BUS CONNECTS
TRANSFORMING CITY BUS SERVICES

NTA
Údarás Náisiúnta Iompair
National Transport Authority

5 Strategies for a Redesigned Bus Network

How More Interchange Can Improve Travel Time

In reviewing the existing network, we have noted several issues:

- **Many overlapping routes,** each with their own frequency, prevent buses from being evenly spaced to minimize waiting. Along with low frequency on some routes, this means many people wait longer than necessary.
- **Complexity.** The sheer number of routes and branches is a barrier to understanding the network and discourages many trips for which service could be useful.
- **Too many buses in the city centre.** Many streets carry extremely high volumes of buses, which produces major delay due to buses blocking each other.
- **Poor Orbital Service.** There is abundant service into and out of the city centre, but poor service for travel between other destinations.

Many of these problems operate on the current assumption that the network should minimize the need for interchange—that is, for people to get off one bus and onto another bus or train.

This chapter explores what might be gained and what trade-offs would occur in a network design that is based on accepting an increased degree of interchange to unlock major solutions to all the problems above.

> ***Important note: This chapter explores only concepts; it contains no recommendations or proposals.*** *Where appropriate, the concepts have been illustrated in the context of what they might mean geographically. Nonetheless, the goal is to illustrate the principles, not propose specific actions. See Chapter 7 for a full description of the revised proposed network.*

How Connections Improve Travel Time: Theory

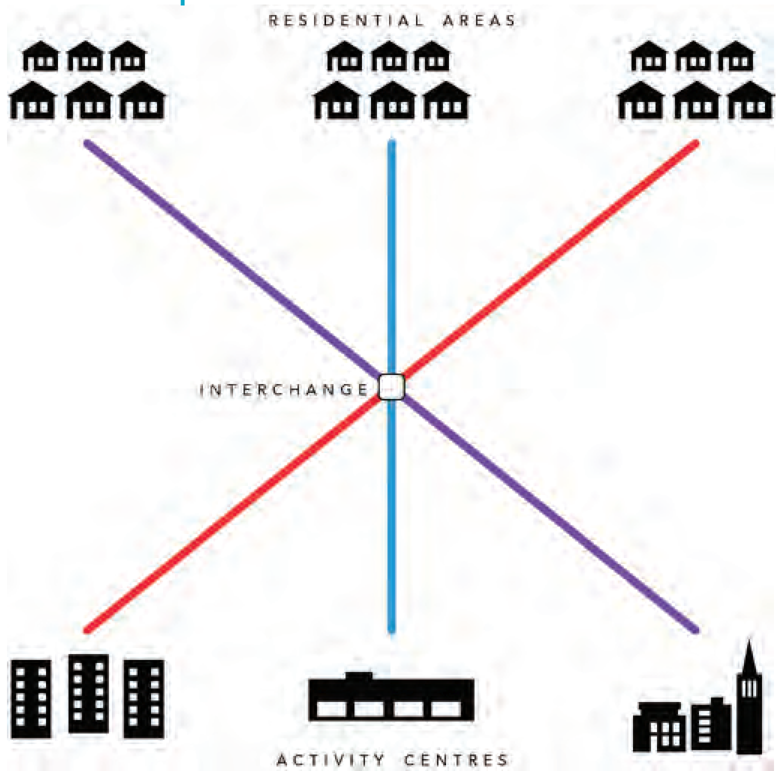
Imagine a simple city that has three primary residential areas, as seen in the diagram to the right along the top, and three primary centres of employment or activity, along the bottom.

- In designing a network for this city, the first impulse is to try to run direct service from each residential area to each activity centre. If we have three of each, this yields a network of nine transit routes, as shown in the diagram at top right. Suppose that we can afford to run each route every 30 minutes. Call this the **Direct Service Option**.

- Now consider another way of serving this simple city for the same cost. Instead of running a direct route between every residential area and every activity centre, we run a direct route from each residential area to a single activity centre, but we make sure that all the resulting routes connect with each other at a strategic point, as shown in the diagram at bottom right.
- Now we have three routes instead of nine, so we can run each route three times as often at the same total cost as the Direct Service option. Instead of service every 30 minutes, we have service every 10 minutes. Let's call this the **Connective Option**.

Figure 73: Example of direct service from each residential area to activity centre

Figure 74: Example of frequent connective service to a central transfer point



The Direct Service option may appear to be the obvious solution to minimising travel time. But if we want to maximise people's ability to get places with our fixed budget, we should use the Connective option.

Consider how long a typical trip takes in each scenario, from the standpoint of a person who needs to leave or arrive at a particular time. **For example, let's look at trips from the rightmost Residential Area to a given Activity Centre.** For simplicity, let's also assume that all routes, in all scenarios, are 20 minutes long.

In the **Direct Service Option**, a service runs directly from the upper right residential area to the middle activity centre. It runs every 30 minutes, so on average, the waiting time is 15 minutes[1]. Once we're on board, the travel time is 20 minutes. So the average trip time is:

Wait 15 minutes + Ride 20 minutes

= 35 Minutes

Now look at the **Connective Option.** We leave the same residential area on its only route, which runs every 10 minutes, so our average wait is 5 minutes. We ride to the connection point and get off. Since this point is halfway between the residential areas and the activity centres, the travel time is 10 minutes. Now we get off and wait for the service to the middle activity centre. It also runs every 10 minutes, so our average wait time is 5 minutes. Finally, our ride from the connection point to the middle Activity Centre is 10 minutes. So our average trip time is:

Wait 5 minutes + Ride 10 minutes

+ Wait 5 minutes + Ride 10 minutes

= 30 minutes

The Connective Network is faster, even though it requires interchange, because of the much higher frequencies that it can offer for the same total budget.

1 Many passengers minimize the wait time at the stop by consulting the timetable or real-time arrival information. Although this reduces wait time at the stop, it does not change the fact that the passengers must still spend extra time wherever they are before they reach the bus stop, or that they must otherwise re-arrange their lives to fit the timetable.. There is still, in all cases, a portion of time where the passengers are not on the way they would like to be going.

Figure 75: Example of a trip taken with direct service from a residential area to an activity centre

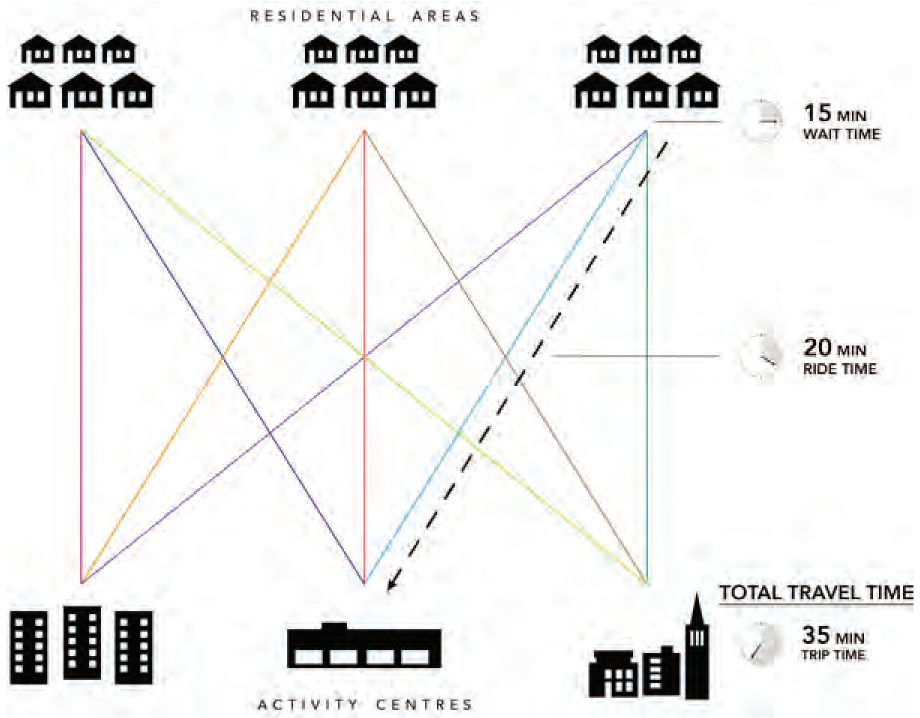
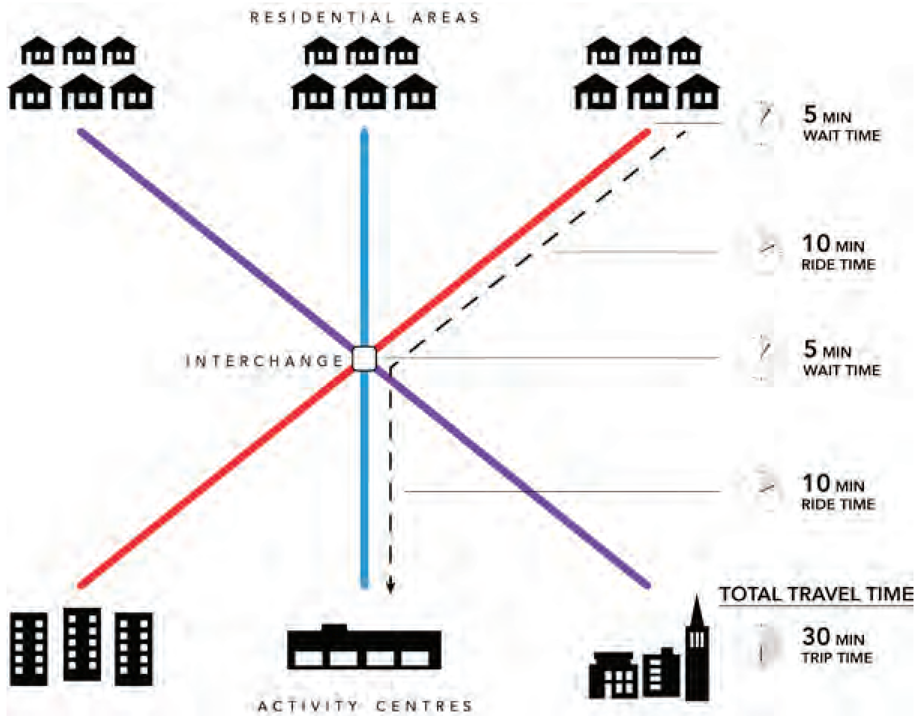


Figure 76: Example of the same trip taken with frequent connective network



As cities grow, the travel time advantages of the Connective Network increase. *For example, suppose that instead of having three residential areas and three activity centres, we had six of each. In this case, the direct service network would have 36 routes, while the connective network would have only six. You can run the numbers yourself, but the answer is that the Direct Service network still takes 35 minutes, while the Connective network is down to only 25 minutes, because of the added frequency.*

The Interchange Penalty Objection

If we were actually using travel time as a means of estimating patronage, we would have to consider the widespread view, built into most patronage models, that connections impose an "interchange penalty" in addition to the actual time they take.

These interchange penalties assume that, even though people say they want the fastest possible trip, they'll actually prefer a slower trip if it saves them the trouble of getting out of their seat partway through the journey.

In the previous example, a patronage estimate might assume that although the average trip in the Connective option is faster, the Direct Service option would give us higher patronage, because the Connective option imposes the inconvenience of the connection.

The modeller might say that this inconvenience is the equivalent of 10 minutes of travel time, so that the Connective option will really attract patronage as though the trip took 40 minutes instead of 30. This common modelling approach assumes that the inconvenience of interchange is something different to, and separable from, the time that the interchange takes.

There is considerable documentation[2] behind the addition of this kind of factor, but the unpleasantness of the interchange experience depends on many details of how the interchange works, and especially on the frequency of service. All factors that affect customer experience of walking and waiting also apply to the interchange walk and wait.

Assumptions about an "interchange penalty" (as distinct from the time the connection takes) therefore must to be scrutinized: What kind of connection experience was used to calibrate the model?

Finally, interchange may affect patronage but it does not affect the liberty and opportunity that a network delivers. The range of places that you can reach in a given time is greatest if you are willing to interchange as needed, rather than allowing the interchange experience to dissuade you.

2 See for example the Scottish Executive Central Research Unit's "Interchange and Travel Choice," by M. Wardman, J. Hine, and S. Stradling. (2001) .

The Commuter's Objection

Many people who make regular commutes would object to the way we have inferred average waiting times from frequencies. After all, if a particular train line has one journey per day, we do not spend half the day at the station waiting for it. We go on with our lives and work, and catch the train whenever it is going. Many people treat schedules in this way, especially when making regular commutes that can be planned into a routine.

However, the average wait is still a valid way of capturing the inconvenience of low-frequency services. For example, if you need to be at work at exactly 8:00 and your half-hourly bus arrives there at 7:35 and 8:05, you will have to take the earlier one. This means you will have 25 minutes to wait before your work starts, which you would probably rather have spent otherwise. You may figure out how to make use of this time, but it's still time you must spend somewhere other than where you want to be, and thus constitutes a reduction of your liberty.

Note too that we have been discussing commutes to work public transport serves many kinds of trips happening all day. You may figure out how to make use of a predictable 25 minute delay at the beginning of your work day, but it's much harder to deal with unpredictable 25 minute gaps in the many trips that you need to make in the course of the day, such as while taking a lunch break or running errands that involve many destinations.

Other Advantages of Connective Networks

In addition to the faster total trip time when interchanging between frequent services, there are other reasons to prefer Connective networks over Direct Service networks. For example:

- The Connective network is made of more frequent services, with the multiple benefits discussed in Chapter 2. Among these benefits is the fact that trips are not only be faster for those who need to interchange, they are even faster for those who would now be on a direct frequent line.
- The Connective network is simpler. Three frequent routes are much easier to remember than nine infrequent ones.

Many public transport systems start as direct networks with little interchange. But as a city grows bigger, direct networks become massively complex. At that point, it becomes useful to transition from a direct network to a connective one. This can require severing direct links to create a structure of very frequent service that saves time and is more broadly legible.

Disadvantages of Connective Networks

We do not want to imply, however, that connective networks, which require more interchanging, have no downsides.

The largest disadvantage to interchange is simply the effort required. Partway through your trip, you must gather your things, exit the bus, walk to another stop, and wait for another bus. Ideally, the walk will be very short, and high frequencies mean that the wait will be short as well. Excellent shelter and information will also be provided. But even then it will still be an inconvenience. The level of effort is also greater for people with limited mobility.

The second disadvantage is that interchange can compound risks associated with reliability. There is always the fear of missing a connecting bus and being stuck at the interchange point.

In a frequent connective network, this will only occur in cases of major disruption. In routine operations, there should be so many buses along each route that waits would be very short.

Assumptions for this Study

In thinking about interchange and the strategies we lay out over the following pages, please assume that:

- **Fare penalties for interchanging are removed.** Any fare paid getting on the bus would be valid for 90 minutes throughout the Dublin public transport network.
- **Progressive improvements in reliability** as the Core Bus Corridors project and other initiatives increase bus priority on Dublin's main roads.
- **Information is available at every interchange stop, and any walk required for the interchange is safe.** NTA would work with local councils to improve stop locations and pedestrian facilities to ensure short and easy connections. A program of improvements would progressively bring better shelter and lighting to all interchange stops.
- **Key interchange facilities can be developed and expanded.** The plan requires only one entirely new interchange, at Liffey Valley Shopping Centre. Several other interchanges (e.g. in Tallaght, Blanchardstown, Dundrum) would need expansion.
- **The network does not increase overcrowding.** A significant part of the effort to revise the proposed network from 2018 to 2019 has been geared specifically at ensuring that adequate service is provided to meet peak capacity needs.

Four Strategies for a More Useful Network

This study has developed a revised network proposal based on:

- The theory and data presented in the Choices Report[3].
- Public approval for the four strategies below, expressed through a consultation in June 2017.
- A collaborative design process with NTA, Dublin Bus, local councils and the consultant team.
- Public reaction to the initial network proposal, expressed through a consultation in summer 2018.
- Updates to the design in response to this reaction, again in a collaborative approach between NTA, Dublin Bus and the consultant team.

The proposed network relies more heavily on interchange to increase usefulness and shorten travel times based on public response to the Choices Report. Here are the four major strategies that were pursued in the design of the proposed network.

- **Strategy #1: Standardize Service Categories**
- **Strategy #2: Simplify Radial Services**
- **Strategy #3: Build Frequent Orbitals**
- **Strategy #4: Grow Suburban Feeder Networks**

All are examples of ways to increase the liberty that public transport confers, measured in how many useful destinations you can reach in a given time. Because of the geometry explained above, this also means relying more heavily on interchange to complete passenger trips.

As the table to the right shows, each strategy is relevant to all of the problems identified at the beginning of this chapter. Together or separately, they are all likely to improve travel times on many more trips than they degrade, because of the geometric relationship between interchange, frequency, and travel time explained at the beginning of this chapter.

Figure 77: Table explaining how the four main strategies behind the bus network redesign help solve known issues with the existing bus network in Dublin.

Tool	Problem addressed: Poor orbital service	Complexity	Low frequency	Buses in City Centre
1 Standardize Service Categories	**Yes.** Categories make planning efficient services easier.	**Yes.** Frequency and span are apparent from the category, without looking at timetables.	**Yes.** Standard categories make frequencies predictable and consistent.	**Yes.** Categories make planning efficient services easier, reducing excess bus trips.
2 Simplify Radial Service	**Yes.** Releases resources for orbital use.	**Yes.** Reduction of complexity, especially in city centre	**Yes.** Higher frequency for travel to, from and through the city centre	**Yes.** Consolidating service to the centre on fewer routes means frequency can be optimized, reducing surplus trips.
3 Build Frequent Orbitals	**Yes.**	**Yes.** The intersection of frequent orbitals and radials produce a pattern that is easy to grasp.	**Yes.** Increased orbital frequency.	**Yes.** Fewer passenger trips are forced through city centre, reducing loads.
4 Grow Suburban Feeder Networks	**Yes.** Improves market for both orbital and radial services to regional centres.	**Yes.** Fewer overlapping routes in suburban markets	**Yes.** Improved local frequency for travel within suburban areas.	**Yes.** Feeder networks support consolidating service to city centre on fewer routes.

3 Chapters 1, 2, 3, 4 and 5 of this report are an updated version of the Choices Report.

Strategy #1: Standardize Patterns of Frequency and Span

In the existing network, a bus route may have any frequency. Although there are tendencies, such as higher frequency at peak, there is no fixed pattern for when certain frequencies begin or end.

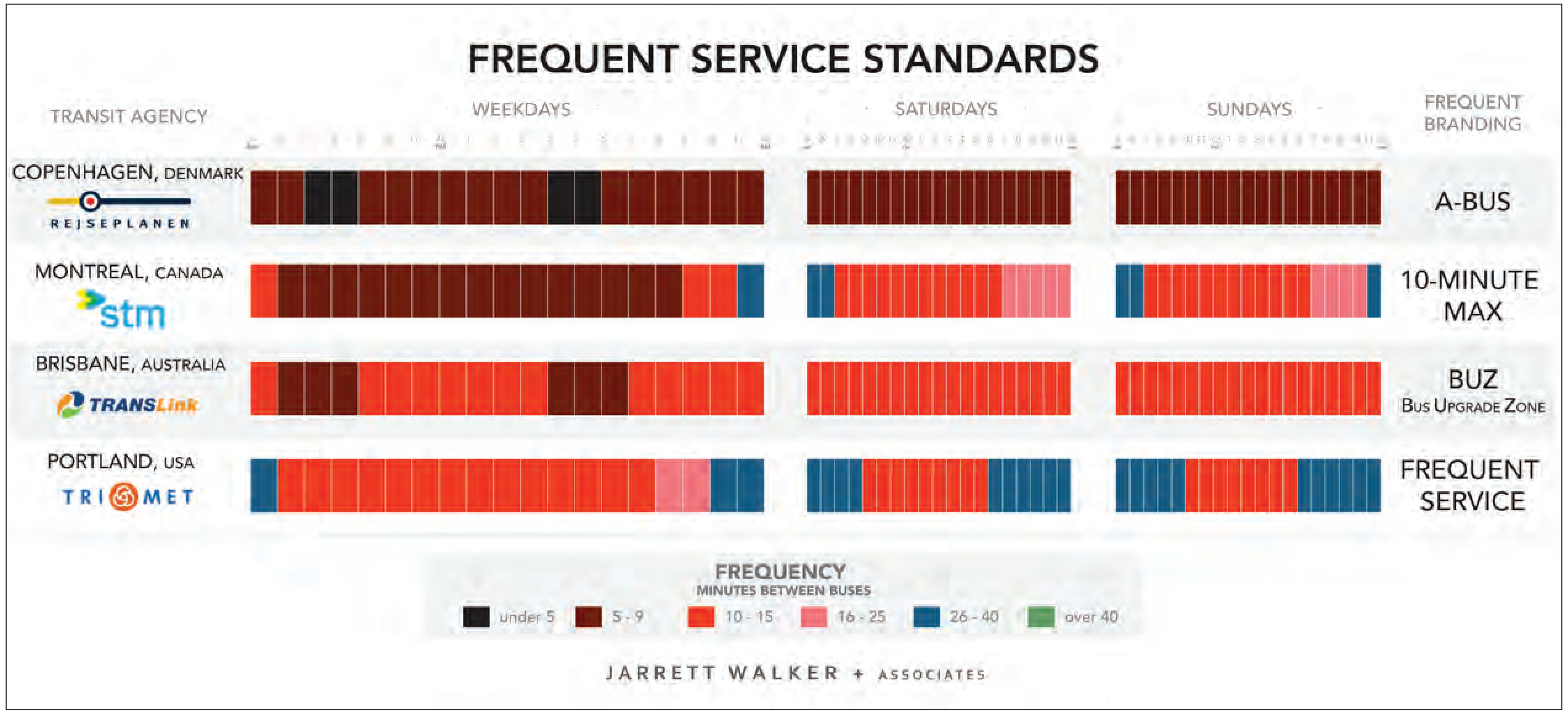
On the one hand, this can seem sensible, as variations in service may respond to variations in patronage. Unfortunately, variations in service also create variations in patronage, since predictable frequency is so critical to making public transport useful for many purposes. This makes it easy to set a service level too low, get low patronage, and never see that demand is being suppressed.

One way to make a public transport network easy to understand is to use a standard set of service categories. Each category refers the user to set levels of frequency and hours of service. Categories can then be highlighted in mapping and public information. This makes it easier to explore beyond the one or two routes you know, because you can easily see what the service level of a route would be by its category.

A typical system of categories would include at least three tiers:

- **Frequent Network** includes routes that are always coming soon. For example, this could mean service every 10 to 15 minutes or more often.
- **Basic Network** are all other routes that operate throughout the day at regular frequencies. This can be divided into several subcategories.
- **Peak and Specialised Routes** are services targeted to specialised needs or surges of demand, such as peak express service, night-time service, or special event service.

Figure 78: Typical frequencies and spans for Frequent Network standards in various cities



The diagram above shows some examples of typical frequencies and spans for Frequent Network standards in other cities. Figure 79 and Figure 80 (below) show how a Frequent Network standard can be turned into a Frequent Network brand, making it possible to instantly visualize easy access provided throughout the city.

Figure 79: Portland, United States - "Frequent Service" bus stop pole and network diagram

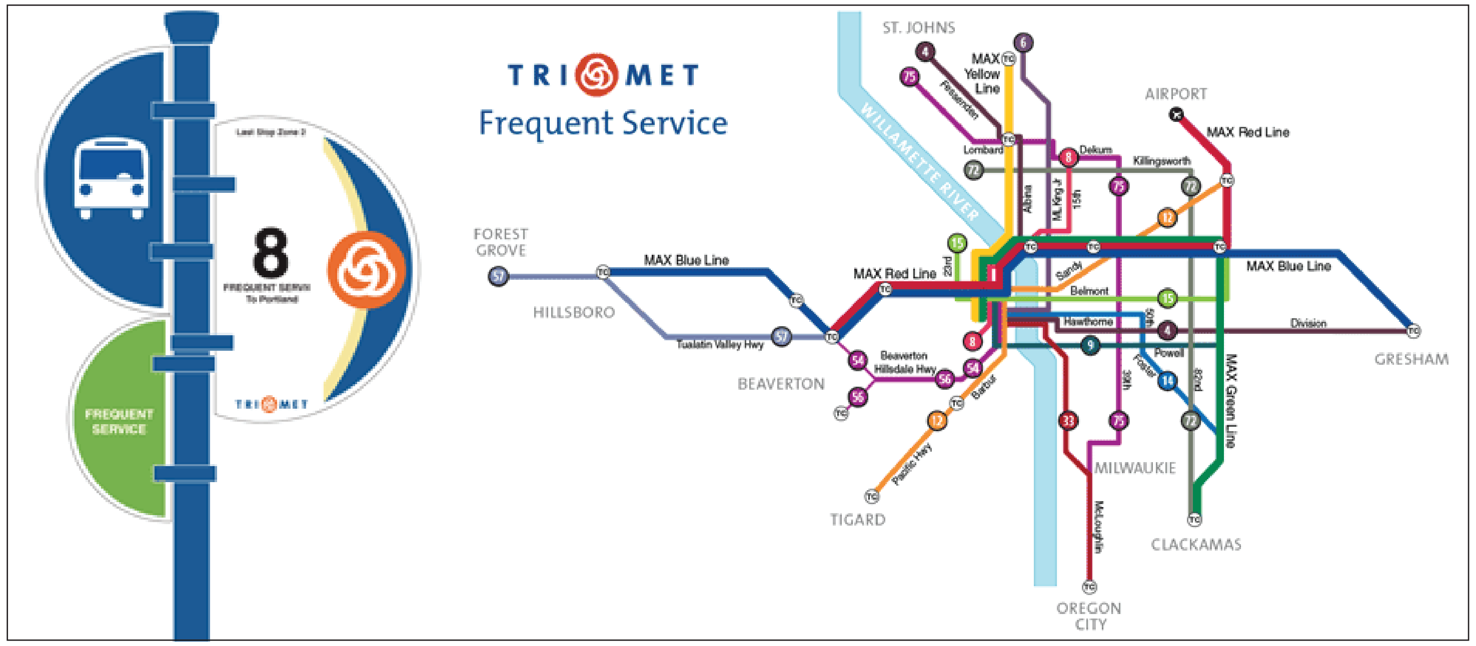


Figure 80: Montréal, Canada - "10 Minutes Max" logo and frequent network map

Strategy #2: Simplify Radial Services to Form Very Frequent Spines

Existing Radial and Cross City Pattern

The diagram to the right (top) is a simplified representation of how radial bus routes are organised in Dublin. As detailed in Chapter 4, each corridor has several overlapping bus routes, which do different things on the opposite side of the city centre.

For example, two overlapping frequent routes from Ballymun approach the city centre from the north, but one continues to Kimmage (Route 9) while the other continues toward Blackrock (Route 4). The advantage of this scheme is that each corridor has direct service to several different corridors on the opposite side of the city, reducing the need to change buses.

But there are at least two disadvantages to the existing pattern:

- Direct service requires waiting for a particular bus rather than taking whichever is coming next. This means lower frequency and thus longer waits.
- The number of cross-city bus patterns creates huge complexity in the city centre. Dozens of routes weave in different directions from different origins, so there are few locations to wait for all buses going out on a given corridor. It is also harder to identify frequent paths useful for short trips in and near the city centre.

Alternative Concept - High Frequency Spines

The diagram to the right (top) shows another way this could work. Imagine if, instead of having direct service from each corridor to several others, all service in a corridor could flow through to a single corridor on the other side.

These services would run together to a certain point, then branch to serve multiple destinations further out. The combined service would form a spine of extreme frequency, in the range of a bus **every 3 to 8 minutes** in the middle of the day. This could also provide other benefits:

- **Simpler cross city paths.** Short trips across the city centre would be easier, because frequency would always be very high and the network would be simple to navigate.
- **Better ability to match service to observed loads.** As service is concentrated on fewer routes, it becomes easier to adjust bus volume to match real demand.
- **Reduced bus congestion in city centre.** Fewer frequent routes are easier to schedule so that buses are not obstructing one another. The total number of bus trips traversing the centre could be slightly lower without any reduction in service to the customer.

Figure 81: Existing Network. Multiple routes from each corridor cross the city centre in different directions.

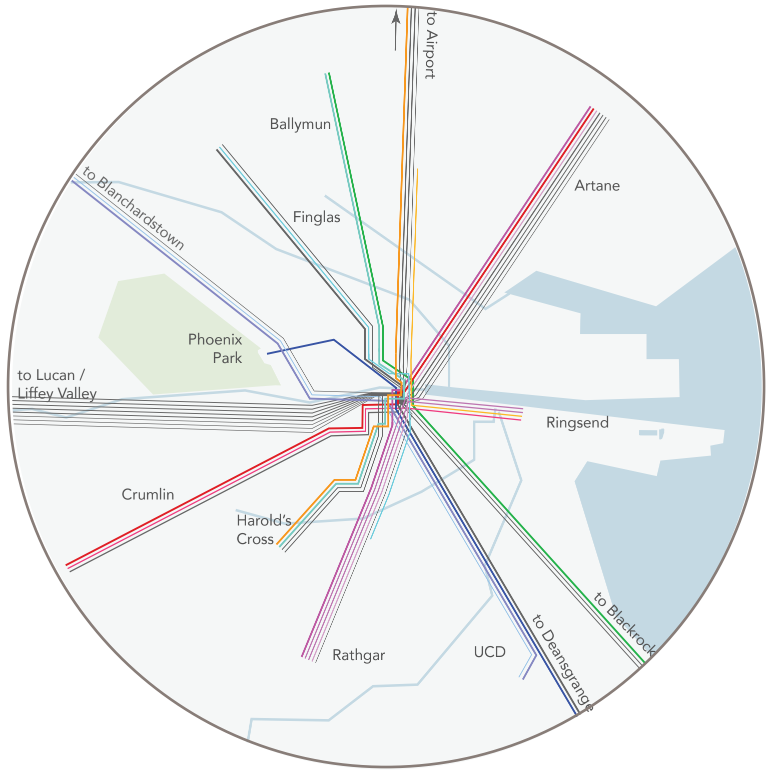


Figure 82: Proposed Network. Each corridor has a single frequent line crossing the city centre on a single path.

Cross City Travel Time Conceptual Examples

Here a few examples of how cross public transport travel times might change, based on the spine frequencies described in Chapter 7.

New Interchange - Harold's Cross to Drumcondra

In the existing network, this trip would use Route 16:

Wait 6 minutes + Travel 35 minutes = **41 minutes**

In the revised proposed network, this would change to:

Wait 2.5 minutes + Travel 20 minutes + Wait 1.5 minutes + Travel 15 minutes = **39 minutes**

New Interchange - Donnybrook to Heuston Station

In the existing network, this trip would use Route 145:

Wait 5 minutes + Travel 30 minutes = **35 minutes**

In the revised proposed network, this would change to:

Wait 2.5 minutes + Travel 20 minutes + Wait 2 minutes + Travel 10 minutes = **34.5 minutes**

Restructured Interchange - Lucan Village to UCD Belfield

At present, this trip would use Routes 66/a/b and 39a:

Wait 7.5 minutes + Travel 32 minutes + Wait 5 minutes + Travel 17 minutes = **61.5 minutes**

In the revised proposed network, this would change to:

Wait 4 minutes + Travel 27 minutes + Wait 2.5 minutes + Travel 17 minutes = **50.5 minutes**

Still Direct - Donnycarney to Crumlin Hospital

In the existing network, this trip would use Route 27:

Wait 5 minutes + Travel 43 minutes = **48 minutes**

In a restructured network with spines, this would change to:

Wait 2 minutes + Travel 43 minutes = **45 minutes**

Strategy #3: Build Frequent Orbitals by Reducing Duplication

The existing network features few orbital routes, none of which are frequent outside peak hours. This means it is difficult to travel between points that are generally on the same side of the city, without going through the city centre. This also means that some of the crowding on services into the city centre consists of people who could avoid the city centre if they had a more direct route.

One way to increase the frequency of orbital service would be to reallocate resources from radial routes with significant orbital components, as in the example below.

Existing Service - Orbital-Radial Overlap

As shown on the map at top right, the existing orbital Route 18 operates every 20 to 25 minutes in the middle of the day, connecting multiple neighbourhoods in the southern half of Dublin City. Route 83 operates every 15 minutes between Kimmage and city centre. Routes 18 and 83 duplicate each other for a long segment between Kimmage and Rathmines Road.

Alternative Concept - Frequent Orbital

Figure 84 shows another way this could work if the resources currently allocated to Route 83 south of the city centre were allocated to Route 18. It would probably be possible to operate Route 18 every 15 minutes or better all day long, and more frequently at peak. At the same time, service on Rathmines Road would remain extremely frequent, even without Route 83.

Travel Time Examples

The examples below show that many **orbital trips would be faster due to shorter waits. However, small areas would have only orbital service**, so must change buses to reach the city centre.

Figure 83: Existing Service - routes 18 and 83

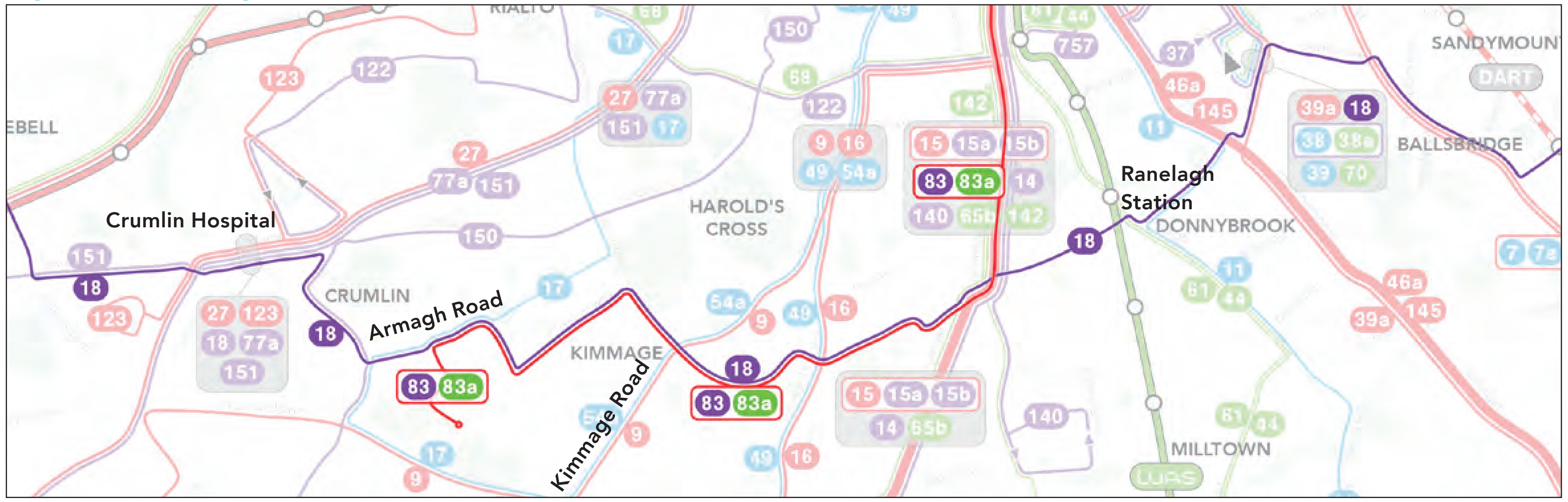
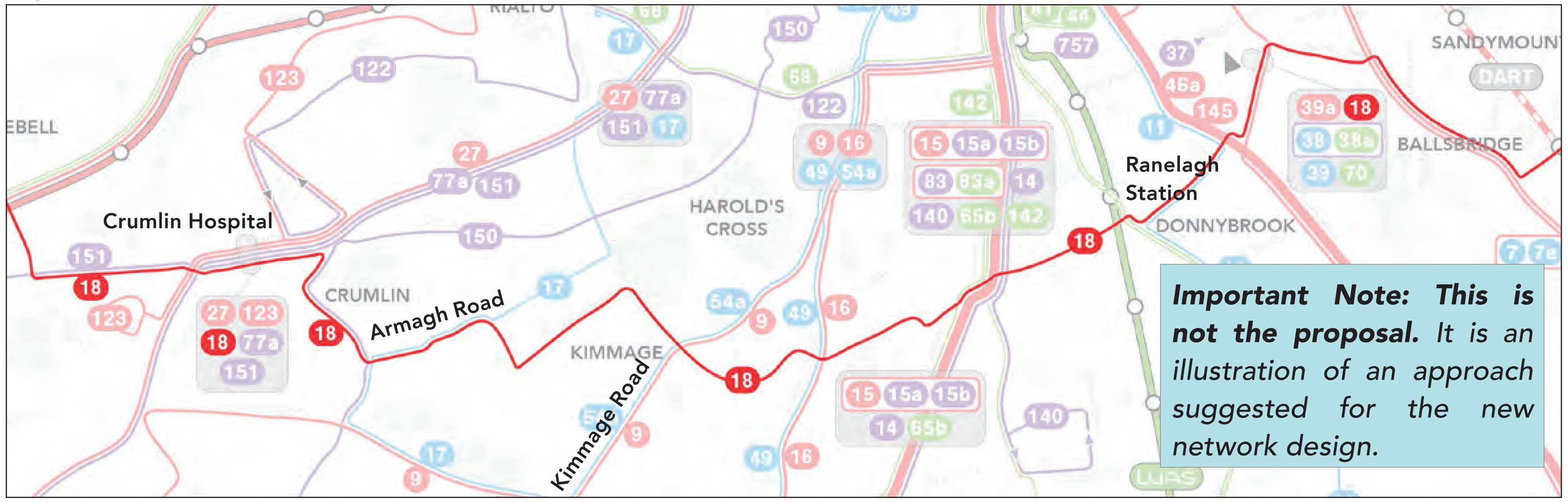


Figure 84: Alternative Concept - frequent route 18



Worst Case Radial Trip - Armagh Road to City Centre

In the existing network, this trip would use Route 83/a:

Wait 7.5 minutes + Travel 29 minutes = **36.5 minutes**

With a frequent Route 18 and interchange at Rathmines:

Wait 7.5 minutes + Travel 12 minutes + Wait 3 minutes + Travel 17 minutes = **39.5 minutes**

Improved Direct Orbital Trip - Crumlin Hospital to Ballsbridge

In the existing network, this trip would use infrequent Route 18:

Wait 12.5 minutes + 31 minutes = **43.5 minutes**

With a frequent Route 18, this would change to:

Wait 7.5 minutes + Travel 31 minutes = **38.5 minutes**

Improved Interchange Orbital Trip - Dundrum to Kimmage Road Lower

In the existing network, this trip would use Luas Green Line and Route 9, with interchange at Harcourt near the city centre:

Wait 3 minutes + Travel 14 minutes + Wait 7.5 minutes + Travel 16 minutes = **40.5 minutes**

This would change to Luas Green Line and frequent Route 18, with interchange south of the city centre at Ranelagh Station:

Wait 3 minutes + Travel 11 minutes + Wait 7.5 minutes + Travel 12 minutes = **30.5 minutes**

Strategy #4: Grow Suburban Feeder Networks Supporting the Major Routes

Nearly every suburb of Dublin currently has a direct bus service to the city centre. At the same time, many suburban areas of Dublin have very low local bus frequencies.

These two facts are linked. The long run into the City typically duplicates many other routes, and consumes resources that could be used to increase local frequencies.

In many cases, if outlying suburbs were served only by a route to their closest regional centre, they would experience significantly more frequent bus service, as in the following example.

Feeder Example - Dunboyne/Blanchardstown

At present, Dunboyne is served by Route 70 to the city centre, and Route 270 to Blanchardstown Centre. As shown in Figure 85, both operate very infrequently in the middle of the day, every 60 minutes on average in each direction.

If all resources dedicated to Route 70 were re-allocated to Route 270, as shown in the diagram at right, it would be possible to provide service to Blanchardstown Shopping Centre every 20 minutes. Passengers going from Dunboyne to City Centre would connect to frequent radial service at Blanchardstown.

Based on existing schedules, **the increased frequency on Route 270 would greatly reduce average travel times from Dunboyne to Blanchardstown Centre and to the city centre.**

Travel Time Change - Dunboyne to Blanchardstown Centre

Under existing service, this trip would use the hourly Route 270, for the following midday travel time:

Wait 30 minutes + Travel 19 minutes = **49 minutes**

With a more frequent Route 270:

Wait 10 minutes + Travel 19 minutes = **29 minutes**

Travel Time Change - Dunboyne to City Centre

Under existing service, this trip would use the direct hourly Route 70, for the following midday travel time:

Wait 30 minutes + Travel 49 minutes = **79 minutes**

With a more frequent Route 270 feeding into Route 39a :

Wait 10 minutes + Travel 19 minutes + Wait 5 minutes + Travel 39 minutes = **73 minutes**

Figure 85: Existing Midday Service - Dunboyne example

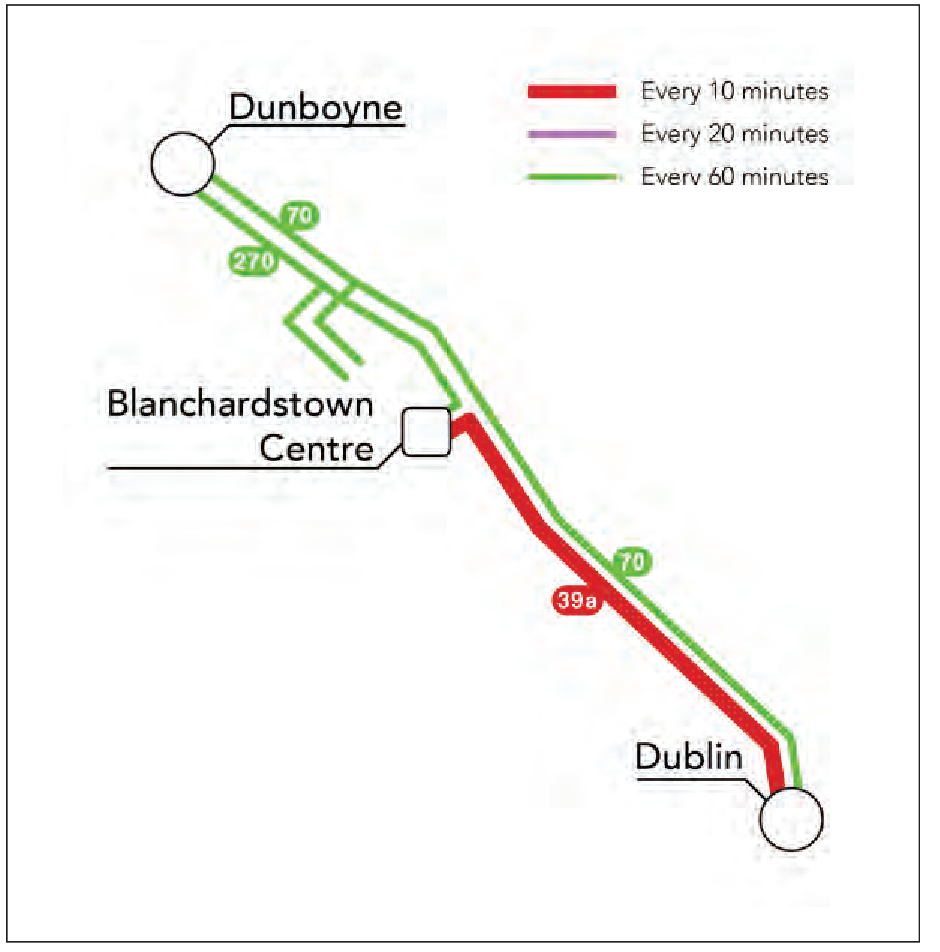
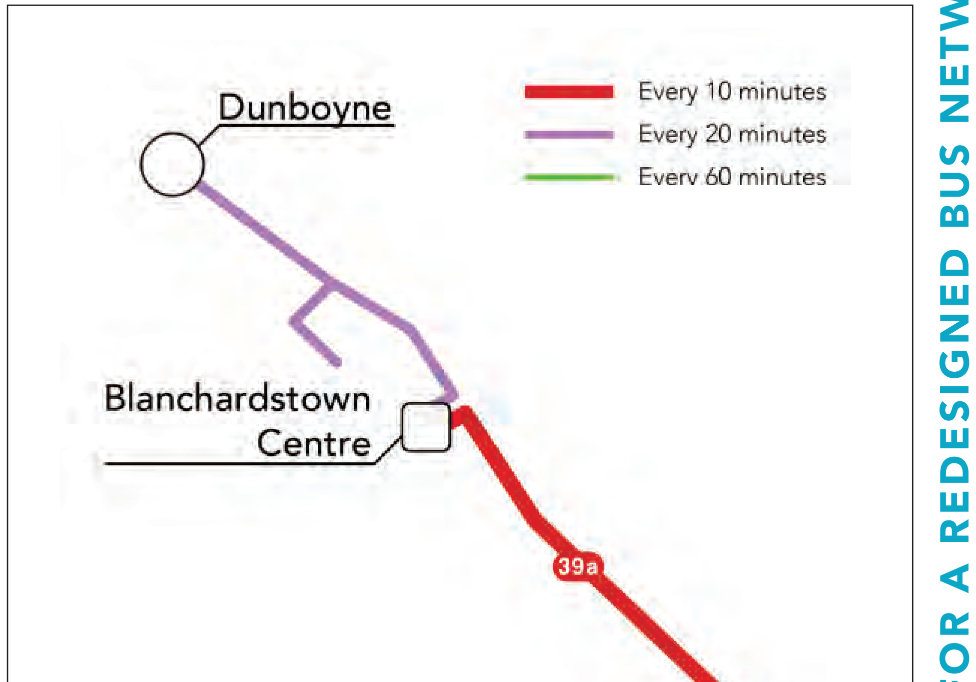


Figure 86: Alternative Concept - Dunboyne example



Important Note: This is not the proposal. *It is an illustration of an approach suggested for the network design.*

Peak Hour Considerations

The following additional considerations should be taken into account when thinking about this concept for peak-hour travel. These issues will be considered in any detailed proposal using this principle.

- **Core Radial Capacity.** Converting Route 70 into a feeder service means that a large number of passengers will interchange to the core radial route into the city centre (e.g. existing Route 39a, or Spine B as shown on page 68).
  - » The core radial route may require additional service may to handle increased loads, and it may be necessary to add a peak express service.
- **Time Delay to Access Interchange.** Many regional centres such as Blanchardstown Centre are subject to peak-hour congestion. This means that the time benefits of feeder service will be less at peak hour than during the middle of the day.

Summary of Choices and Next Steps

To sum up, **the most important choice facing the Dublin area bus network is whether to increase the reliance on interchanging, in return for service that is more frequent and less complex** and offers faster total journey times even for trips where an interchange is newly required.

This chapter has illustrated the advantages and disadvantages of interchange in general, and also has laid out some examples of the kinds of changes that might appear in a plan that embraces the high-interchange, high-frequency principle. These are organised into four strategies:

- **Standardize Service Categories** so that users instantly know the frequency and service hours of any given route, just by looking at a map.
- **Simplify Radial Services** by consolidating core radial routes such that each major corridor is served by a single "spine" that crosses the city centre on a single path, and continues to another single corridor on the other side.
- **Build Frequent Orbitals** to create more frequent and direct paths between suburbs, and to allow suburb-to-suburb trips to avoid the city centre.
- **Grow Suburban Feeder Networks** so that services between outer suburbs and regional centres can become much more frequent, and the number of buses reaching the city centre is reduced.