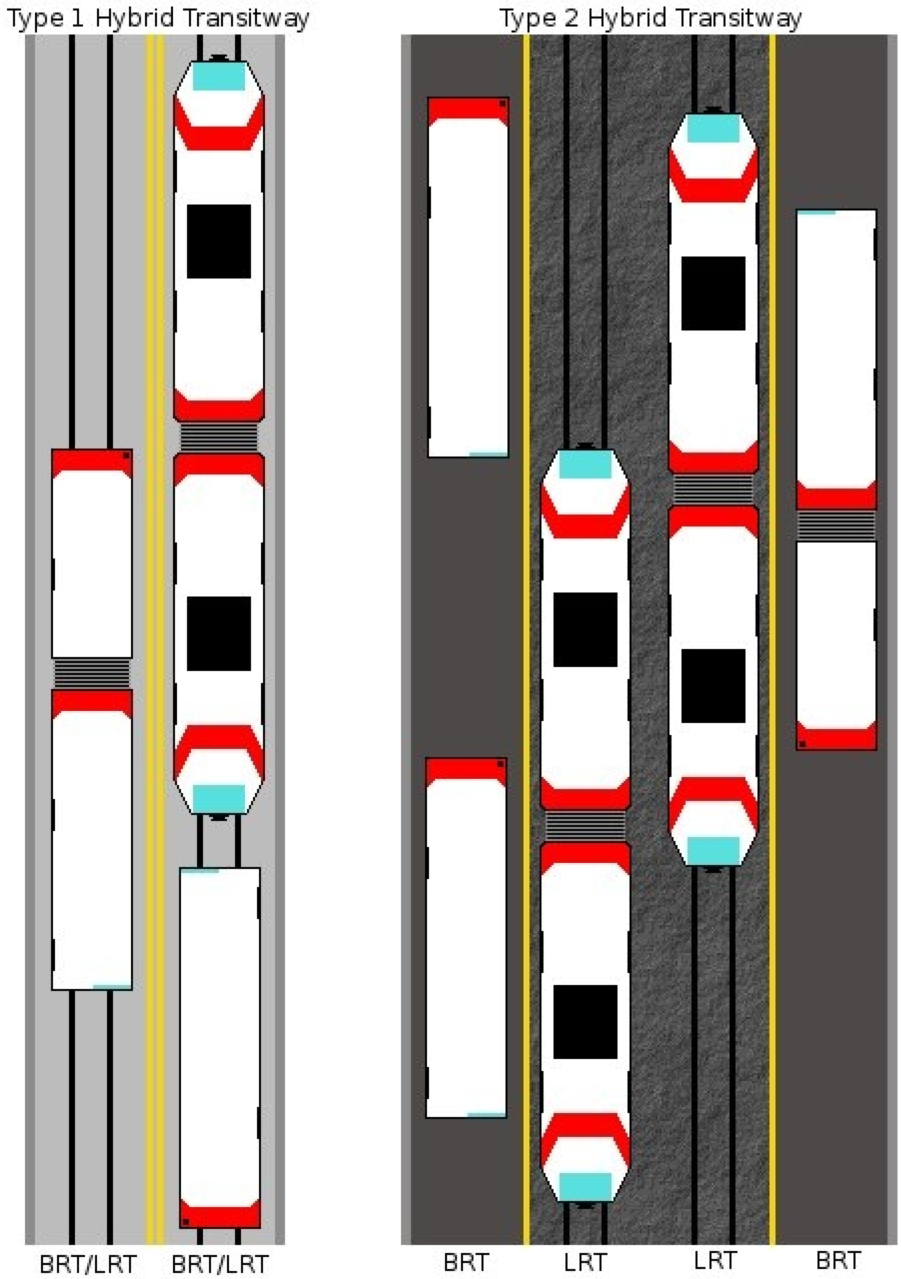

Figure 4.3: Possible hybrid transitways with example vehicles. Light-coloured road surfaces are concrete, dark are asphalt, and the textured surfaces are gravel. Diagram by author.

depending on station layout, below - and there would be additional capacity in the form of light rail. Ottawa's Transitway been built with a 13 m right-of-way (two 4 m lanes, two 2.5 m shoulders) and would need to be widened to at least a 16 m right-of-way (RTES-D, 2003, p. 3). Roadways in Ontario usually have a minimum allowance of 20 m, so it is unlikely that much additional land would need to be purchased to accommodate a 16 m right-of-way. The cost of widening the busway before converting the original two lanes of busway - based on other road widening projects within the City of Ottawa in 2007 (Budget, 2007) and the Southwest Transitway extension across the Greenbelt in 2005 (Budget, 2005a) - would be on the order of $2-3M/km. However, the actual cost of widening Ottawa's Transitway would be higher than that because of the need to replace bridges and widen rock cuts (including the large “Scott Street Trench” rock cut) as they have all been built to the 13 m width. At 16 m there would be no provisions for a shoulder either; including such provisions would push the constructed right-of-way to 20 m or more, which is at least 7 m (or 50%) wider than it is at present and may require additional land acquisitions. Besides the additional cost (see s. 4.5.1), the disruption caused by rock cut widening and bridge replacements would be substantial (the disruption from widening the right-of-way where it is open space would however be minimal).

Hybrid transitway station layouts

Station designs and layouts would depend on those already existing and the amount of space available, but one can envision three basic station layouts, depicted in Figure 4.4. Each has its advantages and disadvantages.

Type A The type A station is simple, with a two lane cross section and two sideloaded platforms where each is used for both bus and LRV operations. It is probably the least costly but suffers from limited flexibility of operations as it is likely that buses would often block the LRVs and vice versa. Passengers however would have a choice of vehicle and would not need to change platforms to get on the first available vehicle. Ottawa's existing stations are not built this way and a hybrid transitway in Ottawa would therefore not use this type of station. It is also unlikely that a type 2 hybrid transitway would incorporate this type of station layout. However, a type A station would be quite appropriate for a single-use transitway, particularly a light-rail transitway (for example, Sunnyside Station in Calgary). It would also be appropriate if used in the median of an arterial road, such as is found in Vancouver with the B-Line system, as part of either a single or dual-use facility.

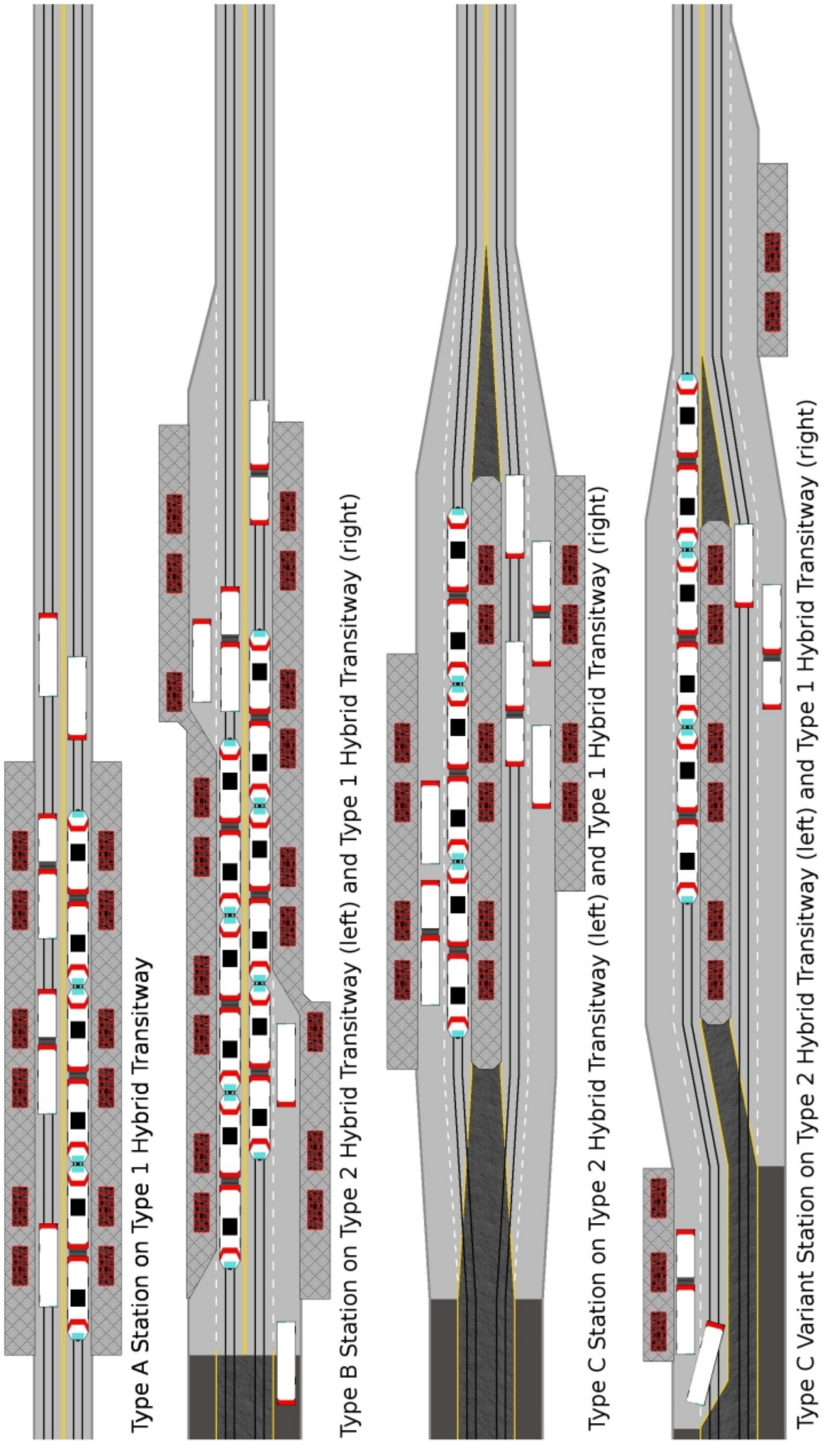

Figure 4.4: Possible station layouts on hybrid transitways with example vehicles. Diagram by author.

Type B The type B station has a four lane cross section and platforms, with the LRVs operating in the inner lanes and buses generally operating in the outer lanes. The LRT platforms would be built-out into the bus lane (as was proposed for downtown in the cancelled NSLRT project), meaning that buses would have to weave into the LRT lane to get around the LRT platform, possibly affecting both bus and LRV operations. All lanes would therefore have to be constructed out of concrete, with the inner lanes having embedded rails. The bus platforms would be adjacent to the bus lanes, and buses would not be permitted to stop at the LRT platforms. This station design arguably requires a lot of length to accommodate reasonably long trains (4 car - 100-120 m) as well as a couple of articulated buses (40 m). Such a design could constrain bus operations but is unlikely to constrain train operations much. Many of the stations on Ottawa's Transitway could be readily modified to such a design as most have the required four lane cross section and platform space.

Type C The type C station features a centre-loading island platform for light rail in the middle of a four lane cross section with sideloading platforms for buses. The station footprint would have to swell to accommodate the width of the LRT platform, making this the widest of all the station layouts. As in current Transitway stations, the bus lanes would be constructed out of concrete for durability; the light rail lane could be left open or constructed out of concrete depending on whether it was thought to be important to be able to allow some buses to pass other stopped buses.

Type C Variant To save on the width required in the type C station, a variant could have the platforms staggered, with the effect increasing the effective length of the station.

Very few existing stations along Ottawa's Transitway are amenable to becoming a type C station (or its variant) because of the location of the existing platforms and the lack of space for outward expansion. Only those stations that are hubs (Baseline, Hurdman) or a terminus (Terry Fox, Orleans) featuring an existing island platform could be expanded to become a type C (or variant) station. The rest would have to be of the type B. It also does not matter if the hybrid transitway is of type 1 or type 2 since the existing stations already incorporate four lane cross sections.

As mentioned, the issue of conversion to a hybrid transitway is one that has surfaced before. The type 1 was the form of conversion envisioned in the Rapid Transit Working

Paper prepared as part of the RMOC's 1997 Transportation Master Plan[1] update as a way of avoiding a complete shutdown of the Transitway during conversion. The consultants that prepared the paper concluded that while feasible, it would be too expensive at the time and that BRT should continue to be the Transitway's form of rapid transit (p. 36). Because of the high cost of this form of conversion, it is unlikely that the Transitway would ever be converted to such a form, though it is possible that future transitways without grade separation in the medians of major arterials (e.g. Carling Avenue) could be constructed according to this model.

The 2003 RTES Transitway Conversion Discussion Paper - which commences by stating "This paper discusses the concept for conversion of the Ottawa Transitway from BRT to LRT/BRT joint use" (p. 1) - proposed the type 2 hybrid transitway as a way to convert the Transitway to avoid disruption.

The main advantages to a conversion to a hybrid facility are the potential to minimize disruption during conversion and the possibility of continuing to use buses from the large fleet of already paid-for buses post-conversion. The disadvantages to a conversion to a hybrid facility are that it would be more costly than a straight conversion and it would probably draw out the conversion over a longer period of time. One of the advantages, the possible continued use of buses post-conversion, could also be regarded as a disadvantage as doing so would reduce the operating cost savings of switching to rail and it could minimize the systemwide gains that might be achieved by redeploying the bus fleet elsewhere in the city.

4.2.2 Vehicle power source

Until recently there have only been two realistic choices for powering light rail vehicles; they could use electric motors and be powered from overhead electrical lines or they could use diesel engines or generators fuelled from an onboard fuel supply. Electrical power is more typically associated with light rail but Ottawa's pilot light rail project uses diesel-powered vehicles, seen in Figure 4.5.

Using electric-powered vehicles has the advantages of being locally cleaner and possibly cleaner overall if the power source is itself clean (as with Calgary's wind-powered

[1] The names "type 1" have been invented for the purposes of this paper and were not present in the original documents in which the proposed forms themselves appeared

CTrains). The lack of onboard fuel and engines cuts down on vehicle weight and helps to give good acceleration. Regenerative braking can also be incorporated so that less energy is lost when braking as it is instead returned to the power grid. Electric LRVs are also generally quieter.

Diesel-powered vehicles do not require overhead wires and other electrical infrastructure - something that is regarded as unsightly by some - because they are capable of independent operations, including during electrical blackouts. This can lower capital costs and it also means that new track can be constructed and brought into use earlier; indeed the use of diesel LRVs would allow the use of temporarily-laid tracks during the conversion process. However, diesel LRVs do produce fumes that can add to local pollution as well as greenhouse gas emissions and may limit their use in tunnels or require that any tunnels be built with extra ventilation systems. They will also be subject to rising fuel costs and because they are heavier they will require more energy to run as well.

Figure 4.5: The O-Train, Ottawa's diesel-powered light rail pilot project and now part of its rapid transit network. Photo by author, May 2007.

The Mayor's Task Force on Transportation (MTFT) recommended the use of electric-diesel bimode rail vehicles, which is a vehicle type that can take power from overhead lines when they are present and from onboard diesel[2] fuel when they are not (2007, p. 23). The use of bimode trains would allow for a more rapid expansion of the network in accordance with the advantages of diesel whilst also allowing for the use of electric power where it most makes sense, such as in tunnels and more densely developed areas with

[2]The diesel is used to fuel a diesel generator, the electricity from which then turns the electric motors, as opposed to a diesel engine that drives the train directly. To complicate matters, many "diesels" are actually diesel-electric (generators and motors) without being bimode.

frequent stops. Further electrification of the system can take place over time as resources permit. The earlier 1997 Rapid Transit Working Paper also noted that it was possible to electrify a line at a later date (p. 31) and that it was possible to mix electric and diesel vehicles on the same line (ibid). A conversion plan making use of this type of strategy could take steps to make subsequent electrification easier, such as pouring the footings for the eventual poles at the time of conversion. However, bimode vehicles are heavier than electric vehicles and therefore have slower acceleration than the latter (even when powered from overhead lines), though the greater torque of the bimode's electric motors would still give them better acceleration than diesel vehicles. Similar to hybrid buses being more costly than diesel buses, bimode rail vehicles are also more expensive than either electric or diesel-only rail vehicles.

4.3 Ridership impacts

One of the concerns that weighs most heavily on converting the Transitway to light rail is that of negative ridership impacts, of which there are two likely sources. One is from the disruption of service that could be caused during the conversion of the Transitway. This impact will be examined in the next section. The second is the impact of extra transferring that would be required once the express bus services would disappear under a hub-and-spoke transit model after conversion to light rail. There are also, of course, potential permanent positive ridership impacts from a conversion to light rail.

4.3.1 Possible negative impacts from ending express bus services

The peak period express bus service is seen as a key element to Ottawa's high transit ridership - 20.1% of commuting trips in 2001 (Ottawa, 2004) - so naturally a change to Ottawa's transit like a conversion of the Transitway to light rail that would obviously affect the express bus service is going to raise questions as to its ridership effects. There is very little in the way of solid knowledge as to the susceptibility of overall transit ridership in Ottawa to a change in the express bus service, but we can surmise a little bit based on the nature of the service.

The express bus service is a transferless service from residential neighbourhoods to Ottawa's downtown via the Transitway. It is virtually door-to-door and has historically been fairly comfortable for the suburban riders it attracts and carries. It is in some ways the Ottawa equivalent of the GO Train service in Toronto and other commuter rail services in other cities. Councillor Hunter pointed out that many of the riders on the express buses are regular riders and are from the same neighbourhood so that there is a degree of familiarity aboard the express buses that is lacking on the buses of the trunk routes.

Councillor Hunter also conducted a survey through his ward email newsletter (his ward is a suburban ward just inside the Greenbelt) with a distribution of approximately 400 in 2006 asking residents who were currently taking an express bus if they would be willing to transfer to another bus[3]. The results of this survey indicated that about 40% of the express bus respondents (there were just less than twenty such respondents) would not continue to use transit if it meant transferring to another bus. Whilst the survey cannot be considered statistically significant - as Councillor Hunter himself noted - for a variety of reasons (adverse selection, small sample size, etc.) the results nevertheless give cause for some concern and ought to be studied further, again as the councillor suggested.

There is one other known source of information of Ottawans' views with respect to transferring and it comes from the public consultations for the 2003 Rapid Transit Evaluation Study. The surveys were in the form of questionnaires distributed at open houses in December 2002 or by subsequent follow-up (RTES-F, 2003, p. 5). 327 questionnaires were received, though the actual response rate varied by question but usually numbered above 300. 11% of respondents never used transit and another 29% only used it occasionally but 30% were daily users and another 19% used it a few times a week, with the remainder using it a few times a month (ibid, p. 8). It was found that some 88% of respondents answered that they would accept transferring (ibid, p. 15). Though the follow-up question did ask under what circumstances transfers would be acceptable, some of those respondents nonetheless attached conditions to that answer. Short wait times was the most frequent response for what makes a transfer acceptable, with availability of shelter while waiting being the next most frequent response. Other factors, such as short walks between transfer points, real-time arrival display boards and the availability of amenities at the station scored substantially lower but were not insignificant either and could be expected to at least improve the experience, especially if used in concert (station amenities become more valuable if one has an idea from the display boards of when one's ride will be arriving, etc.). There was very little variation between frequent transit users and infrequent/non-users in the answers. Given the context of the study (a follow-on to the

[3] This was at the time that OC Transpo indicated that it would gradually be phasing out the express bus services and switching to a hub-and-spoke system based mainly on bus-to-bus transfers to attempt to address the downtown congestion problem, particularly in the afternoon

O-Train diesel light rail pilot project) it is reasonable to assume that respondents probably had in mind intermodal bus-train transfers - especially based on the clearly stated preference for light rail over buses - though of course that cannot be said for certain. It was also the belief of the councillor that the residents of his ward would be more willing to accept transferring if it was to a train rather than to another bus, so long as the transfer occurred early enough in the journey that the benefits of travelling by train (a more comfortable ride) could be enjoyed for a long enough period to compensate for the loss of direct express service. In other words, a conversion of a large segment of the Transitway in one go rather than incremental conversion a station at a time (at least as far as express bus operations are concerned). The councillor also felt that the trains would have to have sufficient capacity as opposed to the crowded conditions that prevail on the trunk routes to keep those riders.

Besides the need to transfer, one other possible factor that might dissuade express bus riders from taking a train instead is that trains that stop at all stops could well be slower than express buses that seldom stop. To prevent this from lengthening travel times the trains would have to make up the difference through faster running speeds as well as through greater acceleration and shorter station dwell times. One of the many criticisms of the north-south light rail (NSLRT) project before it was cancelled was that it would have been quite slow for suburban riders from beyond the Greenbelt because of the many stops in close proximity to one another (typically less than 800m) as it ran through a new suburb south of the airport. The speed factor is one that cannot be ignored in the Ottawa context.

While the express bus system is often seen as important to Ottawa's high transit ridership, OC Transpo's own statistics reveal that is not necessarily the case: only about 8% of total ridership is accounted for by the cross-Greenbelt express services (OC Transpo, 2006b)[4]. Within the Greenbelt, the other "express" services - the limited-stop peak period services - likely account for about the same based on the relative number of routes and frequencies. The potential for drastic losses in ridership stemming from the termination of express services is therefore considerably less than opponents purport. After a transitway conversion, most of the express routes would not disappear but would simply be shortened and/or combined with existing feeder services to terminate at the railhead rather than proceeding all the way downtown. This would require a transfer, but transfers are actually quite common in Ottawa.

[4] Based on ridership by fare category. This measure would exclude riders who use tickets, but it is unlikely that there are many in this category.

Most journeys involving the O-Train already require transfers as there are few origins within walking distance of its stations, and neither end of the line is located at a substantial destination. The original O-Train ridership estimates underestimated the ridership levels that have since been seen, and one possible explanation is an overly pessimistic weighting of the requirements to transfer in the ridership estimation model. Nor is it just the O-Train where high levels of transferring occur in Ottawa; for example, to travel across the Ottawa River to the federal government complexes in Hull requires a transfer at the barren LeBreton Transitway Station, which has no amenities to speak of save a basic shelter. Nevertheless, a large number of transfers occur here to the very frequent cross-river shuttle bus services (20+ buses per hour at peak periods).

Another example of large scale transferring in Ottawa occurs at Hurdman Station, a large hub station where the downtown, Southeast and East Transitways intersect and which is itself located in an otherwise empty field atop a former landfill site[5] with no land uses in the immediate vicinity that could generate or attract or otherwise account for the level of pedestrian activity seen there, both at peak and non-peak periods. Figure 4.2 shows some of this activity at Hurdman during the early afternoon of a summer weekday. The station has large shelters, a confectionery, and, most importantly, transfers are reasonably well organized with generous lengths of platform and a designated stopping point for each route (or rather, groups of routes). In other words, it provides an environment far more conducive to finding one's bus than do the on-street stops downtown.

The everyday observable experience of significant transferring on a transit system *built on a transferless model* is at odds with the theoretical foundations of the system itself. The correlation between high transfer rates and high ridership (such as that found in Ottawa) has been observed before, and not just in large European cities like London:

> ... it appears that the introduction of regional rail trunk routes and their associated bus networks may have the ironic effect of improving the quality of non-CBD transit trips. Obviously, this is a very important consideration given the dispersed nature of travel patterns in American cities. This may explain the otherwise counterintuitive phenomenon that per-capita ridership on North American transit systems seems to be positively correlated with the transfer ratio. In other words, on a systemwide basis, high patronage appears to be associated with heavy transfer traffic and with frequent local service rather

[5]See S. Dykstra's MDP for a more detailed site analysis

than infrequent peak-hour CBD ”one-seat ride” express buses (Matoff, 1994, p. 97).

As time goes on and employment grows at stations/nodes further from the downtown along the Transitway in accordance with its land use objectives (even though it has been sluggish, it is occurring), the less sense the express bus system will make as the express buses will be stopping more often[6] until it gets to a point where each bus route is in effect a trunk route that happens to serve a particular neighbourhood at one end. Operationally, the system will look more rail-like and it will make more sense to operate it as such. The express bus system is ultimately destined to disappear one way or another. Indeed, the recent update of the Transportation Master Plan confirmed that even without a conversion of the Transitway to LRT, the transit system would be moving towards a hub-and-spoke system.

While it would be foolish to dismiss the possibility of ridership losses from discontinuing express services and introducing transfers, it would be equally foolish to overemphasize their importance and bias the decision of what form of transit would be best for the city. As the open house surveys in Ottawa revealed, it is not transfers that are unacceptable but the long, uncomfortable waits often associated with them. Reliable, frequent train service combined with frequent timed bus transfers would go a long way to avoiding transfer penalties.

4.3.2 Possible positive impacts

For non-express bus riders (i.e. those who use the trunk routes, either alone or in concert with feeder buses), it is hard to envision a scenario whereby conversion to light rail would have a permanent negative effect on ridership at all; indeed one would expect an increase in ridership - particularly amongst discretionary or choice riders - because of the quieter, more comfortable ride and greater reliability of light rail (Henry, 2006, p. 3). In their review of previous studies, Henry and Litman (2006) found that American cities of comparable size with rail-based systems had better ridership characteristics than those with bus-based systems only (pp. 3-4). This included periods of ridership decline: cities with rail had less severe declines (ibid). They further confirmed this finding in their own study that examined ridership in American cities between 1996 and 2003 that had built rail systems since 1970 compared to cities of similar size that had not (ibid, pp. 5-9).

[6] An express bus rider can request a stop at any station and on the return trip can flag down an express route bus at any station on the return trip.

Figure 4.6: Terry Fox Station, an island station in Kanata. It has yet to spur any TOD adjacent to it, though Kanata Centrum, a shopping area with 'big box' stores as well as a cinema and a pedestrian mall is nearby. Light rail would be expected to produce more favourable development outcomes. Photo by author, June 2007.

Light rail will probably spur more transit oriented development (TOD) than busway, so one would expect higher densities - both residential and commercial/employment - along the Transitway following conversion, which should result in higher ridership (RTES-D, 2003, p. 4). Transit oriented developed is said to require "high quality transit" (VTPI, 2007) as opposed to just transit to occur. If light rail is regarded as being "high quality" and BRT is not (in much the same way that light rail attracts more discretionary riders), then more TOD should occur around LRT stations than around BRT stations, such as Terry Fox Station in Kanata, shown in Figure 4.6. The pollution, smells and noise (both road and engine) associated with buses probably contribute to an image of BRT as lacking quality[7]. The Ottawa experience tends to confirm this view of the greater potential of light rail to spur TOD as the O-Train - which is not even electric - has already started to spur private sector-led development along it (in particular the upgrading of housing in the Mechanicsville and Hintonburg areas near Bayview Station for use by Carleton University students) within five years, which compares favourably to the slower pace of development along the Transitway, much of which has had more government involvement such as Riverside Hospital and the Centrepointe development (the town hall of the former City of Nepean) around Baseline Station.

[7]The image problem of BRT may be so deep that BRT is not even regarded as being "rapid transit" - numerous letters to the editor have been published in Ottawa newspapers where the writer claims that Ottawa lacks a rapid transit system.

4.4 Disruption of service

Disruption of service from conversion of the Transitway could have two potential manifestations from the perspective of the transit system: the loss of ridership mentioned at the beginning of the previous section and increased cost of operations. The former results from how disruption affects the user whereas the latter results from how it affects the provider, OC Transpo. Disruption of service could also have effects outside the transit system in the guise of increased congestion of roads and related infrastructure such as parking facilities.

4.4.1 Loss of ridership

The loss of ridership from disruption of service is distinct from the loss of ridership from the termination of express bus services. The cause of the potential loss is temporary in the case of disruption - the conversion itself - though the loss itself might not be. Disruption ridership losses would mainly stem from the extra time it might take for journeys during conversion. This extra time could come from reduced running speeds, delays and rerouting to get around construction (both on-bus and off) and from missed connections and transfers. Other factors that could reduce ridership during conversion include more unpleasant rides through construction zones and passenger confusion from reroutings and changed stop locations. The sheer duration of the disruption causing riders' patience to wear thin is another possible factor.

The ridership losses would at first be "temporary" in that people stopped taking transit because of the disruption, but there is a risk that many of the losses could become permanent. This risk was cited by a city planner as one of the major concerns about conversion.

Whilst understandable, the concerns with respect to the effects of service disruption on ridership may be exaggerated or misplaced. For example, Ottawa's last transit strike was in November and December 1996 (Rogers, 2003, p. C1) but it appeared to have no discernable permanent effect on ridership as it had recovered to pre-strike levels in January 1997 (OC Transpo, 2006). More recently, Calgary experienced a lengthy 50 day strike in 2001 (Hubbell, 2006, p. 10) but ridership in 2002 was higher than it had been in 2000 (ibid). Given that a complete shutdown of service during a strike is more disruptive than would be the delays from conversion-related construction in that riders have to find alternatives or make do without, the permanent impact of the latter should be less than the former. Moreover, that is without taking into consideration the effect of anticipated improved service post-conversion, an effect that does not exist during strikes as there is generally no reason to expect that post-strike service would be any better than pre-strike service. Additionally, if the most disruptive aspects of conversion are undertaken during summer months, the ridership impacts could be minimized as there are fewer riders (holidays, fewer students, fair-weather cyclists, etc.) and it is “construction season” anyway during which drivers also experience delays and reroutings.

4.4.2 Increased cost of operations

The increased cost of operations during conversion is a consequence of the slower average speeds that would be present during conversion. Any delays that conversion creates results in a slower average operating speed, which stood at 50 km/h in 1996 (Gault, 1996, p. 6). To compensate for this, extra buses would have to be online to provide the same level of service. This would require both more buses and more drivers to be available, especially at peak periods. The requirement for more buses would increase fuel, maintenance and storage requirements and thus add to the cost of operations, although since each bus would have lower daily mileage at a slower speed the fuel and maintenance costs on a per bus measure should be somewhat lower but probably not enough to account for the increased number of buses in use.

In 2005, OC Transpo had an operating cost of just under $100 per service hour (based on operations and maintenance expenditures of $227.6M and 2.3M service hours that year). If the assumption is made that conversion results in a 10% reduction in the average operating speed of the *entire transit system* (and not just on the Transitway itself), then a conversion taking one year to complete would add 10% to the transit operating expenditures in that year. At 2005 expenditure/cost levels and in 2005$, this would raise the annual operating cost by almost $25M (10% of $227.6M). This estimate puts a reasonable ceiling on the increased cost of operations during conversion, but it would likely be less as a 10% reduction in average operating speed *system wide* would correspond to a far greater reduction on the Transitway, where speeds are higher and service hours proportionately lower. In other words, to slow down the entire transit system would take massive slow downs on the Transitway, or - using the above example - far in excess of 10% speed reductions - perhaps 25% or more depending on the Transitway’s “share” of service hours - to increase overall operating costs by 10% (or $25M in 2005). Nevertheless, for the purposes of comparison, this cost ceiling of $25M corresponds to no more than about 1.5 km of new light rail transitway or perhaps 5 km of converted transitway (see s. 4.5.1); in other words, it is not a substantial cost in the overall picture of converting the Transitway.

From a very narrow (and arguably short-sighted) point of view, a loss in ridership because of disruption might actually mitigate against the requirement to use more buses since with fewer riders there is less of a need for buses. The possibility of that loss becoming permanent however would rule out making use of this tactic as part of an overall conversion strategy.

4.5 Cost and financial viability

One of the major issues in any conversion of a busway to light rail is the cost of doing so. There are two aspects to the cost issue; one is the direct cost of conversion and the other is the opportunity cost (i.e. what else could be done with the same resources).

4.5.1 Direct costs

The direct costs of conversion is probably one of the most controversial issues. There is very little hard data on these costs, and what data there is is fraught with problems. One oft-quoted number is $1B for a conversion of the Transitway from Kanata to Orleans (RTES, 2003, p. 4-2), but this number includes large runs across the Greenbelt where transitways do not exist as the Transitway uses only bus lanes. It also includes the downtown, where there is also nothing to convert. The specific figure of $1B is not even present in the Transitway Conversion Discussion Paper of the very same study.

The 1997 TMP Rapid Transit Working Paper put the cost (in 1997$) of conversion of the Transitway at $12.8M/km for electric light rail and $6.9M/km for diesel light rail. It also estimated that the cost of refitting stations was on the order of $0.5M-1M/station. No breakdown in costing was provided and one has to bear in mind that these estimates were for the conversion to a hybrid transitway with rails embedded in a concrete roadway.

The 2003 RTES Transitway Conversion Discussion Paper cited and then used the same figure for conversion to electric light rail ($13M/km in 2003$) with the caveat that it "may be high" (p. 6) and was subject to verification. Interestingly, it goes on to mention that "Provision of continuous double track, direct fixation trackwork, overhead power supply and major right-of-way improvements (drainage, cathodic protection, structure strengthening, clearances, grades, safety and access etc.) are estimated to be $5M/km, exclusive of stations," (p. 6). The same figure of $0.5M-1M/station was also used. Additionally, estimates were provided for new transitway infrastructure: "Generally infrastructure costs for new BRT and LRT systems are in the order of $12M/km and $20M/km respectively. This includes provision for transitway, yards, signalling track and stations, but excludes vehicle costs," (p. 6).

These estimates raise more questions than they answer. For one, the same figure of $13M/km has been used in both reports, yet each concerns a different type of conversion: the first is for embedded rails (type 1 hybrid conversion) and the second is a widening and then conversion (type 2 hybrid conversion). There is also a significant discrepancy between the costs of providing the LRT infrastructure ($5M/km) and the estimated conversion cost ($13M/km); the difference, $8M/km, is 60% more than the cost of providing LRT infrastructure. Indeed the difference between new busway and new LRT is itself only $8M/km, so to have a conversion cost that is 60% higher than that difference at $13M is puzzling because the most expensive elements (stations as well as bridges, trenches, etc. for grade separation) have already been borne and other direct conversion costs (removal of road surface) would not seem to be that significant. Even the $6M/km (in 1997$) difference between conversion to diesel and electric light rail is difficult to explain as the only practical differences are from the need to install overhead wires and poles to support them as well as the transformers for electric light rail; moreover this difference is itself larger than the later (2003$) estimate of $5M/km for all the infrastructure for electric LRT.

Since the existing conversion estimates - both for electric and diesel in the 1997 report and for electric alone in the 2003 discussion paper - are based on converting the Transitway to some sort of hybrid facility, they cannot be used with any confidence until they are verified and individual components broken out. The 2003 $5M/km estimate for electric LRT infrastructure (essentially a marginal cost) appears to be the only estimate that is unencumbered by other factors such as hybrid conversions or averaging in other costs that may or may not have to be borne in an eventual conversion such as yards, bridges and stations. Though speculative, if the $5M/km figure is accurate, it seems unlikely that the cost to convert a generic kilometre of existing transitway could exceed even $8M. The 30 km or so Transitway network within the Greenbelt would therefore cost approximately $250M to convert to light rail, though there are several sections of missing transitway that would have to be completed at a higher cost, including the downtown (which is currently at full capacity). There would also be costs for yards and maintenance facilities, as well as for the vehicles themselves.

In April 2008, new costing information became available in the supporting documentation for the updated Ottawa Transportation Master Plan, which called for conversion of parts of the Transitway to light rail, as it included detailed cost estimates in Appendix F for various pieces of rail infrastructure. Examination of the cost tables in Appendix F (DTS, 2008) revealed that tracks were priced at $1.215M/km for each track, or $2.43M/km for double track, the electrical traction power system, including sub-stations, was priced at $3.55M/km and the train control system (control, signalling and communication system) was priced at $2.25M/km, for a combined total of $8.23M/km for this basic rail infrastructure. The major increase in cost since the earlier 2003 estimates, which had them at $5M/km, is likely in the electrical and control systems. Additional costs of conversion mentioned in the cost tables include temporary asphalt and clearing and removals of the existing (and temporary) asphalt. These bring the conversion cost up to about $9M/km, and if switches are included the cost would approach $10M/km. It should also be noted that $9M/km is the approximate extra cost of building any transitway as light rail rather than as busway, though additional savings on the average and total cost may be possible through the use of narrower structures and simpler stations. Other costs of building a transitway (whether for a busway or light rail) include such things as property acquisition, utility relocations, right of way clearance and roadbed preparation, bridgework, stations, etc. When converting a busway to light rail, most, if not all, of the initial transitway building costs have already been borne at the time of the construction of the busway, leaving only the cost of providing rail infrastructure and modifying the transitway to be borne at the time of conversion.

4.5.2 Opportunity costs

Perhaps one of the biggest obstacles to converting busways to light rail is the opportunity cost of doing so: for the amount of money spent on conversion, it is quite possible that significant stretches of new transitway could be constructed to bring rapid transit closer to more residents and/or destinations. This was the rationale behind the NSLRT project in Ottawa rather than converting the transitways (RTES, 2003, p. 4-2). However the project was cancelled because, amongst other reasons, it would not have served many current residents nor address existing congestion problems as it was slated to serve as yet undeveloped areas. The conversion to light rail of the existing transitways would likely not have suffered from this lack of public support. There is also an opportunity cost to spending on transit projects other than conversion, such as foregoing the lower operating costs and higher ridership that conversion would be expected to bring about. Future expansions of the transit system will have to address this issue by striking a balance between upgrading what already exists and establishing new corridors.

4.6 When to convert

The issue of when to convert a BRT system to LRT tends to be overshadowed compared to more immediate considerations such as cost, ridership impacts and discussions of conversion versus establishing new corridors, though the imminent end of a busway's useful life and what to do about it may bring the issue to the forefront. Regardless, for a BRT system that is likely to someday reach its capacity and was envisioned to be converted, the issue of when to convert must be considered. As busway and light rail capacities overlap considerably, the essential question at issue is whether conversion should take place once the minimum light rail threshold is attained or to wait until BRT system capacity is reached. For their part, Sound Transit of Seattle, WA, note that "conversion to LRT should be considered prior to the point where demand approaches capacity on the BRT system, which can result in vehicle bunching and passenger delay," (Parsons Brinckerhoff, 2005, p. 18). Additionally, the longer conversion is put off and the closer a BRT system is to its capacity, the more potentially disruptive the conversion will be. With no known conversions having been previously undertaken anywhere, Sound Transit's analysis on when to convert concluded that "any discussion of thresholds for determining when to convert from BRT to LRT is purely hypothetical, and would depend a great deal on the specific characteristics of the corridor in question, including existing and future land use patterns and growth," (ibid, p. 17). Presumably, increasing densities of development along a corridor would favour earlier rather than later conversion so that light rail could benefit from those increased densities whilst the presence of light rail would support continued densification of the corridor.

Ottawa's original rapid transit development program suggested when conversion to light rail could take place: "When capacity considerations require an underground section through the Central Area, the transitway services in the West/Southwest and Southeast Corridors can be converted to a rail system," (DeLeuw, 1978v5, p. 11). Moreover, it estimated that this was not likely to occur for 25 years, by which time the paving and stations would have served their useful lives (ibid). In other words, it was predicted from the outset that a BRT system built on an outside-in approach would eventually exceed the capacity of the downtown streets to handle it, at which point a tunnel would be needed, which would in turn have to be rail-based. The rationale for a tunnel through downtown Ottawa will be examined in greater detail in the next chapter, but there is a fairly wide consensus that a tunnel is now required and furthermore that such a tunnel should be constructed for rail only and not buses. Given the foregoing, the logic for conversions of significant sections of the rest of the Transitway is compelling for otherwise the construction of substantial transfer facilities would be required at the rail terminus points on either side of the downtown. The use of such facilities, while feasible, runs the previously mentioned risk of losing passengers from the need for an extra transfer at a late point in the inbound morning journey. They would also become largely redundant once further outward conversions have taken place and their combination of sheer size and the presence of large amounts of paved area for waiting (and idling) buses would compromise the ability to redevelop the two likely sites - Bayview/LeBreton in the west and Hurdman in the east - into mixed-use, transit-oriented developments, such as that proposed for the Hurdman site by S. Dykstra in his Master's Degree Project (2006).

When OC Transpo got to the point in 2004 that it began to curtail routes downtown, the rationale according to the original rapid transit development documents from the late 1970s/early 1980s for conversion was met: the bus system downtown was at capacity. As if on schedule, this occurred about 25 years after the same reports were published with an estimate that sufficient bus capacity would exist for about 25 years. Given that the Transportation Master Plan had been updated the year before in 2002/2003, the failure to address the imminent downtown capacity crisis - whose signs had been apparent for years - in that TMP update by following through on the original Transitway vision to begin the process to convert the Transitway to light rail must be regarded as one of Ottawa's greatest missed opportunities. Five years on the consequences of the mistake are being realized and only now has Ottawa finally embarked on the first steps towards conversion of the Transitway. In this light, some of the issues addressed earlier in this chapter - such as possible ridership losses - are almost irrelevant; Ottawa's problem now is not the risk of declining ridership but increasing ridership that it cannot readily accommodate. Indeed, Ottawa has quite likely foregone ridership increases it could have had if had already converted the Transitway to light rail.

4.7 Summary

Once a decision to convert a busway to light rail is taken, one of the most problematic aspects of the conversion is likely to be the logistics of it, in particular that of managing continued bus operations to minimize disruption. A straight conversion that would see all buses routed elsewhere would probably be quite straight forward from a construction point of view, but this would see the transitway closed to buses as conversion proceeds and it would not be available again for transit use until light rail vehicles (LRV) are operating on it. The diversion of so many buses onto other roads - many of which are already congested - would be highly disruptive to the rapid transit system. For this reason, both of the earlier papers (1997 and 2003) that examined the issue of conversion of the Transitway followed the route of conversion to some form of joint-use to maintain bus operations both during and after conversion, and both found the cost to be high. The spring 2008 update to the Transportation Master Plan suggested a conversion method that would require a shutdown of at least one direction of rapid transit service on the Transitway. However, none of these papers considered the possibilities of phased, partial shutdowns of BRT operations and phased, partial openings of LRT operations as a way to both minimize disruptions and the cost of conversion. Such a scheme is proposed in the next chapter to address the issues raised in this chapter.

Chapter 5

Conversion

5.1 Introduction

In this chapter, conversion techniques and strategies are proposed after criteria for their design are presented. As with the previous chapter, many of the specifics of the topics covered here are particular to Ottawa but there are also lessons to be learned more generally. In recognition of this, the sections in this chapter are laid out with a view first to a general case of busways built on an Ottawa Transitway model (i.e. as if designed according to Ottawa's Transitway Design Manual (TDM)) followed by Ottawa-specific treatments, discussions or design solutions as appropriate. Maps of key sections of Ottawa and its Transitways are provided in figures 5.11 through 5.13 towards the end of the chapter.

5.2 Experience from other cities

Prior to preparing any techniques or strategies for converting busways to light rail, a literature and documentation search was performed to determine if any busways had ever been converted to light rail, for the purpose of learning from other cities' experience. The search revealed that whilst a number of cities have constructed busways - including some like Ottawa's transitways that were built with provisions to allow for future light rail - none is known to have converted a busway to rail, although Vancouver is replacing a median busway and its BRT service with a subway line. Only Seattle has attempted anything like it with the conversion of its downtown transit tunnel from a bus-only to a shared bus and light rail facility. To effect this conversion, Seattle shut down its tunnel for three years and diverted its bus routes onto multiple downtown streets, with one street, Third Avenue, becoming a transit-only street during both the morning and evening peak periods (Seattle, 2007). The conversion has now been completed and the tunnel reopened to bus traffic in September 2007 but light rail operations (other than for testing) will not commence in the tunnel until 2009 (DSTT).

At first glance, the fact that the Seattle tunnel was shut down during its conversion would suggest that shutting down Ottawa's Transitway may also be required, but that would be a premature conclusion. Seattle's experience concerned the conversion of a bus facility in the central business district where diverting buses onto multiple streets was a viable option as the buses were diverted only once they had effectively reached their destination. In contrast, diverting all buses onto multiple arterial roads for the length of a busway would effectively cause the cessation of rapid transit for the duration of conversion. Moreover, it is far less likely that multiple arterial roads would be in close proximity to the busway and one another, unlike in a central business district where tighter road grid conditions are more likely to exist. Additionally, the need to shut down Seattle's tunnel could be considered particular to Seattle. When the Seattle transit tunnel was built, a decision was taken to install rails for future use by light rail vehicles (DSTT, 2007). This ought to have prevented any shutdown but unfortunately the rails were not properly insulated for stray current protection so they had to be taken out and the concrete roadbed reconstructed with a rubber boot for the rails (ibid). The roadbed itself also had to be lowered (ibid).

The availability of viable on-street alternatives in effect 'allowed' the Seattle tunnel shutdown to take place and the unique reconstruction needs required it. Given the foregoing, one can conclude that the Seattle experience is not transferable to Ottawa in particular and probably not other cities with busways either. As there is no relevant experience to build upon, what follows for the balance of this chapter was based upon studied consideration and analysis of Ottawa's transitways as well as the issues raised in the previous chapter.

5.3 Conversion and the Transitway Design Manual

The introduction to the Transitway Design Manual (TDM) contains a brief summary on conversion to light rail (TDM, 1993, p. 3). Two scenarios were envisioned: a complete shutdown of the Transitway, requiring rapid transit service to divert to adjacent streets, and a widening of the Transitway to 16 m (essentially the creation of a type 2 hybrid transitway). Since these alternatives are highly disruptive and costly, respectively, neither is particularly attractive. Accordingly, the brief alternatives presented in the TDM were not used in formulating the solutions proposed in this chapter and the TDM was only used as a reference point.

5.4 TMP update conversion method

As mentionned in previous chapters, the 2008 update to Ottawa's Transportation Master Plan included conversion of parts of the Transitway to light rail. Appendix H of the supporting documentation, the Transportation Master Plan Infrastructure Requirement Study (DTS, 2008), described how conversion to light rail might take place.

The preamble indicates that there are two basic approaches that might be taken for conversion: complete relocation of Transitway services to parallel road corridors and maintaining only peak direction Transitway services, or various combinations thereof (ibid, p. H1). The method that maintains peak direction service is roughly the following (ibid, p. H3):

(1) Close one lane and install rail infrastructure in that lane, maintaining peak direction service in the other lane while rerouting non-peak direction travel to other corridors

(2) Create a temporary driving surface within the newly-laid track to maintain peak direction service while converting the other lane

(3) (Re)pave both shoulders up to the edge of the outer rails and install a temporary driving surface within the second track to allow two direction bus service while the centrally-located poles are installed

(4) Once the electrical infrastructure is in place and stations have been modified, rail operations can commence

This method creates, in effect, a type 1 hybrid transitway but with a paved rather than concrete surface and reroutes non-peak direction service during conversion.

5.5 Design criteria

The design criteria are the conditions to be met by the conversion solutions proposed in this chapter and they have been derived from the issues raised and analyzed in the previous chapter. Those criteria are:

(1) Maintain rapid transit service during construction, specifically maintain:

- capacity
- high frequency
- express (peak period) bus services during conversion until replaced by light rail; bus-bus transfers where transferless service exists are to be avoided (i.e. express bus to trunk bus transfers)

Rationale: closing down rapid transit service to undertake a conversion would be unacceptable to the public and the City of Ottawa, notwithstanding the fact that rapid transit service has been periodically interrupted by labour strikes. The possibility of ceasing rapid transit service was previously cited in the Rapid Transit Expansion Study (p. 4-2) as a reason not to proceed with a conversion of the Transitway to light rail. Maintaining rapid transit service requires that capacity and a high frequency of service be maintained. In Ottawa, it would also require avoiding the replacement of express services with bus-bus transfers.

(2) Minimize financial cost
Rationale: excessive costs will not demonstrate value for money. Previously proposed conversion techniques were found to be too costly to justify.

(3) Minimize passenger disruptions
Rationale: Conversion techniques and strategies that minimize both the extent and duration of passenger disruption are necessary to maintain the support of the public and city officials.

5.5.1 A note on capacity

The first criterion lists maintaining capacity as part of any proposed solution, the Ottawa particulars for which are elaborated upon here. The peak hour, peak direction ridership on the western approaches to downtown Ottawa at LeBreton Station according to the RTES was 5000 (2003, p. 4-2); on the eastern approaches to downtown at Hurdman Station it was 5300 from the East Transitway and 2200 from the Southeast Transitway. On the central portion of the Transitway at the University of Ottawa, the ridership was 7000[1]. Given ridership growth and a need for a margin of comfort, a peak hour capacity

[1] This is the combined volumes from the East and Southeast Transitways in the morning period, and indicates that as many as 500 “inbound” riders transfered to buses not headed downtown at Hurdman Station

of approximately 6000 riders per direction throughout the conversion process is required on the transitway approaches to downtown. The downtown portion will require a solution capable of carrying approximately 8000 riders per direction during the peak hour.

5.6 Conversion technique

To maintain bus operations during conversion, the proposed techniques will not involve a complete shutdown of the transitway undergoing conversion. In both the techniques and their permutations outlined below, peak period peak direction bus operations will continue relatively unimpeded until a replacement light rail service is in place. Depending on the technique chosen and the volume of buses to be handled as well as the degree of willingness to trade off sped up conversion-related construction against less disruption, other bus operations such as peak period non-peak direction travel and non-peak period travel (one or both directions) can be accommodated as well.

While there is uncertainty with respect to the exact cost of conversion of the transitways to a dual-use (bus and rail) facility as compared to light rail only, there can be no doubt that such a conversion would be considerably more expensive. The proposed techniques have therefore been designed only with conversion to light rail in mind and do so through a partial shutdown or alteration of BRT services leading to a partial opening of light rail services so as to maintain rapid transit throughout the conversion. All the proposed techniques have been designed to be able to follow this sequence (note that the illustrations in this section combine items in the sequence for simplicity, as noted in the brackets):

(1) partial BRT shutdown/alteration (t=1)

(2) construction of single track LRT infrastructure (t=1)

(3) partial LRT opening (t=2)

(4) full BRT shutdown (t=2, though some options maintain optional partial BRT)

(5) construction of second track (t=2)

(6) full LRT opening (t=3)

The techniques presented below all rely on interim single track rail operations during conversion. Ottawa already has experience with single track railway operations in its O-Train pilot project, which the techniques build upon. With a sufficient number of passing tracks (to be located mainly at stations), it would be possible to operate with headways of five minutes (12 trains per hour) to six minutes per direction (10 trains per hour). For single track operations, the limiting factor on headways is the distance between the most widely separated pair of passing tracks (i.e. stations). In Ottawa the greatest distance between any two transitway stations is about 1600 m (Westboro to Tunney's Pasture and Heron to Walkley)[2], a distance that would take less than two and a half minutes to cover at the O-Train's average speed of 40 km/h (it takes 12 minutes to cover its 8 km route - including all stops and waits). At a running speed of 50 km/h - which is well within the capabilities of the current O-Train and most light rail vehicles - 1600 m can be covered in less than two minutes, for a possible headway of as little as four minutes. A five minute headway on a single track system with double track at all stations is therefore quite feasible.

A five minute headway (12 trains/hour) has the required capacities. Assuming trains of approximately 100 m in length (four 25 m Siemens-Duewag SD160 (CTrain) cars at 150 passengers/car or three 30 m Siemens S70 (NSLRT) cars at 200 passengers/car or two 50 m Bombardier Talent (O-Train) three-segment vehicles at 285 passengers each), the required capacity of 6000 passengers/direction/hour can be met (7200, 7200 and 6840, respectively). Indeed, trains running on six minute headways (10 trains/hour, with capacities of 6000, 6000 and 5700, respectively) would also have the necessary capacity. However, five minute headways will not provide the 8000 passenger capacity required through downtown Ottawa. A different solution is therefore proposed for downtown Ottawa in section 5.8.1.

The techniques that follow are mutually exclusive on a given section of transitway, but any combination may be employed on different sections on the Transitway as a whole according to local conditions.

5.6.1 Existing transitway cross sections

Ottawa's transitways come in two basic cross sections: urban and rural, as shown in Figure 5.1. The terms can be misleading (especially 'rural') as they do not necessarily refer to where the transitway is located but rather to the nature of its cross section; there are transitways with rural cross sections well inside the Greenbelt in parkway-type settings. The urban transitway cross section is distinguished from the rural by being slightly

[2] Dominion and Lincoln Fields stations are about 3.3 km apart but they are not on an existing section of transitway - see s.5.6.2 for a discussion of this issue.

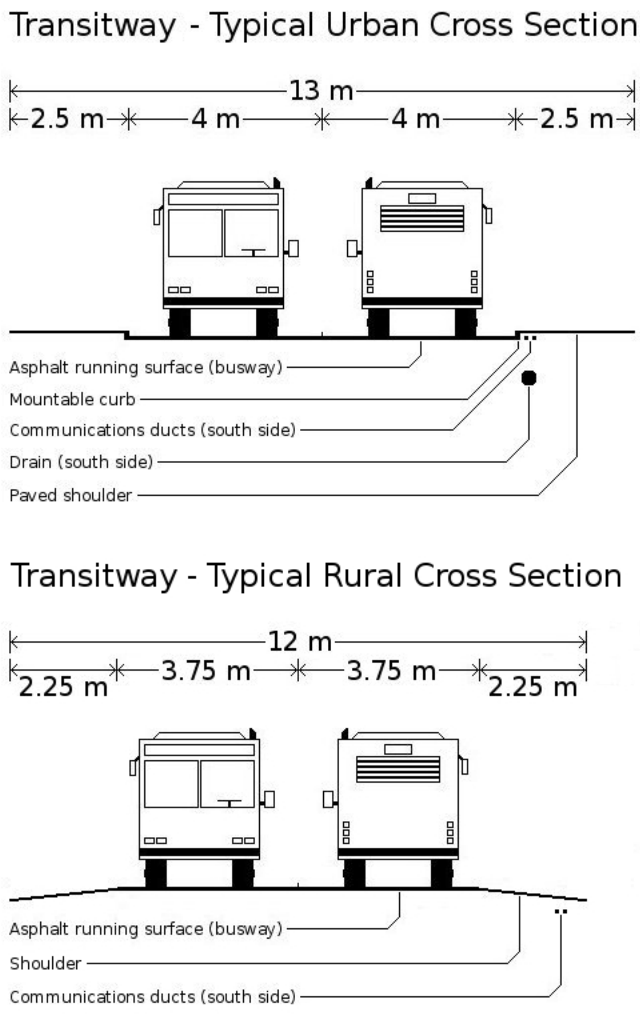

Figure 5.1:]

Existing Ottawa transitway cross sections, derived from Section B of the Transitway Design Manual. Diagram by author.

wider overall (13 m versus 12 m) and having low, mountable curbs (or concrete gutters in trench sections) and paved shoulders. The shoulders can be used for storing disabled buses and snow in the winter as well as for parking maintenance vehicles and acting as an emergency pedestrian sidewalk. The rural transitway cross section has no curbs and its shoulders are unpaved. It is also typically on an embankment (like most rural roads, hence the term) so drainage is handled through open ditches or swales, whereas the urban cross section employs drains and storm sewers. This latter is typically on the south side of the transitway, as is a buried pair of communications ducts (if present). While the Transitway Design Manual does not give a reason why the south side of the transitway is the preferred location for buried utilities, it is notable that most access ramps are located on the north side of the transitways.

Before moving on to the conversion techniques, a note about the accompanying diagrams is in order. While they should be interpretable from either a morning (inbound) or evening (outbound) peak period perspective, they have been drawn from a morning inbound perspective in mind with inbound traffic heading "away" from the reader and outbound traffic heading towards the reader. They have also been drawn from a "west side" perspective with south on the right of the diagram, but, again, this should not affect their interpretation for east end transitways.

5.6.2 Two lane

As the transitways are two lane roads, the immediately obvious conversion technique would see each lane converted from asphalt to rail. One technique to achieve this is given here, and another in the next subsection.

As illustrated in Figure 5.2, construction of light rail proceeds in one lane (time index 1 in the figure) with peak period, peak direction bus operations continuing in the remaining lane. Construction of footings and poles for the overhead power supply (for electric light rail) would be installed in the centre of the transitway. These would need to be protected from crashes by barriers once in place. A parallel arterial road would carry the peak period, non-peak direction bus traffic. Depending on both regular traffic levels and bus volumes, the use of a temporary reserved bus lanes at peak hours in the non-peak direction may be employed. During non-peak hours, operations on the transitway could continue as during the peak period until a direction reversal occurs (i.e. at noon or early afternoon) or it could carry traffic in both directions on a flagman/signalling system, or,

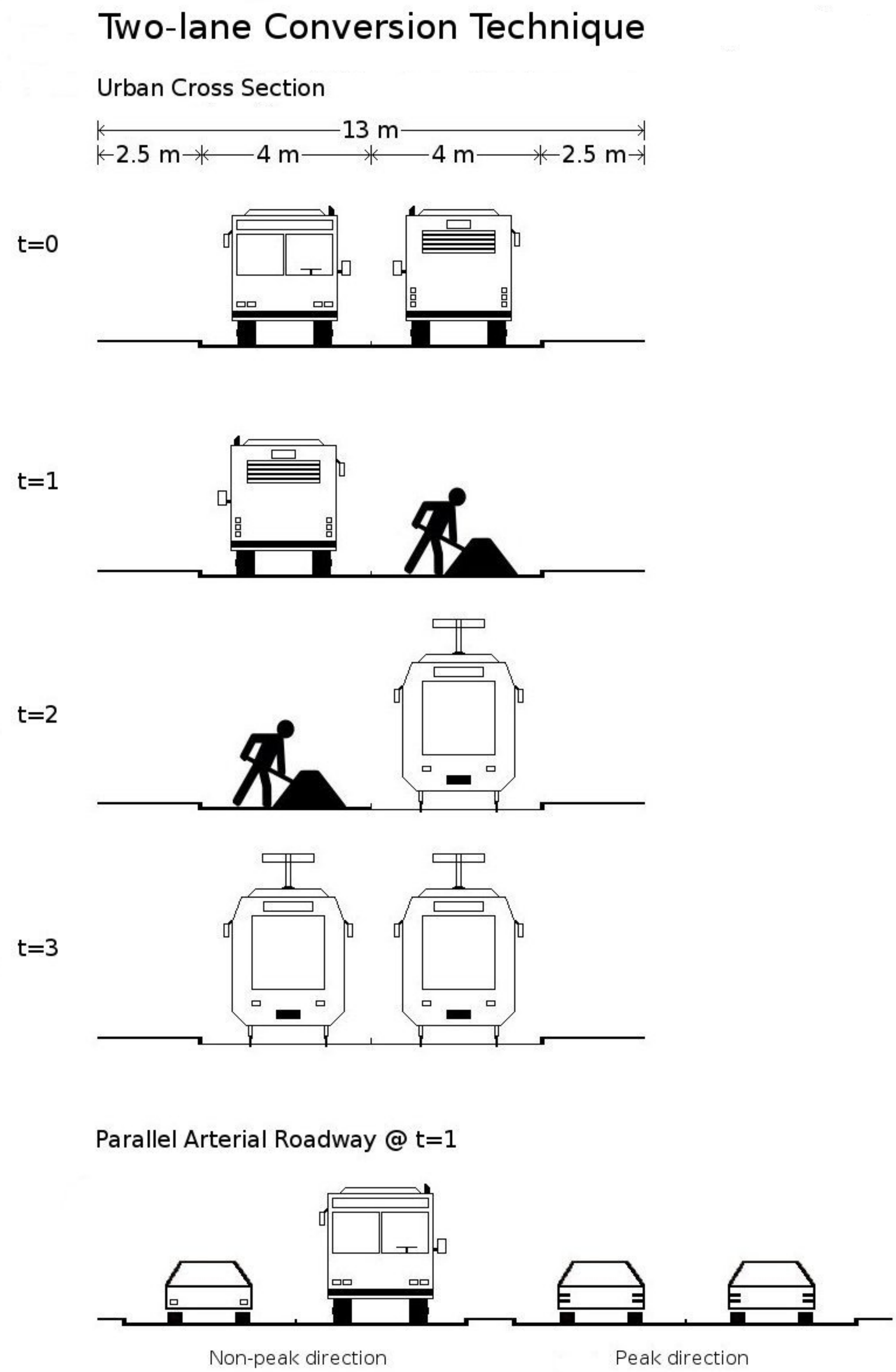

Figure 5.2: Two lane conversion technique. Diagram by author.

finally, it could be closed altogether to expedite conversion (i.e. reduce conflict between buses and construction crews). The decision should be taken on a section-by-section basis and would take into account regular traffic levels on the arterial road and bus volumes during non-peak hours. Figure 5.2 illustrates the technique with an urban cross section; a rural cross section could be converted in the same manner, but the greater flexibility of rural cross sections lends them to conversion via a three lane technique.

Once the first track is in place, it would be brought into operation and bus operations in the remaining bus lane would be shut down (time index 2) to allow construction of the second track. As with the method proposed in the Transportation Master Plan (TMP) update, this technique requires rerouting non-peak direction service. This technique was nevertheless included because it is both an alternative to the method suggested in the TMP update and because it may be of use under certain circumstances where space is constrained and the following techniques, which do not require shutting down non-peak direction service, are not feasible.

5.6.3 Three lane

The three lane conversion techniques take advantage of the fact that the typical urban transitway cross section is 13 m wide, a width that is more than sufficient to accommodate three 3.5-4 m lanes. Using the urban cross section, the initial step would shift the two bus lanes to one side of the right of way. In most places this would require that an extra layer of asphalt of about 2 m width first be added to the roadway surface at the curb edge to bring it up to the same height as the paved shoulder, though in the Scott Street trench section the paved shoulders are separated from the roadway not by curbs but by gutters, so nothing other than a repainting of lane lines would be required.

With the bus lanes shifted, construction of the first track can commence in the remaining width of the transitway. Not only does the continued existence of two bus lanes allow for relatively uninterrupted bus operations at all times, it can also allow for both buses and construction equipment to operate together at non-peak hours with relative ease.

Three possible methods of carrying out a three lane conversion on an urban transitway cross section are provided, and one further option on a rural cross section.

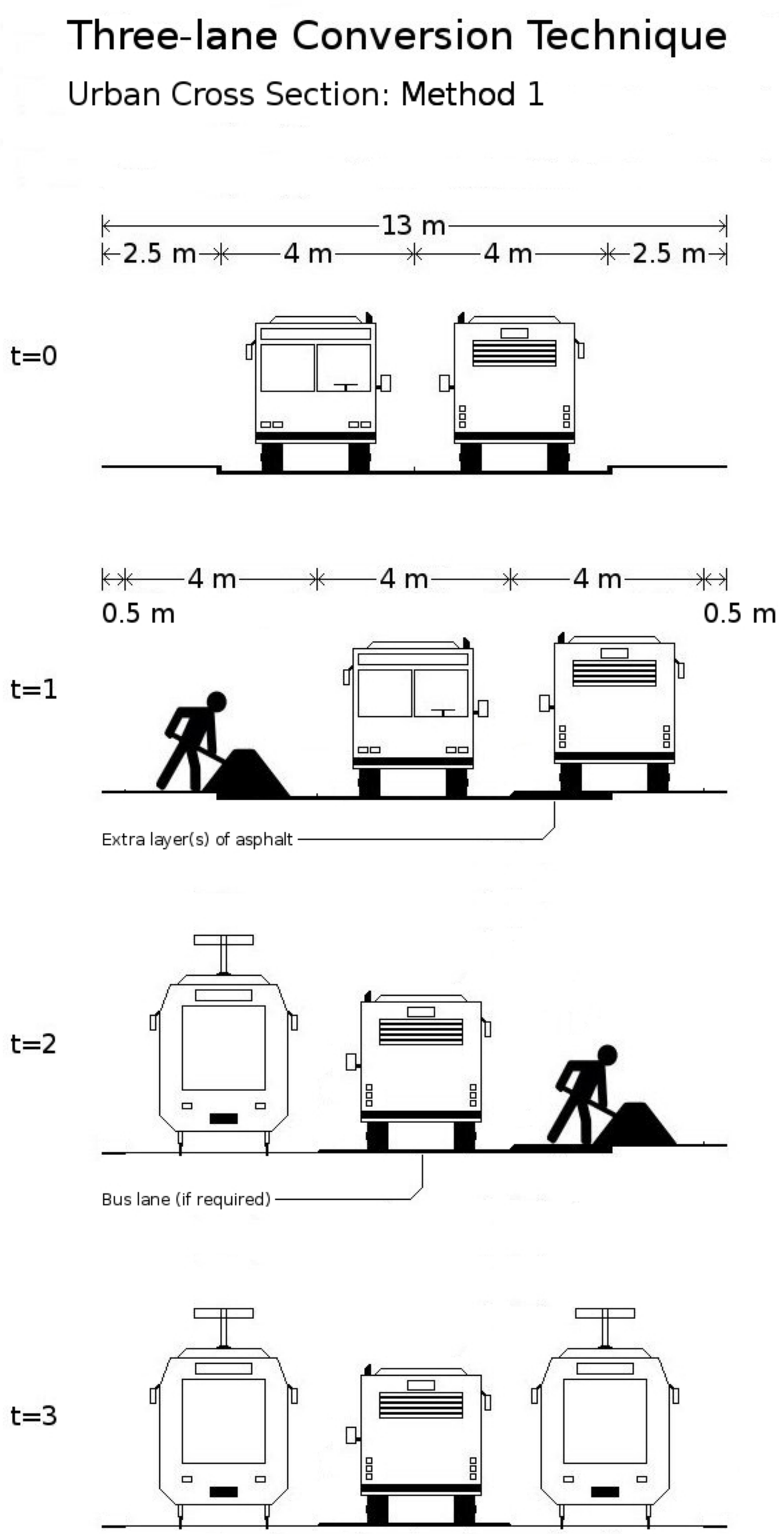

Figure 5.3: Three lane conversion technique, first method. Diagram by author.

Method 1

The first possible method of the three lane technique is illustrated in Figure 5.3. Construction of the first track proceeds on one side of the transitway (time index 1), preferably on the side without the underground utilities (i.e. the north side). Footings and poles for overhead wires could be installed in one of two places: at the edge of the transitway, or between the first track and the adjacent (centre) bus lane.

Once the first track is in place, rail operations would be inaugurated and construction of the second track would commence on the opposite side of the transitway. This would leave in place one lane in the centre of the transitway ("service lane") that could either be shut down and used exclusively by construction crews or could continue to handle some bus traffic. The communications conduit that is generally located on the south side of the transitways would have to be relocated as it would be underneath the second track and therefore inaccessible. It would make sense to install a replacement line at the same time as the lines for the signalling system are put in place for the first track, and remove the original when the second track is constructed.

Method 2

The second possible method of the three lane technique is similar to the first, with the exception that the second track would be built adjacent to the first in the centre lane. This is illustrated in Figure 5.4. The remaining space would be a mixture of original shoulder and built-up bus lane. If desired, it could be reconstructed as a proper lane or simply left as is. Conceivably, this lane could continue to serve some peak period peak direction express buses post-conversion, even though the ability to do so was not a design criterion. The same is also true of the first method.

Centre or edge service lane

Methods 1 and 2 are identical in concept but differ only in the layout of the final design. The advantages and disadvantages of each method are presented in Table 5.1.

Method 3

The third possible method of the three lane technique results in a symmetric two lane/track cross section when complete and is illustrated in Figure 5.5. Compared to the previous two methods, this method makes fuller use of the available right-of-way by reducing the

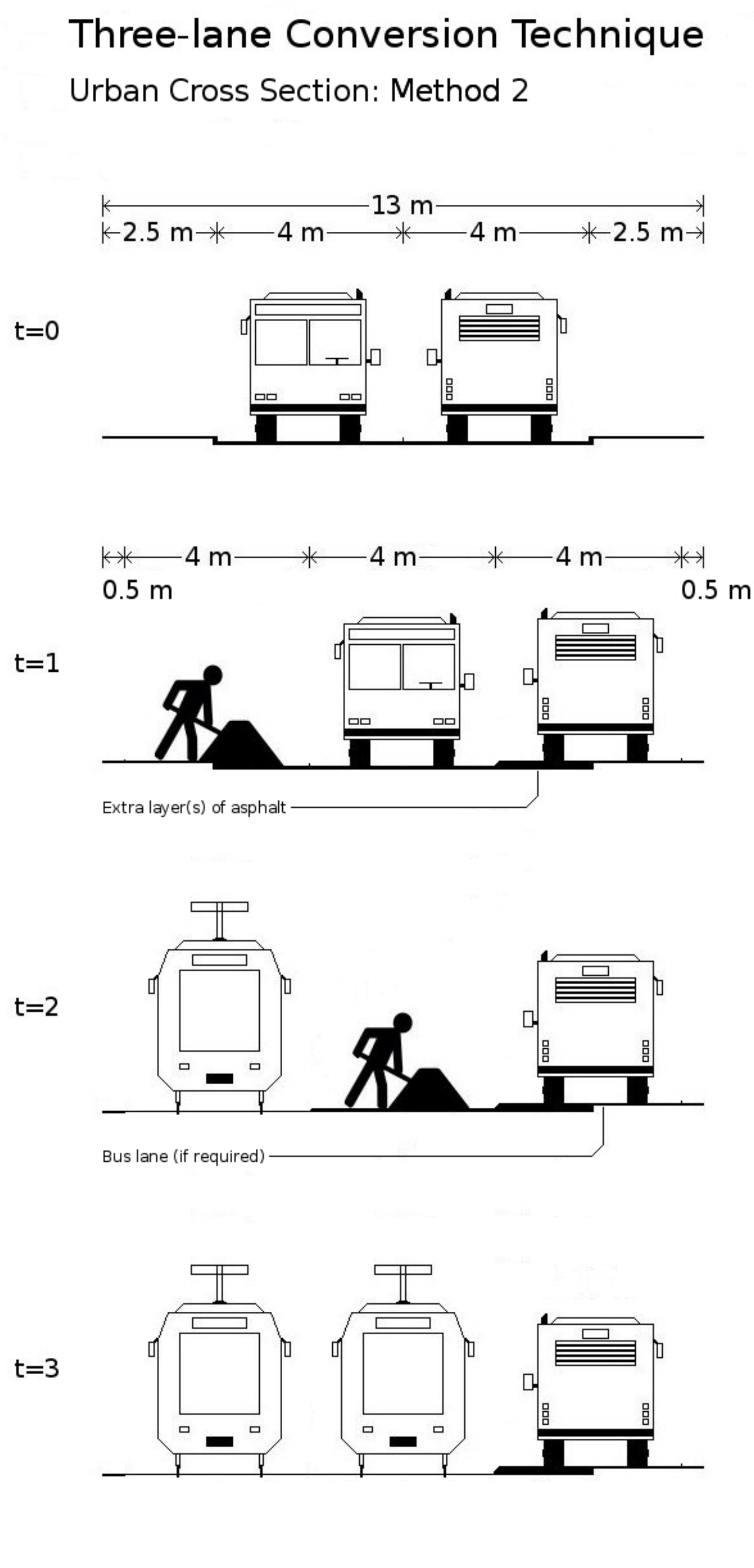

Figure 5.4: Three lane conversion technique, first method. Diagram by author.

	Method 1 - Centre service lane	Method 2 - Edge service lane
Advantages	-symmetric: reduces track deflection near stations, aesthetically more agreeable -remaining lane is properly cambered, no further reconstruction required -provides a logical space for future addition of extra passing/storage track	-utility relocation can be avoided -side-by-side track placement allows use of single pole for overhead power supply
Disadvantages	-two poles for overhead power supply -relocation of utilities may be required	-in urban cross sections, will likely require reconstruction of service lane for long term to reestablish drainage -increases track deflection for one track compared to other at stations

Table 5.1: Comparison of the advantages and disadvantages of a central or edge service lane

shifted bus lane widths to 3.5 m - the minimum lane width specified in the Transitway Design Manual. Despite this economy, the bus lanes still cross the centreline of the transitway by 0.5 m, which could make the installation of centrally-located footings and poles for overhead wires problematic. Where space allows, the transitway could be temporarily widened by about a metre on the side with the interim bus lanes to 14 m overall, so that the shoulder is a full 3.5 m wide and therefore wide enough for one lane of bus traffic (not illustrated). This would provide space for the poles in the centre of the transitway and would also eliminate the need to build up a layer of asphalt on the existing transitway. Alternatively, the poles and their footings could be located at the outer edge of the tracks and not in the centre between them, but this would require twice as many installations[3]. Finally, the use of diesel-electric dual-mode light rail vehicles could eliminate the need for poles at the time of construction of the first track and leave the installation of the footings until the time that the second track is installed at time index 2. The poles could be installed at that time or at a later date.

With this method, unlike with the previous two, there would be no possibility of continuing bus services during construction of the second track (time index 2) or post-conversion unless the shoulder widening option had been pursued.

Rural option

Converting rural cross section transitways could follow any of the methods described thus far, but the greater availability of space on either side of the transitway opens up another

[3] In the Scott Street trench section where widening is out of the question, overhead wire supports could be fixed into the walls of the rock cut.

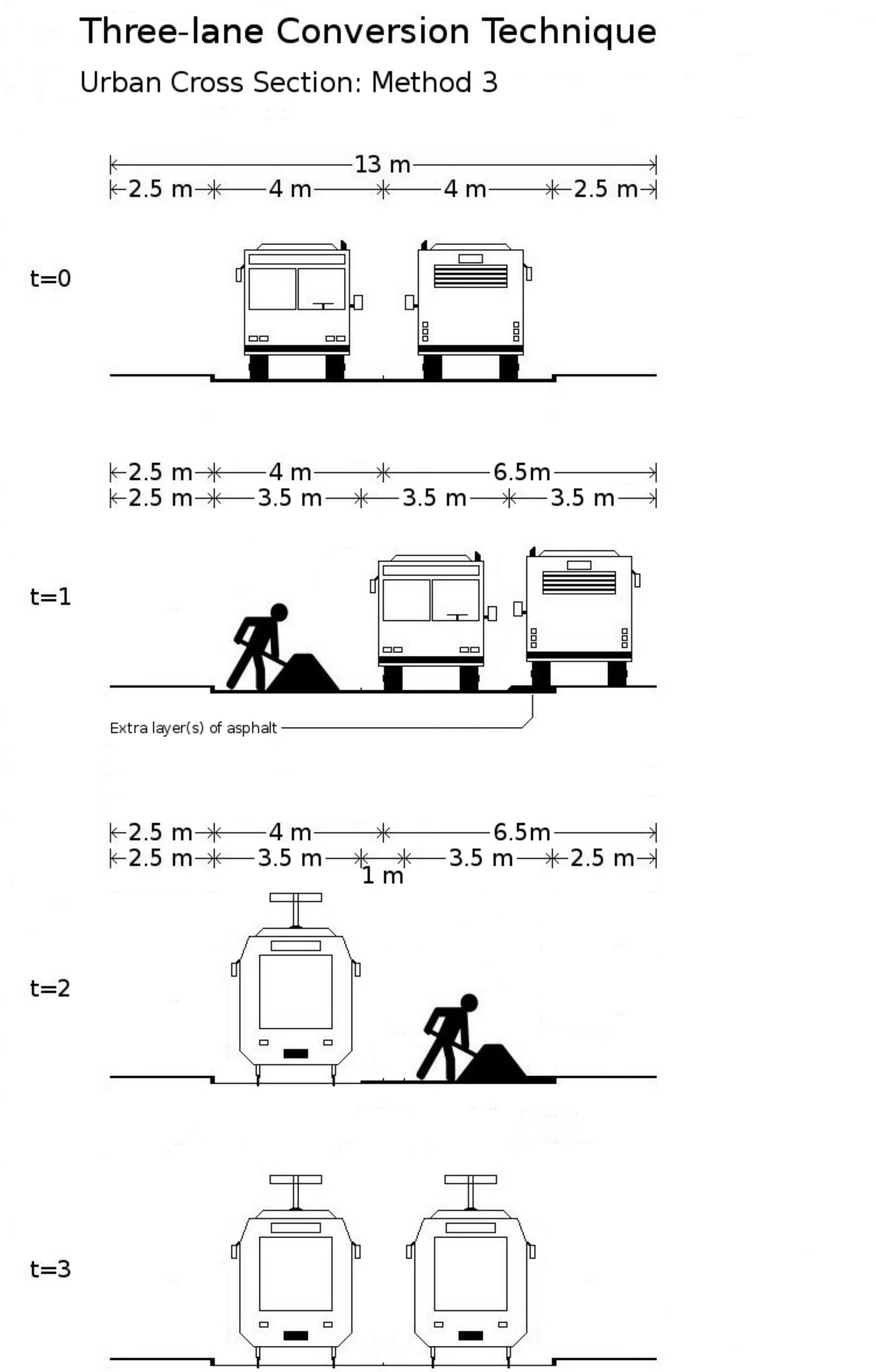

Figure 5.5: Three lane conversion technique, third method. Diagram by author.

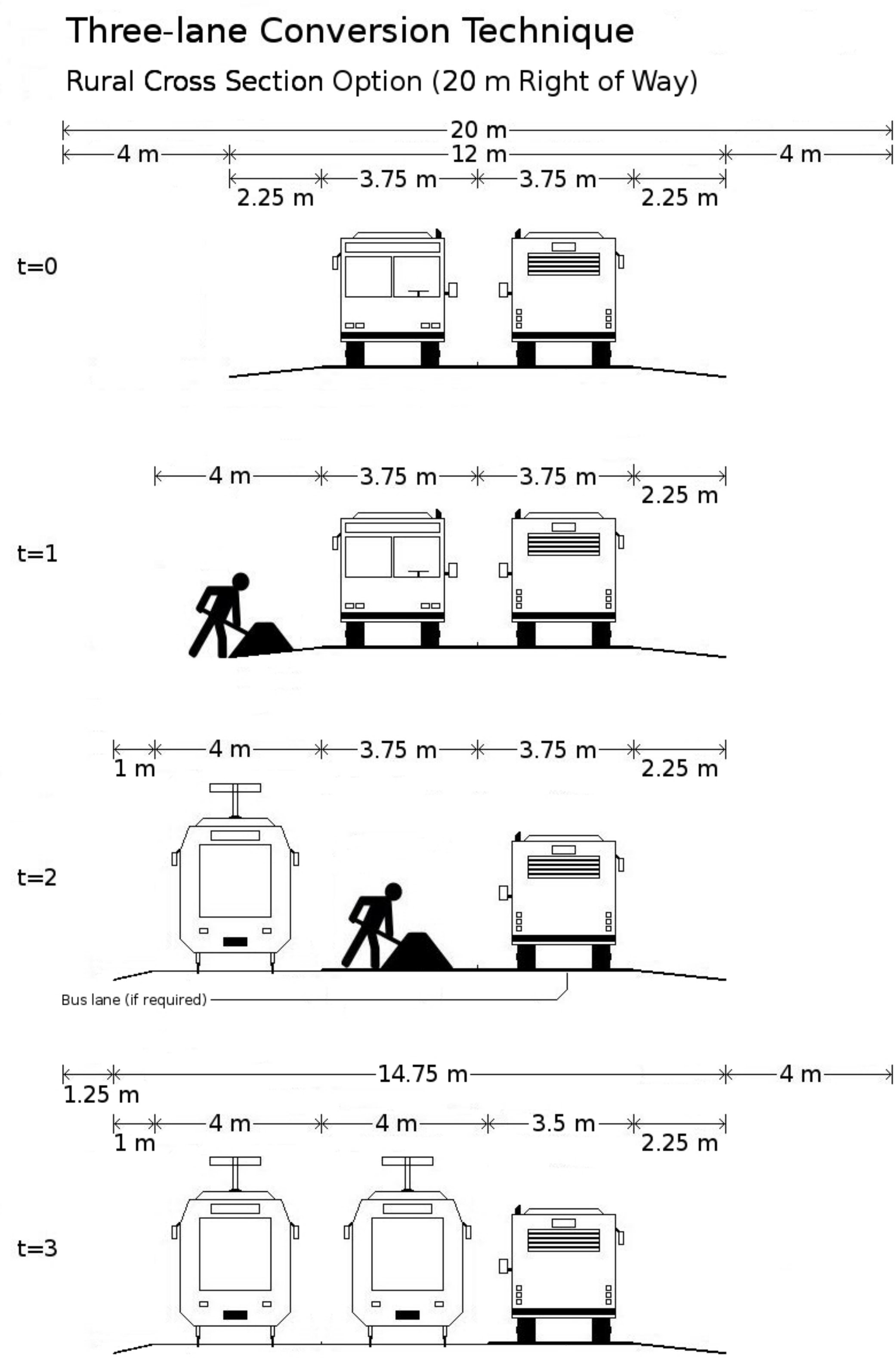

Figure 5.6: Three lane conversion technique, rural option. Diagram by author.

option for conversion. As illustrated in Figure 5.6, construction of the first track would simply take place by widening one of the shoulders (time index 1), leaving the existing bus lanes untouched. Once the first track is complete, the adjacent bus lane would be replaced with the second track and the remaining lane would continue to exist as a service lane.

This option assumes that the transitway is in the centre of its right of way; if the transitway is significantly offset to one side (more than 2 m) then widening for light rail should proceed on the side that has more space, bearing in mind that doing so may require relocation of underground utilities.

Bridges and other transitway right-of-way narrowings

Several transitway bridges in Ottawa are only wide enough for two-way traffic and have been built without shoulders, which limits their amenability to three lane conversion techniques. Moreover, the bridges have been designed under the assumption that future rail tracks would be placed in the "expected" lateral positions and not offset to one side or another. A variation of the two lane technique would be required to convert these narrowings. Examples of such situations in Ottawa include the Rideau River crossing near Hurdman Station, the Riverside Drive overpass near to the Train Station and the railway overpass at Bayview Station.

In the general case of a narrowing, one lane would be closed for conversion to a single track. Buses would continue to use the remaining lane on a signal/flagman basis. While this would introduce bottlenecks, the number of such narrowings is minimal and disruptions could be minimized if conversion of these sections were limited to a weekend, preferably a summer long weekend, close to the end of the entire conversion process.

Other options could also be considered for each specific case:

Rideau River bridge at Hurdman Bus traffic that would normally go over the Hurdman bridge could divert to the Queensway but congestion is likely as well as being a circuitous route, though that is less likely to be an issue if employed only by deadheading express buses. An alternative would be to embed the first track in a temporary driving surface for the duration between constructing the track and the start of rail operations. Complicating matters further is that this bridge may need to be double tracked from the outset since it is on the busiest section of the Transitway (see the note on capacity, section 5.3.1, and section 5.6.2). If this is indeed the case, then temporary driving surfaces or a type 1 hybrid transitway will be required over the bridge on at least one lane.

Riverside Drive overpass The bridge over Riverside Drive on the approach to the VIA train station could simply be bypassed (especially by express buses not needing to stop at the train station) by diverting to Riverside Drive and Tremblay Road.

Bayview railway overpass Similarly, bus traffic going over the railway overpass near Bayview Station could be reduced by diverting some of it to one or both of the Ottawa River Parkway and Scott Street.

5.6.4 Testing and training

If conversion of the Transitway is to be a success, there must be a period for testing of the system and operator training before bringing it into use. In the conversion techniques described earlier, that period is between time index 1 and time index 2 in the diagrams. At that non-illustrated stage two-way BRT service remains operational but the infrastructure to allow for single-track railway operation would be available for testing and training purposes before BRT is shut down (at time index 2) to proceed with the rest of the conversion.

5.6.5 Electric traction power infrastructure

Electric traction power, if employed, would require the infrastructure to be available before any vehicles could operate. Assuming the power is delivered via overhead lines, there are two basic positions for locating the poles that support the overhead lines: between the two tracks (however placed) or at the side of the transitway. The latter would require twice the number of poles than the former. Also required would be the underground conduits that supply electricity to the poles and lines for use by the rail vehicles.

The choice of conversion technique (and method for the three-lane technique) would dictate the options for installing the electrical infrastructure in terms of both timing (before or during conversion) and placement (one line of shared poles between tracks or two lines of poles, each to the outside of a track). Installing the electrical infrastructure in advance of conversion could help reduce the duration of conversion if the installation work itself is not excessively disruptive

To install the electrical infrastructure in advance of conversion, the least-disruptive option to ongoing BRT operations would be to employ two lines of poles at the margins of the transitway. The work of installing the footings and electrical conduits, and subsequently the poles, could be carried out at non-peak periods of the day and since the work would be to the sides of the transitway the bus lanes would be unaffected. This option would be compatible with the two-lane conversion technique and methods (1) and (3) of the three-lane conversion technique. However, this option would be more costly than using one line of poles/utilities and would also require more time/resources due to the doubling of the number of footings, although only one line of poles would be required in advance of conversion due to the initial single-track operation (the other would be installed at the same time as the second track).

To install only a shared single line of poles in advance of conversion would impact the running lanes of the transitway and would effectively limit the conversion options to the two-lane technique and method 3 of the three-lane technique where the poles would be centrally-located within the transitway right-of-way (i.e. on the centreline). The poles themselves would have to be protected with concrete barricades, thereby physically separating the lanes. Methods 1 and 2 of the three-lane conversion technique would not be possible since the pole locations would be in the same space required by buses until the buses are removed from the transitway.

If the electrical infrastructure is installed during the conversion period, then the only non-viable option is that of a single line of shared poles combined with method 1 of the three-lane conversion technique.

5.6.6 Stations

Both techniques and their various methods of implementation described above require that all stations on a section of transitway being converted be ready with two rail-served platforms and switches to connect both tracks within the station area to the single track on the transitway. Reconstructing stations without disrupting their use by buses during the conversion period may prove more difficult than converting the running ways themselves.

The typical station on the Transitway is inline with a four lane cross section, as can be seen in Figure 5.7 at Westboro Station. The existence of two lanes in each direction allows for two placement options for the tracks - in the stopping lanes adjacent to the existing platforms or in the passing lanes. However, before discussing the merits of the two track placement options, the problem of platform height and platform (re)construction during conversion will be examined.

Platforms

Even the use of low-floor light rail vehicles (LRVs) will require that existing station platform heights be raised to enable level boarding and alighting for the outer track arrangement option or require new platforms for the passing lane option. This is probably not, in and of itself, all that difficult, but doing so while bus operations continue could prove more difficult.

Figure 5.7: Westboro Station is typical of most stations on the Transitway as it is inline with four lanes. Conversion could place the rails in either the outer lanes adjacent to the existing platforms (where the buses are stopped) or in the passing lanes, with platforms occupying the current outer lanes.

One option to consider would be to establish temporary bus platforms during the conversion period beyond the ends of the length of platform to be used after conversion. The temporary platforms could be placed upstream or downstream of the existing platform, or both, but the downstream placement could cause back-ups within the station area. With the temporary bus platform(s) in operation, the main platform would be reconstructed for light rail use.

While establishing temporary bus platforms during conversion could work for lower volume stations, at the higher volume stations (such as Tunney's Pasture) such arrangements could cause excessive levels of disruption and back-ups upstream of the station. Accordingly, the alternate solution proposed here is not to modify the existing platforms until after bus operations have ceased, though since many platforms will also need to be lengthened (at least for the stopping lane track option) work can proceed with constructing the lengthened portions of the platforms at the new height prior to the cessation of bus operations.

Prior to the inauguration of light rail service each station would be stockpiled with a number of wooden decks. The location for the stockpiled decks could be at the end(s) of each platform, or on any newly constructed and lengthened full-height platforms. The height of the wooden decks would be chosen such that the decking will be at the same height as the floor of the LRVs when placed alongside the track. The required deck height may therefore vary from station to station. When the changeover to light rail takes place, the decks would be placed alongside the tracks to match the door locations of the chosen LRV when the LRV comes to a stop at a pre-determined position. With light rail running, the rest of the permanent platform would be constructed to the new height around the wooden decks. Once enough of the platform is constructed it would be put into service by adjusting the LRV stopping position and the wooden decks would then be removed to allow construction of the remainder of the platform.

The wooden decks would have to be large enough to meet required passenger movements, but small enough so that collectively they do not occupy the majority of the platform length. This would entail decks with dimensions of 2.4 to 3 m on the sides parallel to the tracks. The decks would also require ramps and possibly steps depending on their height.

In reconstructing the platforms to their new height, special consideration would have to be given to any existing stairs, ramps, elevators and shelters to ensure continuity with the raised platform height.

Track placement

One track placement option is to place them in the outer lanes adjacent to the existing platforms. Placing tracks in the outer lanes would reuse the platform space and also has the advantage of freeing up the passing lanes post-conversion for other uses, such as extra train storage or as passing track for skip-stop service. It does, however, have the disadvantage of disrupting bus and passenger operations during construction and would likely require that the roadbed be rebuilt with tracks embedded in concrete or a temporary driving surface installed (asphalt, wood (as at railway crossings)) to allow buses to continue using the space until the changeover to light rail takes place. Since the platforms are quite long (and would need to be lengthened anyway), the modifications can be phased in sections along their length in the same way as the construction of concrete pads at some stations in Ottawa (including Westboro) was accomplished a few years ago.

A second option is to place the tracks in the passing lanes. Placing the tracks in the passing lanes would reduce disruption to bus and passenger operations since construction of the tracks could procede without affecting the platform lane, although it would impede the function of the passing lanes themselves: to enable some buses to pass other, stopped buses. A temporary driving surface could restore this functionality if needed. Tracks placed in the passing lanes would also tend to reduce track deflection on the approach to most stations compared to placing them in the outer lanes. The platforms would have to be constructed in the current outer lanes, but this construction could not commence until they were no longer being used by buses, therefore requiring some form of temporary platform (as previously discussed) for the period between the opening of light rail service and the construction of permanent platforms. A notable disadvantage of this track arrangement is that it could be considered an innefficient use of space to fill-in a lane with a platform because platform space exists already and there would be no opportunity to use the passing lanes for vehicle storage or skip stop service.

It is also possible that the two options could be combined to produce a four-track cross section with outside platforms. Initial station modifications would proceed according to the second option - placing the tracks in the passing lanes, thus minimizing disruption to bus operations. Once light rail is operating, temporary platforms would be installed in the outside lanes but instead of building permanent platforms in that lane tracks would be gradually laid down, shifting the temporary platforms as appropriate. Meanwhile, modification of the existing platforms would proceed, raising them to the final height. Once both track and platform are ready, the temporary platforms would be removed and the permanent platforms put into service along with the adjacent tracks. This combined option avoids the disruption that would be caused by the first option and also avoids the waste of space of the second.

5.7 Conversion strategy

The conversion strategy differs from the conversion technique in that its focus is on how to proceed with the conversion of the system as a whole rather than how to convert a particular section of transitway, but the two are naturally related. The design criterion of maintaining rapid transit service throughout the conversion drove the basic theme of the conversion techniques employing the following sequence on a particular section of transitway:

(1) partial BRT shutdown/alteration

(2) construction of single track LRT infrastructure

(3) partial LRT opening

(4) full BRT shutdown

(5) construction of second track

(6) full LRT opening

The choice of conversion strategy determines what to do after step 2 has been achieved on a given section of transitway (i.e. between two stations, such as Bayview and Tunney's Pasture on the West Transitway).

5.7.1 Incremental conversion

The incremental conversion strategy would see each section of transitway (essentially station to station) converted to a fully operational state before moving on to convert the next section. In other words, steps 3 through 6 would follow step 2 and then the cycle would be repeated to the next station and so on until the transitway was fully converted. This conversion strategy is illustrated in Figure 5.8 using a two lane conversion technique for simplicity but it would apply equally to a three lane technique. Of note is that the incremental conversion strategy requires that each station become a temporary modal transfer station at some point in time.

5.7.2 Large segment conversion

The large segment conversion strategy seeks to limit the number of stations that would be temporary modal transfer stations to minimize customer disruption (and aggravation). It is illustrated in Figure 5.9. Once step 2 has been reached on a given section of transitway, work would cease on that section and move to the next section, where it would once again cease once step 2 had been reached. This process would carry on until a large suburban hub station (station D in Figure 5.9) had been reached and only then would conversion proceed to steps 3 and 4, which would apply not to just one section but

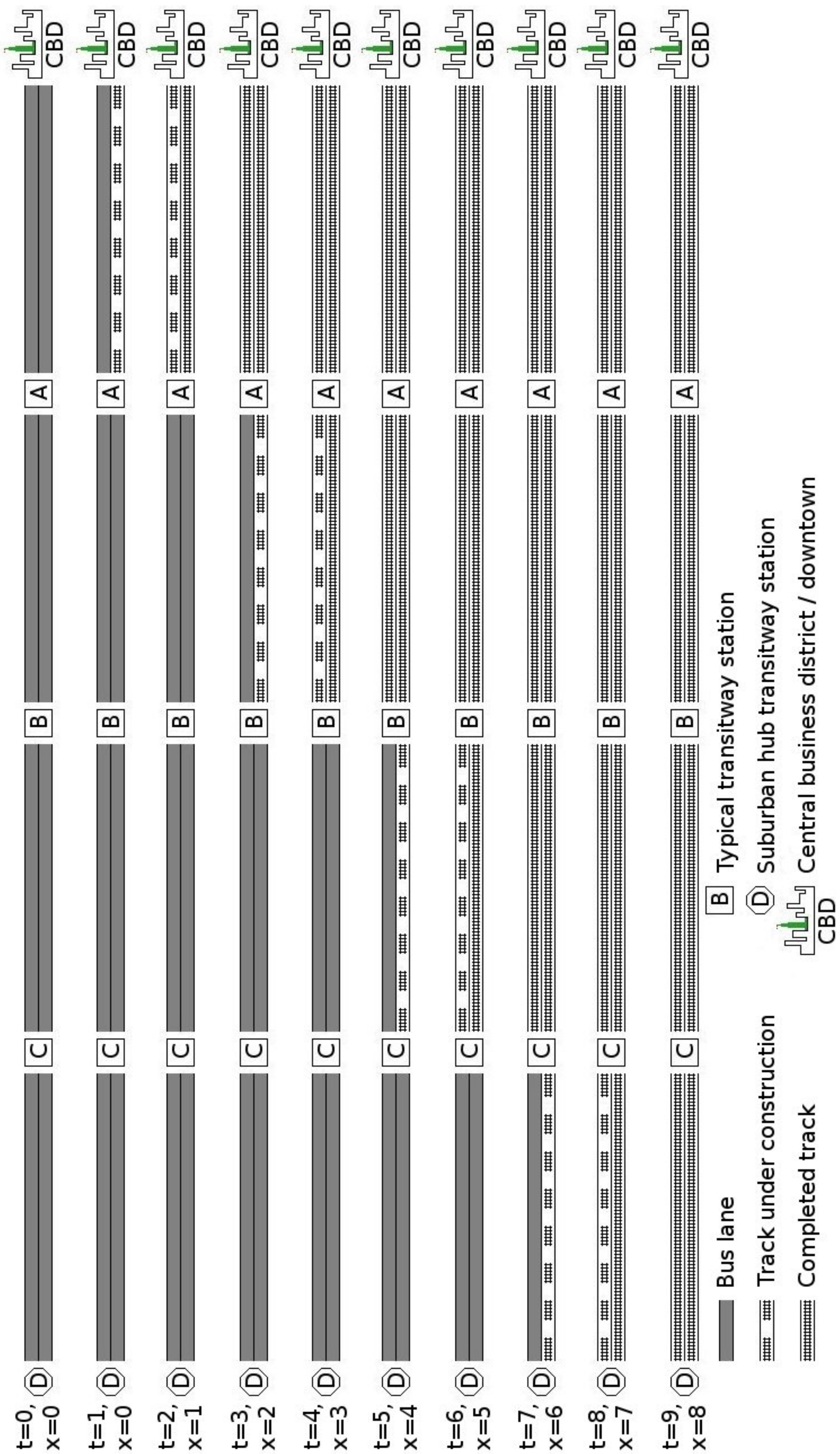

Figure 5.8: Incremental approach. Diagram by author.

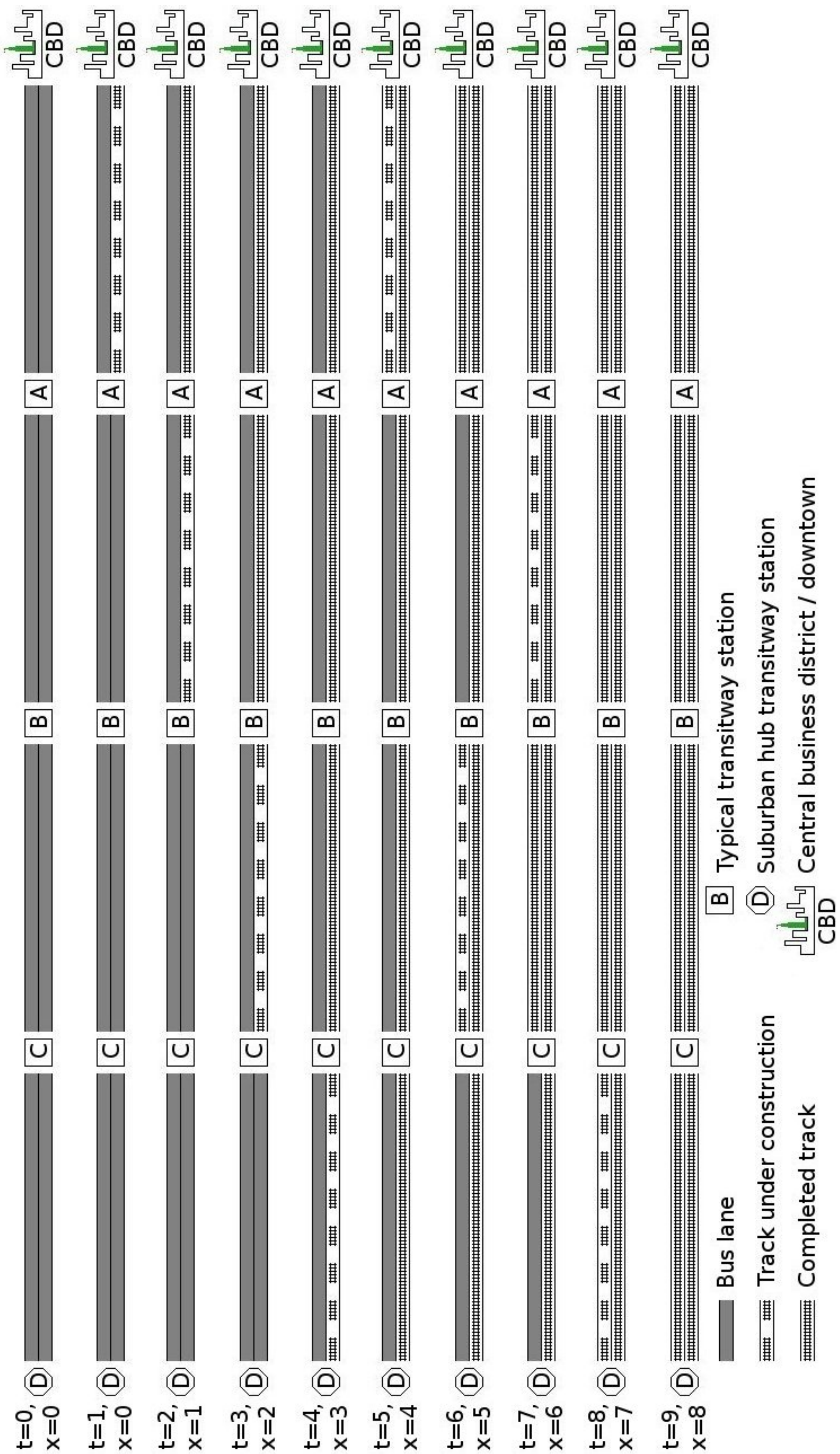

Figure 5.9: Large segment approach. Diagram by author.

to the entire segment up to the suburban hub station. Similarly, step 5 would be carried out on the entire segment and would be followed by an opening of the full system (step 6).

To the west of downtown Ottawa, potential suburban hubs on Ottawa's Transitway are Lincoln Fields Station near the intersection of West and Southwest Transitways, or, further out still, Baseline Station on the Southwest Transitway and Bayshore Station on the West Transitway. To the east, potential suburban hubs are Billings Bridge Station or Greenboro/South Keys Stations[4] (distant) on the Southeast Transitway and St. Laurent Station or Blair Station (distant) on the East Transitway.

5.7.3 Incremental versus large segment conversion

At first glance, an incremental approach would appear to be the better option as it would bring sections online sooner. However, a large segment conversion may in fact be the better overall option, as this section explains.

For the purpose of this discussion, if one assumes that the distance between any two stations is the same (including the downtown as a 'station'), then the number of hours of labour required to convert to single track between any two stations may be given as 'x' (these numbers are included for reference in Figures 5.8 and 5.9), and, therefore, 2x hours would be required for a full conversion between any two stations. The following analysis assumes that all stations will be double tracked once reached so that stations are also, in effect, passing tracks. Figures 5.8 and 5.9 are used as references.

After 1x hours, both approaches will have reached station A with one track, but under the incremental approach that track will be brought into use (shutting down all BRT operations) whereas it will not under a large segment approach (BRT operations continue).

Under an incremental approach, 2x hours will buy a fully operational LRT line between the CBD and station A, whereas a large segment strategy will buy a still non-operational single track to station B. After 3x hours, the incremental approach now has an operational single track line to station B in addition to the full line between the CBD and station A. Passengers are now transferring from buses to trains at station B. The large segment

[4] South Keys is at the end of the SE Transitway but it may not be suitable as a major transfer point unless arrangements are made with adjacent land owners, but Greenboro, the next station, would have no such problems. However, it would not make sense to leave South Keys unconverted because it is located next to employment, retail and entertainment destinations.

approach has reached station C with single track but is still non-operational.

However, at 4x hours the large segment approach has reached station D, the suburban hub, with an operational single track system. Instead of taking buses all the way to the CBD, passengers will transfer from what are now effectively local (or short-haul trunk) buses to the train. By contrast, the incremental approach has only reached station B, though the line is fully double tracked.

At 5x hours the incremental approach has reached station C with single track, whereas the large segment approach has been able to double track between the CBD and station A. Full double tracking will exist to station C after 6x manhours under the incremental approach. With 6x hours, the large segment approach could double track from the CBD to station B and continue with single track to station D, but it could also double track the section between stations B and C instead. This would increase the effective length of the system's passing tracks, thus allowing for more trains to be run and better flexibility in the event of incidents. After 7x hours, the incremental approach finally reaches station D, the suburban hub.

Both approaches will ultimately take 8x hours of labour to achieve full build-out, but

Figure 5.10: The off-line or 'local' platforms of Lincoln Fields Station, a suburban hub station in Ottawa's west end. Photo by author, June 2007.

the large segment approach was brought online further afield much sooner. The large segment approach also did not need to consider how to turn ‘standard’ stations into temporary transfer facilities. This last point would be worth untold hours of grief: the number of bus movements at the stations nearest the downtown could easily exceed 150 (trunk, express and local feeder combined) during the peak hour, and 200 is not inconceivable. Most of these buses would be subject to complete emptyings and fillings as passengers will be transferring to and from the trains. The logistics of managing all this movement of buses and passengers - possibly upwards of 5000 per hour - on the local bus platforms (the trains will be occupying the transitway platforms) could prove daunting. The logistics would also have to be worked out for each and every station that found itself as a temporary rail terminus. By contrast, the suburban hub stations have larger ‘local’ platforms and lay-up areas that are better able to handle those volumes, as shown in Figure 5.10. Moreover, the volumes themselves would be lower as some passengers will be transferring at other stations closer to downtown.

There is another compelling reason why a large segment conversion is preferable: at least one LRT storage and maintenance facility will be required somewhere along the line. A large segment conversion increases the likelihood of finding sites for such facilities (potential sites in Ottawa are discussed in section 5.6.4).

5.8 Ottawa-specific issues

5.8.1 The Downtown

Ottawa’s Transitway was built on an outside-in approach whereby outer segments were constructed first and the downtown portion (Figure 5.11) was run along bus lanes on Albert and Slater streets with a permanent solution to be sorted out later on. “Later on” has come about and it has now been recognized by most observers and City staff that the downtown portion of the Transitway is at or approaching failure at peak times. Various improvements, such as replacing regular buses with articulated buses and providing real-time information for customers, might stave off failure a bit longer but with continued growth it is now inevitable.

Converting the downtown portion to light rail poses a number of unique challenges. The cancelled North-South Light Rail (NSLRT) project would have seen the current bus lanes (the second lane from the curb) converted to dual use by placing tracks in them. The bus stops would have been moved to the sidewalk and accessed by bus from the outer-

Figure 5.11: Ottawa's Central (downtown) Transitway. Diagram by author overlayed on Google Maps image.

most lane where onstreet parking and loading zones are currently located; the LRT stops would have been located roughly at the current transit stop lane bulb-outs. If the project had proceeded a traffic management plan would have needed to have been submitted by the winning bidder prior to commencing work on this portion, but as it was cancelled such a plan was never submitted (Steacy, 2007).

Whilst an onstreet LRT operating with one track each on Albert and Slater streets would work in theory, in practice it could be problematic. The Mayor's Taskforce on Transportation (MTFT), after visiting and meeting with transit officials in Calgary and Edmonton, concluded for the purposes of system reliability in the event of an accident, disabled LRV, utility maintenance or other problem, that it was best to have the tracks running in the same physical corridor so that problems could be bypassed by switching LRVs over to the other track (MTFT, 2007, p. 33).

Surface LRT could instead be constructed as a transit mall on one of the east-west crosstown streets, as with 7 Avenue in Calgary. This might have been viable a quarter century ago when the Transitway was first constructed (which, as it happens, is also when Calgary began work on 7 Avenue), but the current situation in Ottawa is that the downtown streets have developed around the current transit system. There are simply too many buildings with access on only one street that would be affected for a transit mall to be practical (Steacy, 2007). Indeed, the option of running the NSLRT in the leftmost lanes of Albert and Slater streets was rejected for this same reason (Steacy, 2007).

Placing LRT in a tunnel under downtown Ottawa as Edmonton has would avoid the potential problems with LRT on separate streets and the real problems of an LRT mall on any of Ottawa's streets, which is what the MTFT concluded. Ottawa's downtown geology actually facilitates a tunnel, especially in the west end. Ottawa's downtown sits atop a significant escarpment that overlooks LeBreton Flats to the west. It would be quite straightforward for an LRT line running on the surface across LeBreton Flats to enter a tunnel portal dug into the face of the escarpment (position indicated in Figure 5.11) without needing to lose much height, though it would have to have sufficient depth to clear the Rideau Canal on the east side of the downtown.

A downtown tunnel would add significantly to the cost of converting the Transitway to light rail, but it should also be noted that (1) the downtown portion of the Transitway - which is now approaching failure anyway - has long been overlooked relative to the rest of the system, much of which is grade-separated, and (2) to address the downtown bus congestion issue twin bus tunnels, which widened at stations to accommodate an extra lane, was proposed in the late 1980s. The bus tunnel plan never went ahead because it would have been quite costly, in part because of the need for both extra width (which resulted in two distinct tunnels under separate streets, not one) and heavy ventilation, neither of which would be required for electric light rail. The MTFT estimated the cost of a tunnel under downtown Ottawa - based on recent tunnelling in Montreal and Edmonton - at about $450M, inclusive of stations. They also found that there was some private sector interest in partnerships for the building of the stations through integrating them with existing buildings in downtown Ottawa.

A tunnel would, however, take several years to plan, design and build, and in the mean time the bus congestion that is placing the system under strain would continue to get worse. Building LRT on the surface would have the benefit of a shorter implementation timeframe and would not preclude building a tunnel later so long as another use for the surface LRT infrastructure could be found[5].

A tunnel or a surface light rail line would be built with two operational tracks from the outset, thus allowing higher frequencies without running the risk of tight scheduling issues on a single track. The higher frequencies would provide for the 8000 person per hour capacity required in the downtown portion.

Laurier-Hurdman (Canal/Nicholas St.)

Without any doubt, the most difficult section of existing transitway to convert will be the section from Hurdman Station to the vicinity of Laurier Station (see Figure 5.12) adjacent to Nicholas St., the University of Ottawa and the Rideau Canal. While this section is not strictly in downtown Ottawa, it has to be considered at the same time as the downtown from a practical point of view. This is the busiest section of the Transitway and, to complicate matters, it has the narrowest right-of-way: only two lanes with no shoulders nor any available space for them, so a pure three lane strategy is out of the question. Converting this section will therefore be disruptive, regardless of what strategy or method is used on the rest of the Transitway. All of the various proposals that have been published by different parties for the future of Ottawa's transit system since the cancellation of the NSLRT

[5]The current (c. 2003) Transportation Master Plan has a tram line that would go downtown and the possibility of a light rail loop across the Ottawa River to Hull always exists.

Figure 5.12: Ottawa's Central Transitway, Laurier to Hurdman. Diagram by author overlayed on Google Maps image.

- regardless of what they propose for the rest of the system - have proposed converting this section of transitway to rail. Since it is quite likely that this section of transitway will be the first to be converted it is of more than simple academic interest.

Conversion of this section to hybrid dual use transitway with buses and LRVs “sharing” the same lane (i.e. a type 1 hybrid transitway) is one possibility. While this would be costly, it may be worth it to avoid excessive disruption as construction could progress a few dozen metres at a time in each lane. It would also allow buses to continue operating until such time as a tunnel and other light rail infrastructure (especially a storage and maintenance facility) were available and brought online. Once the light rail infrastructure is ready, bus operations would cease and would be replaced by light rail vehicles, thus avoiding the logistics of simultaneously operating over 150 buses and 15-20 trains per hour in one corridor so that the “sharing” never actually takes place.
A complete shutdown is another possibility, at least from Laurier Station to the transitway access ramp near Lees Station. This has the benefit of getting the conversion completed in as short a period of time as possible so long as it is coordinated with the downtown solution, as well as bringing a full two tracks online at once, thus providing the required capacity and avoiding tight scheduling issues. Evidently, buses would have to be diverted onto parallel corridors. Nicholas Street, a four lane expressway, is the first obvious candidate, however it is very busy with regular traffic as it connects downtown Ottawa (and Hull) with the Queensway. Removing two of its four lanes from use by general traffic would likely prove to be unacceptable. The use of Nicholas Street would also completely bypass the University of Ottawa and afford no access to it until the vicinity of Laurier Station at the north end of the university campus. The other candidate is King Edward Avenue, a four lane arterial running to the east of the University of Ottawa. The stretch of King Edward parallel to this section of transitway is relatively isolated from the rest of the arterial road grid but is accessible to buses from the Transitway at Lees Station. The suspension of any onstreet parking for the duration of construction could help provide the extra needed capacity. A temporary stop to replace Campus Station could also be established, but this would result in northbound buses having to change lanes from the curb lane to the left lane as a left turn would be required at Laurier to rejoin the regular Transitway route. Running speeds on King Edward would be considerably reduced even with reserved lanes because it runs through a pedestrian-oriented university district. Carrying out the conversion between the months of May and August would minimize disruptive effects of using King Edward Avenue.

Conversion of this section of transitway should also incorporate a reconstruction of Campus Station. The current westbound platform is characterized by excessive deflection of the transitway on both sides of the station. A reconstruction would see the cross-section narrowed to two lanes, leaving only the two eastbound lanes at the station. The new westbound platform would be built on the location of the two westbound lanes. An opportunity would exist for negotiations with the University of Ottawa to incorporate a new westbound platform and the site of the existing westbound platform into a new university building that could serve as a gateway to the campus.

A complete shutdown using King Edward would minimize the duration of disruption as well as the costs incurred in converting but the uncertainties in the timing of the availability of an in-place downtown solution and the need for continued reliable bus operations during the conversion period may require that a hybrid transitway be constructed in this critical section instead.

5.8.2 Other missing segments

Besides the downtown portion of the Transitway, there are a few other missing segments that would have to be filled in and constructed as light rail for a conversion of the Transitway to light rail to proceed. For the most part, these can be seen in Figure 5.13.

West Transitway - Ottawa River Parkway

The most glaring gap in the Transitway is that part of the West Transitway between Dominion Station and Lincoln Fields Station. At present, buses run on the National Capital Commission's (NCC) Ottawa River Parkway (ORP) in mixed traffic through an agreement with the NCC. It has never been determined what permanent route the Transitway should ultimately take through this part of the city. To complicate matters, one of the possible routes, a former CPR right-of-way (RoW) parallel to the ORP has been built upon with houses in the vicinity of Woodroffe Avenue. Another RoW parallel to the ORP, a former tramway between Byron Avenue and Richmond Road also exists, but access to it from the existing transitway in the area around Dominion Station is becoming increasingly difficult with the continued infill development in that area. The tramway is also being used as a linear greenspace and is heavily treed in places; moreover it runs between many residential neighbourhoods for much of its length. A route using pieces of both the tramway and the CPR RoW is still possible but would require protection from further incursions. The final possibilities involve the transfer of land from the NCC for a light rail transitway; such

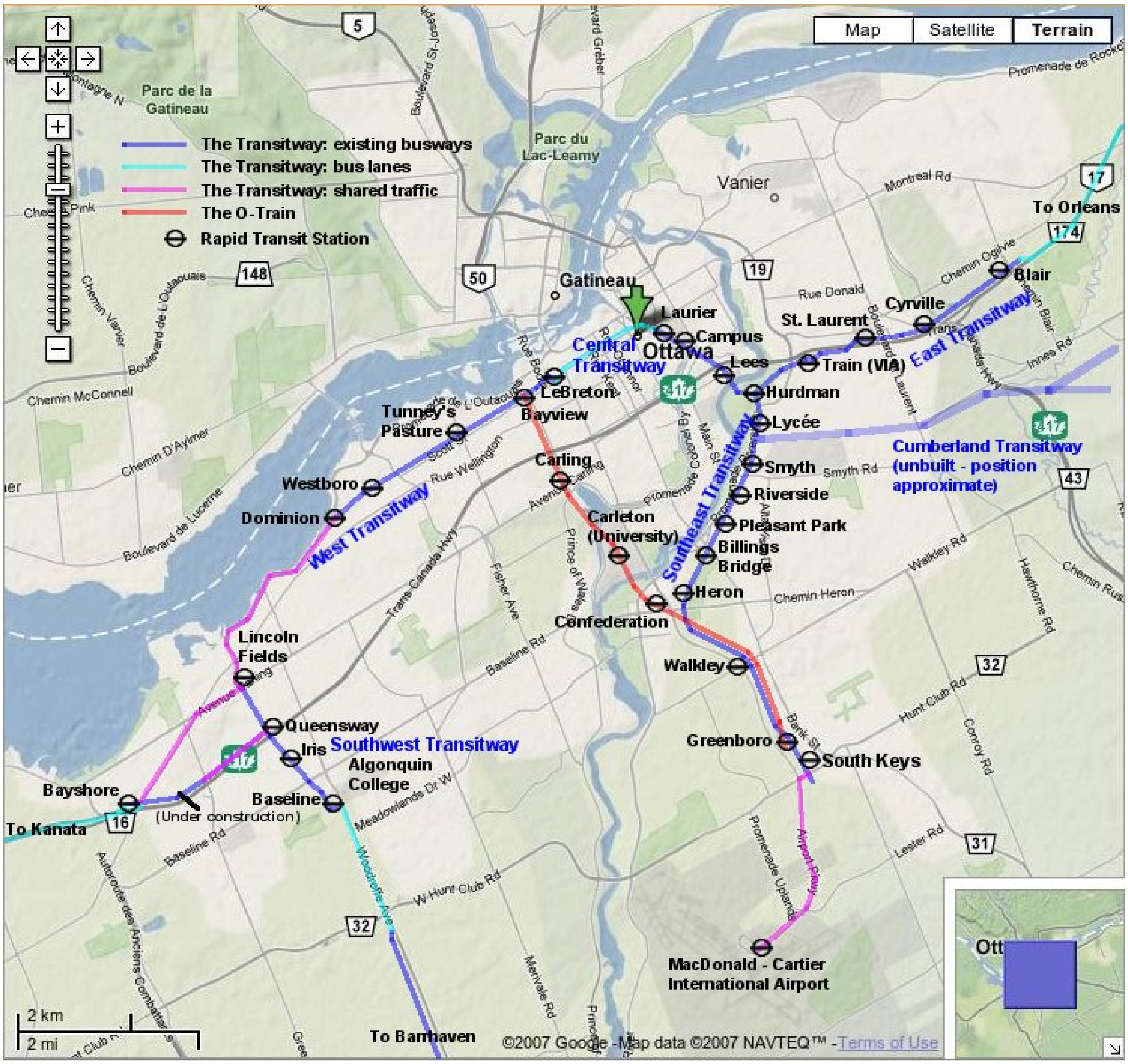

Figure 5.13: Ottawa's Transitway (inside the Greenbelt). Downtown stations have been omitted. Diagram by author overlayed on Google Maps image.

an alignment could be to the south of the eastbound lanes of the ORP, in the wide median between the east and westbound lanes or in the space occupied by the eastbound lanes. The last option would reduce the ORP to a two-lane parkway in the current westbound lanes, which might in fact be feasible because of the ORP's lightly-used nature west of Island Park Drive and the Champlain Bridge to Quebec (a fact that has allowed the Transitway to operate along it for so long in the first place). The viability of this option could be tested relatively easily by simply closing down the eastbound lanes to regular traffic west of Dominion Station and running buses in them and regular traffic in the westbound lanes.

Whichever route is ultimately chosen, it will no doubt require considerable negotiations with various stakeholders and land acquisition costs could be considerable (though this would be the case with building a busway here as well). However, the fact that buses could in all likelihood continue to use the ORP during construction of this segment will reduce the amount disruption caused by it.

West Transitway - Lincoln Fields/Queensway to Bayshore

At present, the West Transitway west of its interchange with the Queensway to Bayshore consists of running in bus lanes and mixed traffic along the Queensway. A new segment of transitway to the north of the Queensway is being constructed from Pinecrest Avenue to Bayshore. East of Pinecrest Avenue there is also room to the north of the Queensway for a new segment of transitway, but only as far as an OC Transpo bus garage. To join the Transitway west of the bus garage with the rest of the Transitway, it was proposed to tunnel underneath part of a residential neighbourhood (McCormick Rankin, 1994, pp. 14-10 and 14-17). As with the ORP section, negotiations and discussions with stakeholders would likely be necessary. Compared to building a bus tunnel however, a tunnel for light rail only would probably cost less as there are no requirements for shoulders or extra ventilation with light rail.

West Transitway - Bayshore to Kanata

West of Bayshore, buses currently travel along the Queensway to Kanata in shoulder bus lanes. Rights-of-way have however been reserved on the north side of the Queensway (RMOC, 1996, p. 5-14) and bridge structures in Kanata already incorporate underpass spaces for a future extension of the transitway. If conversion of the Transitway was to take place before these segments are constructed as bus transitway, they could instead be built as new light rail transitway with little or no disruption.

Southwest Transitway - Baseline to Hunt Club

Baseline Station is one of the oldest stations on the Transitway and was for a long time a terminus. South of Baseline Station the Transitway runs in bus lanes on Woodroffe Avenue until just south of Hunt Club Road across from the Nepean Sportsplex where a new segment of transitway begins on the west side of Woodroffe. To the west of Woodroffe Avenue from Baseline Station until Knoxdale Road just south of the railway is a large reserved right-of-way from the Greber plan that is available for use as a transitway. That leaves a short stretch of about 2/3 km between Knoxdale Road and Hunt Club Road without any obvious place to run a new transitway. The likely options include a large scale expropriation of property to the west of Woodroffe Avenue or a section of tunnel underneath Woodroffe Avenue or the property to its west. The north portal to the tunnel would likely incorporate an underpass of the railway.

East Transitway - Blair to Orleans

East of Blair Station to Orleans, buses run in shoulder bus lanes along Ottawa Road 174 (an urban freeway). A long abandonned railway right-of-way exists parallel and immediately to the south of the 174. Since the railbed already exists, it would only need to be widened to accommodate double track light rail, not built completely as new as in the west to Kanata.

Cumberland Transitway - Hurdman to Cumberland/South Orleans

The Cumberland Transitway has yet to be built but is present in the Transportation Master Plan and can be considered to be “missing” from the overall rapid transit network. As it is not yet built or designed, from a perspective of switching the entire Transitway network to light rail it would be preferable to build this new transitway as light rail and not as busway. Moreover, doing so would, in the short term, relieve some of the traffic on the roughly parallel East Transitway to Orleans if it were to be built prior to conversion of the East Transitway.

5.8.3 St. Laurent tunnel

St. Laurent Station is located in a tunnel that also underpasses the Queensway. St. Laurent Station itself resembles more than any other Transitway station an underground metro station, complete with an enclosed lower level Transitway station, a mezzanine connecting with St. Laurent Shopping Centre and an open air upper level for local bus platforms, all connected with stairs, escalators and elevators. The tunnel itself has very high vertical clearances to allow for ventilation equipment suspended from the ceiling and it has horizontal clearances throughout of at least 13 metres. The three lane conversion technique would not be put in difficulty at this location.

5.8.4 Train maintenance and storage yards

When converting a busway to light rail, locations for maintenance and storage facilities would have to be identified. Ottawa has a number of such potential sites along its transitways. Two such sites exist to the east of downtown Ottawa on either side of the Rideau River adjacent to Lees Station and Hurdman Station. Both sites are brownfields with railway histories, with Hurdman also being the site of a landfill. Another pair of sites exist to the west of downtown Ottawa at Bayview and LeBreton Flats. These two are also former railway-related brownfields. Further afield, there is the previously-mentionned bus garage near to the split of the West and Southwest Transitways that might have some potential. The route of the proposed Cumberland Transitway takes it past numerous industrial and brownfield sites that could prove suitable. The Walkley railway yard, which currently serves as home for the O-Train, is another potential site owing to its location next to the Southeast Transitway. This site, as well as all the other sites listed above, are adjacent or near to existing railway lines and would enable delivery of light rail vehicles by rail. Finally, all the inline four-lane stations would have, post-conversion, two surplus lanes. These surplus lanes could be converted to tracks to provide storage for extra trains (at least two per station) during non-peak hours.

5.9 Summary

Several variations on techniques to convert bus transitways to light rail were presented in this chapter. No one variation is recommended overall but rather all are presented in a suite of multiple options that allow for the most appropriate option to be selected for each particular section of transitway being converted. However, for urban cross sections where space allows, the variation on method 3 of the three-lane conversion technique that temporarily widens the transitway by a metre has the distinct advantages of positioning the tracks in the "obvious" location of the existing lanes and not requiring reconstruction or relocation of utilities whilst providing for installation of central poles from the outset.

5.9.1 Limitations of the techniques

The conversion techniques presented in this chapter rely on the use of interim single track rail infrastructure with passing tracks at stations until a second track can be constructed. It has been shown that this setup has sufficient capacity for approximately 7200 passengers per hour per direction when using four-car trains (at 150 passengers per car) running every five minutes. With longer trains, and/or more passengers per car, higher capacities may be possible, but at some point - probably below 10,000 passengers per hour per direction - a single track will be insufficient and by extension so too will any conversion techniques based on using single track. It is notable that the volumes at which a single track system would be insufficient are still within the capacity of BRT systems, leading to a possible situation where passenger volumes on a BRT system are high enough to make the inexpensive conversion techniques presented in this chapter impossible or impractical. Should that occur, double tracking would be required from the outset. The options that are left - while still maintaining rapid transit service - are to undertake more expensive solutions involving either a widening of the transitway (i.e. the type 2 hybrid transitway mentionned in chapter 4) or to lay down some form of temporary driving surface on at least one of the tracks while the second track is being constructed, as in the method suggested in the TMP update. This fact has strong implications with respect to the broad question of ‘when to convert a BRT system to LRT?’.

Chapter 6

Summary and Recommendations

6.1 Introduction

The final chapter of this project is split into three broad sections. The first section outlines a basic plan for the conversion of Ottawa's Transitway to light rail. It includes corridors that will need to be converted and contains several optional steps that would facilitate an overall conversion. The second section contains recommendations for the design of new bus transitways with a view towards facilitating their subsequent conversion and also includes a discussion on the concerns and policy implications that this project has revealed with general policy recommendations to address them. The final section is a discussion on the "convertibility" of "convertible" busways, including the fact that no such busways have ever been converted, and the implications this has on the choice between busway and light rail.

6.2 A plan for the conversion of Ottawa's Transitway to light rail

Since Ottawa's Transitway is still incomplete in the sense that there are several missing sections, a plan to convert it to light rail is not quite as simple a matter as carrying out one or more of the conversion techniques in accordance with one of the conversion strategies in the previous chapter. The following is a basic "plan of action" that could be followed to carry out the conversion of Ottawa's Transitway to light rail and to establish a light rail network in Ottawa.

(1) The Transportation Master Plan will need to be altered substantially to change its

focus from a rapid transit system based mainly on bus rapid transit with light rail playing a supporting role to one in which light rail forms the backbone of the system with bus rapid transit in a supporting role in accordance with the measures suggested here. Environmental Assessments (EA) will have to amended and initiated as appropriate, but the recently modified (2007) “Municipal Class EA” will make many of the new EAs much simpler than they would have been in the past (Ottawa, 2007b).

(2) Identify sites for maintenance and storage facilities along transitway corridors, and co-ordinate their construction with other activities as appropriate. An EA will be required, but would probably be part of an overall conversion EA.

(3) Proceed with a downtown tunnel and co-ordinate planning activities and construction with the shutdown and conversion of the Laurier-Hurdman section of transitway. An EA is underway concerning a downtown transit tunnel. This EA should provide the particulars for a light rail-based tunnel, including costs, routing, stations, etc.

(4) (Optional) Proceed with the Cumberland Transitway as a light rail transitway to the edge of the Greenbelt/Highway 417 at a minimum and preferably all the way through to Cumberland/South Orleans. This step is not strictly necessary, but it would relieve pressure on the parallel East Transitway - particularly at peak periods - and allow for the latter’s expedited conversion since express replacement/feeder services could be routed towards the Cumberland Transitway instead of the East Transitway. With pressure relieved on the East Transitway, the simpler two-lane conversion technique would be easier to carry out it as there would remain only the trunk routes whose passage could be managed with signals; the necessity of diverting non-peak direction buses would thus be removed. EAs already exist for the Cumberland Transitway but will require amending for completion as light rail.

(5) (Optional) In the west and south, existing railway lines could be upgraded as per the Mayor’s Task Force proposal with passing tracks and stations. The proposal also calls for them to be connected to the downtown tunnel, and bi-mode rail vehicles would be employed (electric in the tunnel, diesel on the existing railway lines). Similar to the Cumberland Transitway in the east, this would help relieve some of the pressure on the West and Southwest Transitways, particularly at peak periods, and would make conversion easier. EAs may be required for this step.

(6) Any of the missing gaps in the Transitway would be filled in, but as light rail and not busway. This would include the construction of any new stations, which could

be designed as rail stations and not busway stations (i.e. without extra width for unneeded passing lanes and possibly island platforms where it makes sense to do so). Where EAs exist for the missing gaps, they will need to be amended. New EAs will be required for the remaining gaps, but could probably be part of an overall conversion EA.

(7) Proceed with transitway conversion using a large segment strategy to Bayshore, Baseline, Greenboro/South Keys, and Blair stations. The choice of conversion technique would depend upon the section in question and whether the overall conversion plan included the establishing of parallel light rail corridors. An overall conversion EA would be needed.

(8) Once the transitways within the Greenbelt have been converted, the bus network would need to be reoriented as appropriate.

(9) Light rail transitways could be extended across the Greenbelt to Kanata (to serve Scotiabank Place, the current name of the arena of Ottawa's NHL franchise, the Ottawa Senators) in the west and to Orleans in the east once the network inside the Greenbelt is complete. Again, new EAs would be required and existing EAs would require amending.

6.3 New transitways: design and policies

Whether in Ottawa or elsewhere, as part of the planning process for new bus transitways in corridors where there is an expectation of future conversion to light rail or a reasonable possibility thereof, more attention should be made towards both the design of the new bus transitways themselves to facilitate conversion and to the policies surrounding their life cycle and the transition from busway to light railway. Given the experience of the past few decades, it should no longer be acceptable to simply design busways "to accommodate light rail" without giving any regard to how it will be accomplished. Similarly, the issue of when or at what point to convert as well as the cost to do so should be laid down from the outset of the planning process.

6.3.1 Design of bus transitways

New bus transitways should be designed not just to allow future conversion to light rail, as is the case with Ottawa's transitways, but instead to facilitate their conversion. The

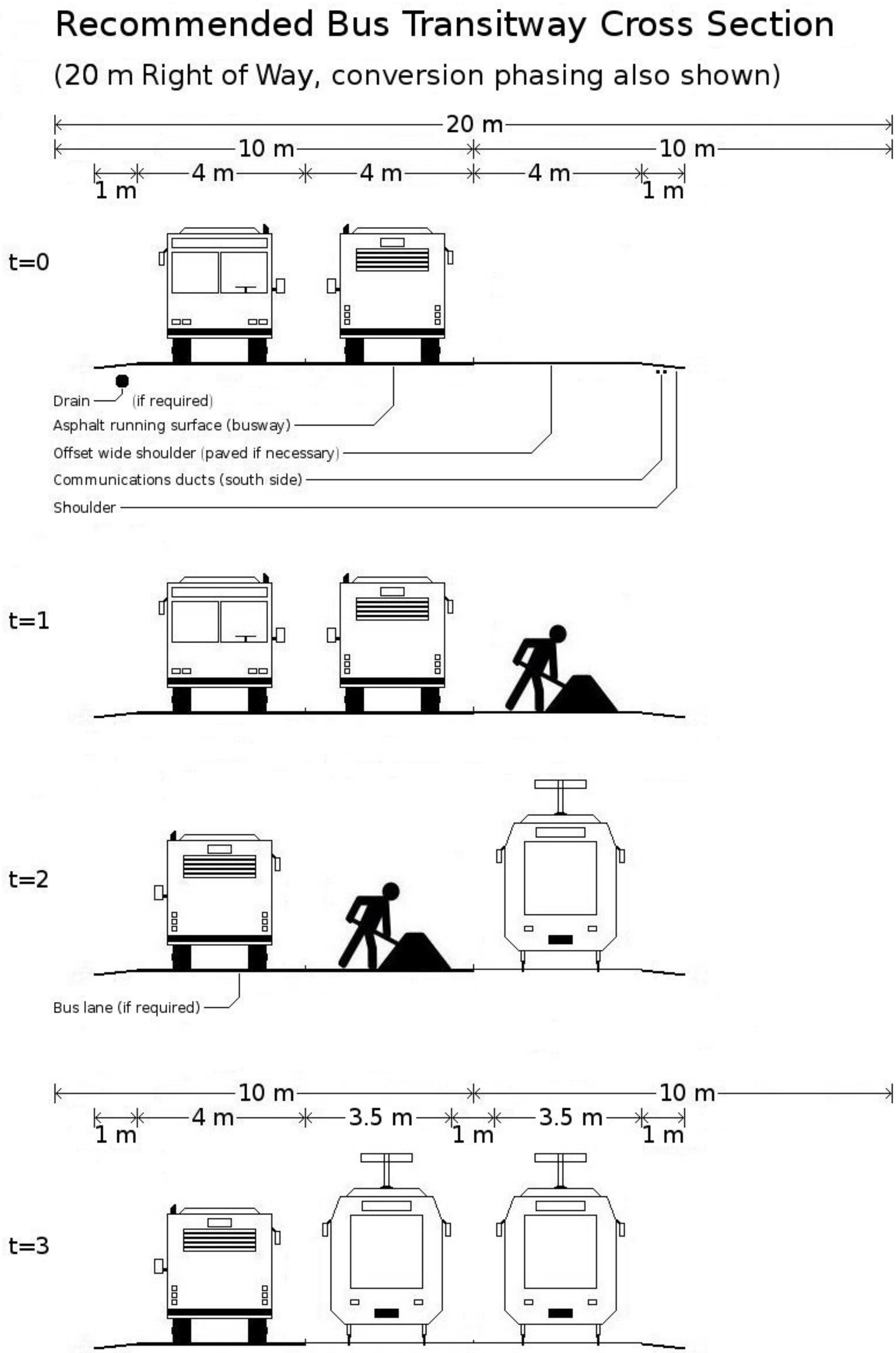

Figure 6.1: Recommended cross section for new bus transitways, with conversion also illustrated. Diagram by author.

recommended cross section is presented in Figure 6.1. The main innovation is the offset of the busway within the transitway such that one edge of the busway is the centreline of the transitway. This would avoid the need to shift the lateral position of the buses during conversion. The secondary innovation is to use unequally-sized shoulders. The shoulder that commences at the transitway centreline would be wider, at least 4.0 m, to allow it to become the first track during conversion to light rail. While BRT is operated, any disabled buses would be parked on the wide shoulder regardless of which direction it had been travelling. Snow would also be gathered on the wide shoulder for removal; the smaller shoulder need only be large enough for one snow furrow as any snow deposited there would be pushed across to the other side during removal operations, thereby allowing for just one pass of the snow removal equipment. The shoulders need not be paved unless there is a compelling reason to do so. Finally, the use of curbs should be avoided due to their throwaway nature post-conversion. Where required, drainage systems in the busway would be limited to gutters that could remain in place post-conversion. If funds allow, the footings for the future poles should be installed at the time of initial construction so as to minimize future reconstruction. The poles themselves may even be installed and used as lamp standards if it is felt necessary for the busway to be lit.

Bridges and tunnels

Bridges and tunnels should also be designed to facilitate rapid conversion to light rail. One possibility would be to construct them as a type 1 hybrid transitway (rails in roadbed) but without inserting the rails. In place of the rails would be an easily-removable filler material that could be quickly removed and replaced with rails at the time of conversion. Given that bridges and tunnels are concrete structures already, the extra cost of providing this additional modification to the design should not be substantial. Naturally, bridges and tunnels would be constructed on the centreline of the transitway, not the busway, which means that the approaches to such structures would have a “kink” in the road or busway, although such kinks would be tapered out.

Stations

New station designs should better accommodate future conversion, with particular attention on ensuring that elevators will not require modification. In practice, this means avoiding the need to modify station platforms during conversion, particularly the “permanent” or core parts of the station immediately surrounding stairwells and elevator shafts. This would be accomplished by setting them at a height suitable for light rail and would involve tapering the platform height down to a height suitable for buses further along the platform. However, this would not be practical without also changing the layout of stations. Since bus platforms are generally shorter than rail platforms, the bus platforms within a station area should be staggered rather than being directly opposite one another as at present. Only at the core parts of the station would platforms be opposite each other, and these would be at light rail heights, not bus heights. This staggered layout would reduce the station width requirements from four lanes to three lanes as the passing lanes would in effect be staggered as well. Once conversion takes place, the platforms on each side would be extended to “complete” the station area. Ideally, the station extensions would be long enough to accommodate the initial train lengths so that the bus platforms could continue to be used without significant disruption and only modified to the new height after conversion, or even left until much later when longer trains are in use.

Within the station area, the stopping lanes would be constructed out of concrete with the permanent rail positions already determined, as on bridges and tunnels. Adding rail would be a relatively straight forward exercise that would not require significant or lengthy reconstruction and disruption.

6.3.2 Policy implications and recommendations

Trigger for conversion

At the conclusion of chapter 5 it was noted that there are distinct limitations to a conversion technique based on the use of single track infrastructure. There is a very real risk that by the time that Ottawa gets around to converting its transitways to light rail that the techniques presented in this project will prove impossible to make use of. That would be unfortunate for numerous reasons (extra cost and extra delay and disruption to the transit user prime among them) but it would also serve as a reminder to other cities that they should begin planning to convert their busway-based BRT systems to light rail once they have surpassed approximately 5000 passengers per hour per direction (pphpd) and are approaching 6000.

Establishing triggers for conversion in the 6000 pphpd range is of considerable importance. At these passenger volumes a busway still has plenty of capacity remaining, perhaps as much as 4000, before it would “need” to be converted. Because of this, there is the risk that conversion to light rail would be put off until it is “needed” but doing so will likely involve much greater disruption and greater costs because single track conversion techniques will be unfeasible. The municipality or transit authority would then be faced with having to shut down the entire transitway being converted or will have to lay down temporary driving surfaces above one or both tracks for most of the length of the system. Such an approach is proposed in Appendix H of the recent Transportation Master Plan Infrastructure Requirement Study (DTS, 2008) as a way to convert Ottawa's Transitway and may become necessary on at least some portions of the Transitway if conversion does not commence in the next few years.

Estimates of the cost and timeframe

When a decision is taken on the form of transitway (busway or light rail) for a new rapid transit corridor, an estimate of the timeframe until the conversion trigger is met should be provided. Similarly, the future cost of conversion should be available to decision makers so that the cost of building a bus transitway and the converting it later can be compared with building a light rail transitway from the outset. The future cost of conversion should also remain present in a municipality's long term capital plan if a decision to build as busway first is taken. It can remain unfunded - as much municipal infrastructure does - but it should nevertheless be present as a reminder to all that it is an outstanding project. The availability of an estimate of the cost of conversion along with an estimate of the time-frame until conversion when the decision on the form of transitway is taken will provide decision makers with the information they require to make a properly-informed decision. In Ottawa, this type of information has never been provided, and, therefore, the decisions that have been taken regarding the Transitway were done so without sufficient information.

6.4 Convertibility of 'convertible' busways

The topic of the convertibility of 'convertible' busways is not whether such busways are convertible from a purely physical sense - clearly they are - but rather from a practical sense. Existing busways based on current designs are not easily converted as they require considerable workarounds such as those presented in the preceding chapter. The political context also affects the practical convertibility of busways. Resistance to conversion may come from institutional inertia - conversion has unknown risks, whereas the problems of the status quo are well known - and also from entrenched economic and political interests that may be negatively affected by the conversion of busways to light rail. Institutional inertia and financial considerations also come in to play once a transit authority has a large bus fleet and bus driver staffing whose role could become uncertain post-conversion due to the possibility of much of the fleet becoming surplus.

The ‘convertibility’ of busways makes busways more attractive to the public and public officials than they might otherwise be, which gives busway advocates an advantage in marginal cases over light rail. However, the practical difficulties of converting busways militates against their conversion once they exist. Decision makers of the past did not foresee these difficulties, but current decision makers can now look around at the practical difficulties of converting existing busways - a fact that affects the very saleability of busways as well as the choice of busways and BRT against light rail. Both of these issues are explored in this section, and the section finishes with recommendations for the design of new busways to facilitate their eventual conversion to light rail.

6.4.1 Selling busways by advertising convertibility to light rail

Bus rapid transit (BRT) solutions involving the construction of dedicated busways have often been “sold” or at least presented partly on the basis that the busways themselves can at some point in the future be converted to rail when demand warrants. In the case of Ottawa’s Transitway, this is presented in the first volume of original rapid transit development program: “planning and design standards should be adopted to allow conversion to a higher capacity technology” (DeLeuw, 1978v1, p.5), to wit: “clearance and alignment standards used in planning of the transitways will accommodate high capacity, fixed guideway rapid transit ...” (ibid, p. 13). Politically, it was also found necessary to include such provisions to garner support from part of the public (Hunter, 2007). Currie, in an overview of bus rapid transit projects in Australasia, noted that “BRT’s flexibility to expand to rail at a future date is a part of the justification for choice of BRT in most cases,” (2006, p. 19). Whether implicitly or explicitly, the convertibility of busways to light rail is used to “sell” or gain support for proceeding with a busway-based rather than a light rail-based rapid transit solution. Events in the last decade in Ottawa have, however, called into question the very convertibility of these “convertible” busways.

While it is difficult to determine at what point demand on Ottawa’s Transitway had passed a necessary minimum threshold for light rail - some would argue it had it from the outset - there is no doubt that BRT’s practical maximum capacity had been exceeded in 2004 when OC Transpo decided to cut back on some routes operating in downtown Ottawa during the afternoon peak period. There is further recent evidence of the practical maximum capacity being exceeded; on several snowy days in the winter of 2007-2008, BRT service came to a crawl in downtown Ottawa because of delays caused by slowed-down passenger movements on snowbound or slippery sidewalks. Not only did slowdowns occur in the evening peak period when boarding is the main passenger movement, more surprisingly they also occurred in the morning peak period when alighting is the main passenger movement. The BRT system is being operated so close to capacity in Ottawa that the delay from a few extra buses or poor weather conditions can cause failure. The author has even seen failure of the BRT system first hand on a sunny afternoon in April 2008 at Tunney's Pasture Station (which is on grade-separated transitway with passing lanes) where buses were queued well beyond the upstream end of the platform. Ottawa, therefore, should logically already have begun planning to convert the Transitway to light rail - probably at about the time of municipal amalgamation in 2001 when transit ridership was again picking up - but it has not. The Rapid Transit Expansion Study of 2003 gives an indication of why Ottawa has not in the appendix paper on Transitway conversion:

> A busway can be designed to LRT geometric criteria, - and even LRT load requirements - but the in-place investment in the busway guideway is not something easily disposed of - and the BRT argument for equivalent capacity is hard to refute. Where a constraint on that capacity (such as downtown congestion) constrains the busway substantially, the case [for conversion] may be made successfully (RTES-D, 2003, p.8).

Dubious claims of "equivalent capacity" notwithstanding given the higher actual and potential throughput of light rail systems like Calgary's CTrain, it is readily apparent in the view of the authors of the paper [1] that, while feasible, conversion (in this case, conversion to hybrid transitway) would be costly with a strong implication that it is not worth doing. Ironically, the year after the Rapid Transit Expansion Study was released, downtown congestion did constrain the capacity of the whole system.

In many respects the 2002-2003 Rapid Transit Expansion Study (RTES) and the 2003 Transportation Master Plan (TMP) that followed from it is the single greatest failure in transit planning in Ottawa in the last few decades. Capacity failures downtown were to occur within a year of its release and should have been easily predictable at the time. Instead of making the quite defensible claim that the Transitway as constituted had been a success and it was now time to move on to a higher capacity system - as originally envisionned - RTES and the 2003 TMP clung to the notion that BRT could continue to

[1] The paper itself does not draw any ultimate conclusions on conversion of the Transitway

provide the backbone for rapid transit in Ottawa. Within the main RTES report, the option of converting the Transitway to light rail was dismissed in less than a page (RTES, 2003, p.4-2) and was even accompanied by a brief - and unrelated - discussion claiming that a downtown tunnel "would not be justified within the planning period [to 2021]" (ibid, p.4-3), yet less than five years on and Ottawa is contemplating both. The plan that was promulgated in 2003 would see light rail not as the backbone of a rapid transit system supported by a bus network but rather as a secondary tier of the rapid transit system supporting the existing BRT system. In this role there would not be an opportunity to make use of the economy of scale and efficiency advantages of rail-based systems. The following three years were then lost on planning to replace the existing O-Train and extend the corridor with an electrified version, despite scant evidence of any real need, while the pressing problem of downtown bus congestion continued to worsen. Only through a series of rather extraordinary events involving the intervention of local federal politicians was the plan cancelled and an opportunity opened to begin rethinking rapid transit in Ottawa.

Finally, some five years after the original 2003 TMP when it was up for review in 2008 did a change in direction in Ottawa at last become evident: the Transitway will be converted to light rail. However, even there the change in direction is only a partial one: only some of the existing Transitway will be converted in the medium-long term (out to 2031 according to the TMP update) and many new segments of bus transitway will be added to the system before a single train is running on any of it. The amount of transitway to be converted was based only on converting the absolute minimum, including a terminus station, that allowed for a workable line to feed a new tunnel downtown (DTS, 2008, p.53); nothing else was considered. There continues to exist in Ottawa a goal to "complete the Transitway by 2015", as if this were a laudable goal in and of itself; indeed this curious goal even features in a comparison chart as an "advantage" of particular implementation scenarios in the recent 2008 update of the Transportation Master Plan.

Ottawa's reluctance to convert the Transitway may, in part, be explained by the fact that Ottawa has often been cited as an example of a successful implementation of BRT by many BRT advocates and promoters, including amongst them a small number of consulting companies (and their staff of many ex-municipal employees) that have had a substantial role in planning, designing and building the Transitway. They have subsequently gone on to promote the concept and design BRT systems based on the Transitway elsewhere. There is perhaps a concern amongst these consulting companies, who are still involved in transit planning in Ottawa, that were Ottawa to shift away from BRT and more fully convert the Transitway it might negatively impact their line of work. While on the surface this is understandable, what has likely not been appreciated is that these impacts could occur anyway because the greater the resistance to conversion and the longer the footdragging goes on in Ottawa while transit service worsens and operating costs escalate, the less attractive the BRT-to-LRT option will appear to other cities considering it.

Over the course of assembling documents and resources for this project, it became evident that references to Ottawa as a BRT "success story" tended to be from older documents (until the late 1990s) or were of older data. The fact that Ottawa has exceeded the capacity of BRT but has not, until very recently, planned to convert its transitways to light rail does little to bolster the argument for phasing in BRT and later converting to light rail if system growth is expected. Ottawa, to put it simply, has ceased to be an example of BRT worth mentioning in any detail as closer scrutiny quickly reveals its underlying problems while its heretofore unwillingness to address them through conversion to light rail casts doubt on the very feasibility of conversion. The choice of BRT therefore takes on the appearance of being less an interim implementation and more of a permanent one that is difficult to, in effect, 'reverse'. Indeed, without an example of a city that has successfully converted a busway to light rail, even after three decades of busway building, cities that ultimately expect to require light rail but which face a technology choice between BRT and LRT in the medium term are opting to forego full-fledged busway-based BRT solutions and are opting instead for light rail from the outset or for inexpensive, low-capacity near-term "BRT" solutions. For example, in December 2007, the City of Edmonton cancelled its proposed busway/BRT project and will use transit priority measures instead while focussing more resources on its LRT network. Calgary's on-street, limited stop implementation of BRT scarcely deserves the epithet of BRT, but it is also used only as a precursor to light rail in the same general corridor. In October 2007, the transit authority in Houston, Texas, following a change in funding rules on the part of the US Federal Transit Administration (FTA), decided to build light rail in a corridor previously slated for BRT initially but conversion ultimately to light rail.

In short, if early adopter cities of busway-based BRT systems like Ottawa that have now reached a point where BRT capacity is exceeded do not begin converting their busways to light rail as originally envisionned, then the case for choosing busway-based BRT in the first place is weakened since the feasibility of the busway to LRT upgrade path by which busway-based BRT is frequently "sold" is called into question.

6.4.2 The busway/light rail choice

While this project has proposed ways of converting busways to light rail while minimizing disruption, it would be hard not to conclude that some of the issues and difficulties in converting busways to light rail necessitates a re-evaluation of the initial BRT/LRT choice. Most comparisons of this choice revolve around capital costs (often based on a compiled average), operating costs, flexibility, phasing, and to some degree attractiveness and comfort. While important, they are also “generic” without any real regard for the specific environments in which they are to be installed. Capital costs, for example, can vary widely from city to city and even within cities for reasons that have little to do with the busway/light rail choice but rather with the nature of the corridor itself. Busway projects in Ottawa vary substantially in cost, and, moreover, the remaining gaps in the system will be the most costly to plug. Indeed, the very fact that light rail is often more suitable than busways in expensive-to-build-in built-up urban environments means that it will get chosen more often for such environments than busways - a fact that will also tend to raise light rail’s apparent average cost when data are aggregated. Overly simplistic comparisons using average cost data from light rail projects with a heavier weighting in more costly urban corridors and busways with a heavier weighting in less costly suburban corridors without noting the apples-and-oranges nature of the comparison do little to inform the public or decision makers. It is for such reasons that a list of additional factors to consider when making the busway/light rail choice has been compiled, and it should be noted that many of the listed factors directly affect capital costs on a corridor basis.

Physical nature of the transit corridor

The number and significance of streets crossing the corridor Grade separations are, without doubt, the most significant potential cost for major transit projects (and the biggest source of cost variation between projects), so reducing the number of grade separations is of interest to all concerned about the cost of transit projects. BRT has both a lower passenger volume threshold and a lower cross street traffic volume threshold for requiring grade separations than does light rail because of the greater number of required separate transit vehicles. However, it may be easier to add grade separations to a busway at a later date than to a light railway. Three basic corridor scenarios can be envisaged:

(1) Passenger and cross street volumes are low enough that neither a busway nor a light railway would require many grade separations in the near term
All else being equal, a busway would be preferable. If grade separations are required

in the future, conversion to light rail can be considered then as some of them may be avoidable (see next scenario).

(2) Moderate passenger and/or cross street volumes requiring many grade separations for a busway but few for a light railway in the near term
All else being equal, a light railway would be preferable, but care would have to be taken to allow for the possibility of future grade separation requirements.

(3) Heavy passenger and/or cross street volumes requiring many grade separations for both a busway and a light railway
In this scenario, the decision would be taken on other grounds, since both are effectively equal as far as requiring grade separations is concerned. That said, it seems improbable that heavy passenger volumes would dictate anything other than light rail, though a scenario of heavy cross street but low passenger volumes could suggest a busway.

Tunnel If a tunnel is required or desired (e.g. in a central business district), light rail is preferable as it has narrower right of way requirements, simpler station arrangements, fewer ventilation requirements and provides for a less noisy passenger environment.

Is proposed transit corridor in a rail or freeway corridor? If a proposed transit corridor will be in a rail corridor then it makes more sense to proceed with light rail because modifying a rail corridor to reuse and/or add additional tracks is easier to carry out than to remove tracks and build a busway. This is especially true if the corridor is likely to become a rail transit corridor at a future date anyway (i.e. there is little point in converting a rail corridor to busway and then convert that busway to rail again). An existing railway can either be used for light rail (depending on other rail traffic) or extra tracks can be added to the corridor for light rail, as in Calgary. A recent example is San Diego, which has just inaugurated (March 2008) a light rail service (the Sprinter) using diesel-powered vehicles in an existing rail corridor by upgrading the tracks in that corridor and adding lengths of passing tracks. By contrast, a freeway corridor is more amenable to the gradual phasing in of BRT and busways than of light rail. With light rail in a freeway corridor, grade separations will be needed everywhere immediately whereas BRT can employ bus lanes and modified off- and on-ramps initially before upgrading them as need, time and resources allow. Once enough of the busway is in place, conversion to light rail can be contemplated.

For corridors other than rail and freeway corridors, other factors would determine the choice.

Natural areas If a transit corridor will be passing through or using significant natural areas (e.g. river valleys), a rail solution should have a lighter footprint. Run-off from busways, particularly in climates with cold winters requiring salting, can be harmful to other life in those corridors. Railways require no such salting and railway roadbeds are also less impervious than busways so the potential for run-off is much reduced. Buses have larger noise envelopes than light rail vehicles and their sightline requirements mean that a wider cleared corridor is needed to accommodate a busway than a railway. Additionally, the greater number of individual vehicles needed for a given passenger volume for BRT as well as the wider cleared corridor means that wildlife crossings of the corridor are more likely to result in collisions and/or less likely to take place at all (i.e. through habitat fragmentation). However, a fenced railway corridor (because of a fear of railways as being dangerous) will have effects similar to those of busways on habitat integrity.

Role of the corridor in the transit network: orbital or radial

An orbital or circumferential transit corridor is more likely than a radial corridor to have a permanent bus presence in the form of feeder and mainline buses heading to, from or between the main radial corridors of the transit network. An orbital corridor is also less likely to have potential for further ridership growth beyond a certain level (unless intensification occurs), whereas a radial corridor could conceivably see continued growth as an urban area and/or transit ridership continues to expand and grow. Therefore, a busway could well provide all the capacity that an orbital corridor is ever likely to need and provides for the flexibility to permanently accommodate feeder buses. By contrast, radial corridors - particularly those well supported by the aforementionned orbital corridors - could reasonably be expected to see continued growth in passenger travel and therefore would benefit more from being built as a railway.

Time horizon and projected ridership

The choice between BRT and light rail can depend on the time horizon until capacity would be reached (if ever) if BRT is chosen initially. In general, the sooner BRT capacity is likely to be exceeded and the conversion threshold met, the less sense it makes to build busways. The following list of time horizons provides guidance on choosing busways or light rail

(1) BRT will be sufficient in the corridor for an extended time (50+ years)
The corridor can be designed to allow conversion - in particular with respect to long-lived infrastructure like tunnels and viaducts - but without any other special provisions to facilitate conversion since the roadbed will likely need rebuilding by such time anyway.

(2) BRT sufficient for a moderate time, but conversion will be required (20 years)
The corridor can be built as a busway (depending on other considerations, such as the nature of the corridor) since it will last long enough before requiring a rebuild and the return on investment for rail may not be sufficient but it should also be designed to facilitate conversion as per the recommendations in this chapter. A conversion plan should also be drawn up early in the life of the BRT system and implemented in a timely fashion.

(3) BRT sufficient for a short time (10 years)
Proceed with LRT from outset, or employ on-street BRT until LRT established. The large busway investment will be difficult to justify for such a short period of time, particularly if there are many structures (including stations) that need to be built to extra width compared to what would be required for light rail.

(4) BRT sufficient only for current loads
Proceed with LRT and employ on-street BRT only as an interim/temporary measure. Short of no expectation of further ridership growth, a busway cannot be justified under these circumstances.

Ottawa's rapid transit choice: a redux

Given the foregoing criteria, if one applies all the above considerations to Ottawa when rapid transit was first being planned in the late 1970s and early 1980s, it can be argued that the West and Southwest Transitway corridors, which were along a former Canadian Pacific Railway corridor adjacent to Scott Street and a creek valley further west, should have been built as a light rail corridor (and would have avoided the need to create the Scott Street trench), although this would likely have delayed the early introduction of rapid transit service between Baseline and Lincoln Fields stations. Similarly, the Southeast Transitway corridor follows both waterways (a river and a creek) and railways with numerous road crossings so it would have been a good candidate for light rail as well. The East Transitway, however, largely follows the Queensway, a freeway corridor[2], so its initial

[2] Which once was a railway corridor

construction as a busway made more sense than for the other corridors.

Given that Ottawa went with bus rapid transit and busways everywhere, one can conclude that considerations such as those presented here were either not considered or not weighted heavily when it was decided to build the Transitway. Had they been considered, it is possible that Ottawa's rapid transit network would look very different today and would be a mix of LRT and BRT rather than nearly exclusive BRT.

6.5 Concluding remarks

Ottawa's experience with bus rapid transit, the most extensive in North America, has provided much useful information on building and operating such systems, information that can be considered by other cities when they decide on establishing and operating BRT. The Transitway is part of the policy and infrastructure mix that has helped Ottawa maintain its position as the North American city with the highest transit ridership for a city its size. This success of the Transitway has resulted in a system that is now at capacity and is in need of upgrading if transit is to continue to play a role in Ottawa's growth.

Fortunately, Ottawa's Transitway was designed to allow it to be upgraded to light rail when needed. However, little thought has ever been put to how this might be accomplished without causing a cessation of rapid transit service or expending considerable sums on widening or laying concrete roadbeds.

This project has proposed several techniques to convert the Transitway to light rail based on the use of single track rail operations during the conversion. Ottawa already has experience with single track rail operations through the O-Train pilot light rail project and calculations show that it can provide sufficient capacity up to 7200 passengers per hour and perhaps as high as 8000. However, since busway-based BRT has a maximum capacity that is higher than that, a policy of busway to light rail conversion must ensure that conversion takes place at levels below maximum BRT capacity to ensure that a single track conversion technique remains a feasible option. To put it succinctly, waiting until BRT capacity is reached is not advisable if conversion to light rail is envisaged.

While this project has concerned itself with converting busways to light rail and has presented additional factors that should be considered when choosing between BRT and LRT, it should not be interpreted as a work that is "against" BRT. There will always be a place for bus rapid transit in cities where light rail is the rapid transit backbone. Rather than following the Ottawa example of regarding BRT as a transit service that can rival or even replace light rail it should be regarded and employed in way that is supportive and complementary to light rail. It can act as a pre-cursor to light rail through its on-street implementations whilst busways that connect the arms of light rail network together will help bolster the entire network by improving feeder and orbital services, especially where it can serve dispersed suburban office parks and retail centres not on the main rapid transit network. A good example of the flexibility and advantages of BRT is to increase the capacity of arterial roads. Where widening of a four-lane arterial is contemplated, the reconstruction of the roadway with a median busway should be considered instead. Since the construction of a median busway can be phased-in over time and in discontinuous segments, it offers a flexible way of improving transit service and increasing capacity in the arterial road corridor. BRT and LRT corridors can have a synergistic effect on transit ridership if properly planned together.

By happy coincidence, while this project was being written, Ottawa's City Council approved an update to its Transportation Master Plan that would see large segments of the existing Transitway converted to light rail. This project is therefore quite timely and it is hoped that it will be considered as Ottawa moves forward with its transit planning.

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Appendix A: Glossary

- BRT: See Bus Rapid Transit
- Busway: Roadway built for the exclusive use of buses (though emergency vehicles are often excepted). A busway may be in its own right-of-way or corridor, as in Ottawa, or it may be found in the median of an arterial road corridor, as in Vancouver.
- Bus Rapid Transit (BRT): As defined by McCormick Rankin Corporation for the Canadian Urban Transit Association, BRT is "a rubber-tired rapid transit service that combines stations, vehicles, running ways, a flexible operating plan, and technology into a high quality, customer focused service that is frequent, fast, reliable, comfortable and cost efficient".
- Commuter rail: A peak-period ("commuter") railway-based transit service. It generally operates on existing railways, sharing track with inter-urban passenger services and freight services. Commuter trains generally look similar to inter-urban passenger trains and often use the same type of locomotives, but with some modifications. Toronto's GO Trains are a commuter rail service.
- Heavy rail: See Metro
- Interlining: A practice in transit operations whereby a transit vehicle, typically a bus, upon completing one run of its route does not return to that route's origin but rather becomes a different route. The practice is commonly associated in Ottawa with express routes.
- Light Rail Transit (LRT): Any of many different types of urban rail-based transit systems, including mixed-traffic streetcar systems, semi-exclusive tramways and exclusive (or mainly exclusive) urban railways, but for the purposes of this project light rail could be regarded as a "light metro" and its characteristics are summarized as follows:

  - operating mainly in exclusive right-of-way with limited semi-exclusive right-of-way in high density urban areas (i.e. only other vehicles are buses, which should be few in number)
  - grade-separation and/or transit pre-emption with only limited use of transit priority measures
  - multi-unit trainsets for high passenger:operator ratios (at least two cars or carriages per trainset)
  - stops on average every 1 - 2 kilometres, except in very high density downtown environments
  - relatively high operating speeds - i.e. comparable to busways

- Light Rail Vehicle (LRV): A relatively light weight rail vehicle used on light rail systems. LRVs are usually powered by electricity and are also usually capable of bidirection operation and of being joined with other LRVs to form trains.

- Light railway: A railway used by or for light rail transit. The term tends to be used for situations where an existing railway is put to use for light rail and is associated more with the diesel-powered incarnations, such as Ottawa's O-Train.

- LRT: See Light Rail Transit

- LRV: See Light Rail Vehicle

- Metro (Heavy rail): Metros are rail-based rapid transit services. The vehicles are quite heavy (hence the term "heavy rail") and they operate on exclusive, grade-separated rights-of-way typically using third rails for electrical traction power. Metros are often called a "subway" in cities where they operate mainly or exclusively in tunnels. The London Underground is perhaps the most famous metro system.

- Regional Municipality of Ottawa-Carleton (RMOC): Prior to 2001, the city that is now the City of Ottawa was composed of an upper-tier regional municipality - the RMOC - that was responsible for issues of a regional nature, such as transit, and about a dozen lower-tier municipalities, comprised of cities (such as the former City of Ottawa and the City of Kanata), townships and villages that were responsible for more local functions. The 2001 amalgamation essentially dissolved the lower-tier municipalities and their responsibilities into the regional municipality, which was then renamed the City of Ottawa.

- RMOC: See Regional Municipality of Ottawa-Carleton

- Transitway, A ("transitway"): Right of way for the exclusive (or near-exclusive) use for rapid transit. It is usually grade-separated and since most transitways are used by buses they are often used interchangeably with the term "busway". The term "bus transitway" however is the correct term for a transitway configured for buses only or as a busway, and the term "light rail transitway" if configured for light rail. A transitway may also be configured for both buses and light rail. In this project, such configurations are termed "hybrid transitways".

- Transitway, The ("Transitway"): The branding of Ottawa's bus-based rapid transit system. Often used in text incorrectly to refer to a transitway, as in "Ottawa is building a new Transitway between Bayshore and Pinecrest." The names of individual transitways may also be capitalized since they are proper nouns, such as the East Transitway and the Southwest Transitway.