Dublin Area Bus Network Redesign
Choices Report

JUNE 6, 2017

National Transport Authority

Table of Contents

1 What is the Bus Network Redesign?

What Services Constitute the Bus Network?

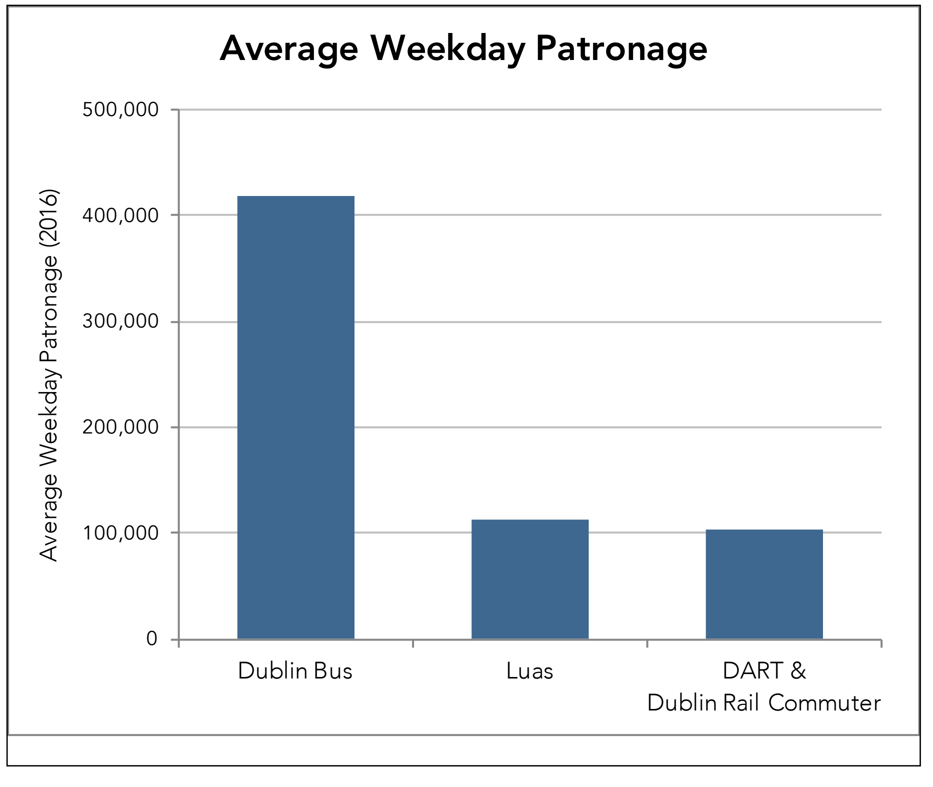
Buses are the backbone of Dublin's public transport system

Public transport is essential to a city of Dublin's size and density, because there is simply not room for everyone's car.

The vast majority of public transport in Dublin is provided by buses. Because it takes a very long time to plan and build new rail lines, this will remain true, at minimum, for the next ten or more years, and will always be true to some extent. Even in cities like Paris, where almost everyone is within 800m of a metro station, enormous numbers of people travel by bus.

As a result, a study of Dublin's bus network is a study of most of the public transport in Dublin. It is also a study of what can be done soon, because buses are the only public transport technology whose services are easy to revise.

Figure 1: Average weekday patronage on the three primary public service transport operators in the Dublin area. Buses carry approximately 2/3 of total patronage.



How buses are regulated and funded

Public transport throughout Greater Dublin, including bus and rail, falls under the jurisdiction of the National Transport Authority (NTA). NTA's task is to make all service work together as a single coordinated regional network.

NTA is the *regulator* for all public transport services, but it is also the *planner and purchaser* of almost all of them.

Services planned and purchased by NTA are called the Public Service Obligation (PSO) network. The bus portion of the PSO network is currently operated by Dublin Bus under contract with NTA.

Outside the PSO network are a small number of *commercial* services. This term means that the operating company expects to make a profit without public subsidy.

Because they serve specialised markets, most commercial services are not considered part of the coordinated regional network. A good example of commercial service is the set of airport express lines, which charge higher fares and have special space for luggage.

Only one route with diverse nonspecialised ridership is commercial, namely the Swords Express service between the City Centre and Swords. This route will be taken into account in this study.

With that exception, a study of the PSO network is a study of all services designed for a diverse public, and intended to work together to provide mobility across all of Greater Dublin.

Introducing the Network

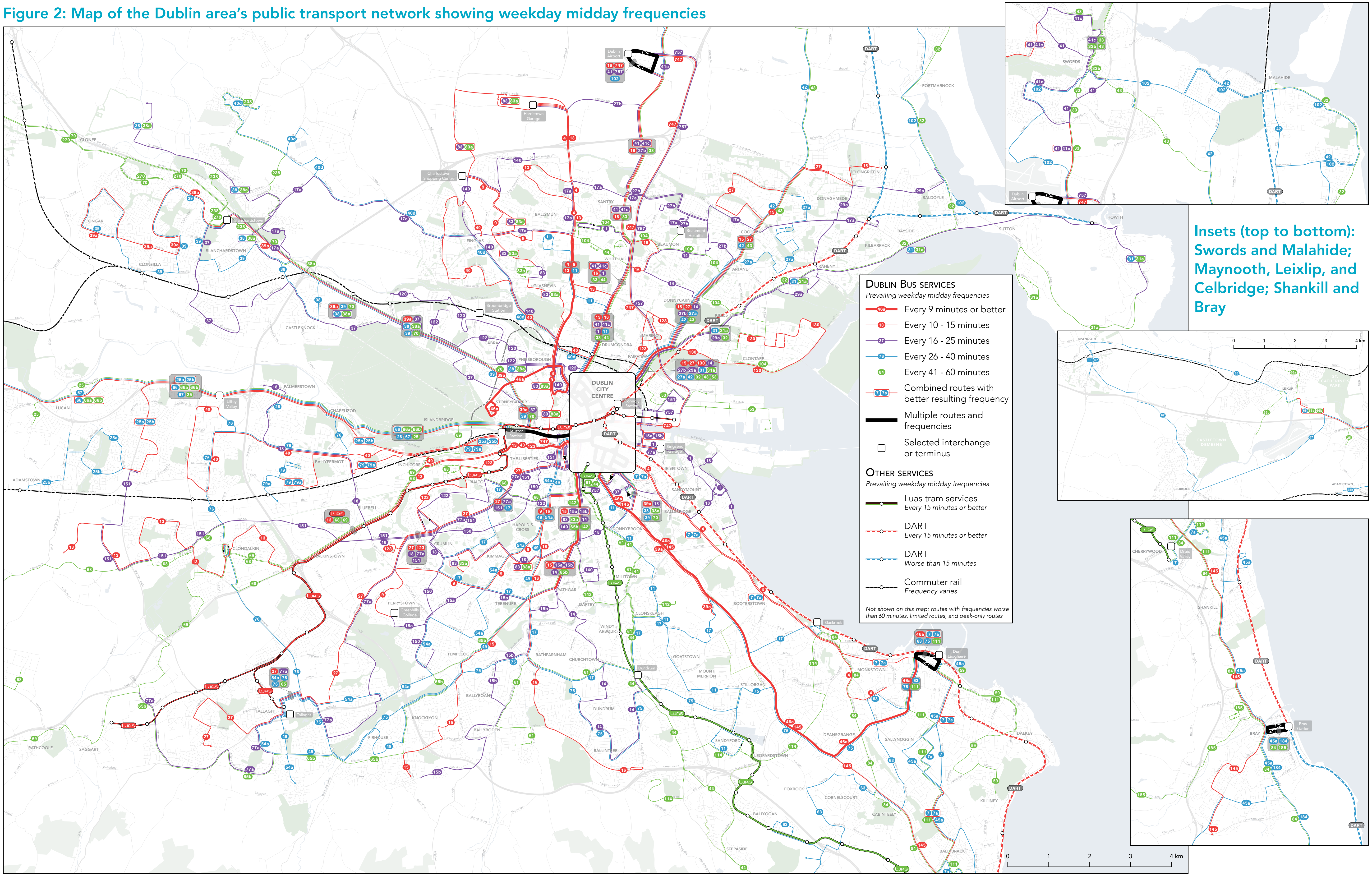
The PSO network (Figure 2 on page 5) covers all of the built-up areas in Dublin City, South Dublin, Dun Laoghaire-Rathdown, and southern Fingal.

A few lines extend further out, reaching as far as Blessington, (Co. Wicklow), Newcastle (Co. Wicklow), Maynooth (Co. Kildare), Dunboyne (Co. Meath), and Balbriggan (northern Fingal).

The maps on page 5 introduce a style used throughout this report, in which colours mostly represent frequency of service. Bright red lines are frequent service, which means that they run every 15 minutes or better, all day. This is necessary because frequency is a critical element of service, and a network can only be fully understood if the patterns of frequency are apparent.

Map of Dublin's Public Transport Network

Figure 2: Map of the Dublin area's public transport network showing weekday midday frequencies



Insets (top to bottom): Swords and Malahide; Maynooth, Leixlip, and Celbridge; Shankill and Bray

Why Redesign the Bus Network?

Redesigning Dublin's bus network is an opportunity to review the evidence for public transport demand, and to design a network that meets those demands most efficiently. Redesign does not necessarily mean massive change, but it can have that outcome.

The key point is that thinking is not constrained by the existing network. Where the analysis suggests that existing service patterns make sense, those elements are retained. Ultimately, the goal is to provide a network designed around the needs of Dublin today and tomorrow, rather than one based on the past.

Limitations in Space

Like most European cities, Dublin presents features that make public transport essential, and require that it be highly efficient:

- **Severe road space limitations.** Across most of Dublin, especially in the older core, the road-width is fixed and will never be wider. Efforts at widening roads in built-up areas are extremely costly and frequently destructive.
- **Intensification of land use.** In response to growing demands for housing and commercial space, both central and outlying areas are growing more dense. More and more people are living within the same limited area.

These two factors combined mean that more and more people are trying to use a fixed amount of road space. If they are all in their cars, they simply do not fit in the space available. The result is congestion, which cuts people off from opportunity and strangles economic growth.

Figure 3: Road space required to move the same number of people using public transport, bicycles, and cars

The only alternative to congestion is for a larger share of the public to rely on public transport and other alternative modes. This requires services that most efficiently respond to the city's changing needs, as well as corridor improvements – also being pursued by NTA – to give buses a level of priority over cars that reflect the vastly larger numbers of people on each bus.

Emerging Patterns in the City Centre and Regional Centres

Meanwhile, several other types of changes are challenging the structure of the existing network:

- City Centre street space is increasingly constrained. There are increasing demands to devote more space to bikes, pedestrians, and other aspects of civic life, in addition to catering for vehicle traffic and bus movements. All of these competing needs put increasing pressure on the limited road space available.
- Regional centres such as Blanchardstown, Tallaght and Swords are growing larger and denser. And other major destinations, such as the employment hub of Cherrywood, are emerging around the edges of the region. The growing number and importance of these suburban centres will trigger more orbital demand for travel that bypasses the City Centre.

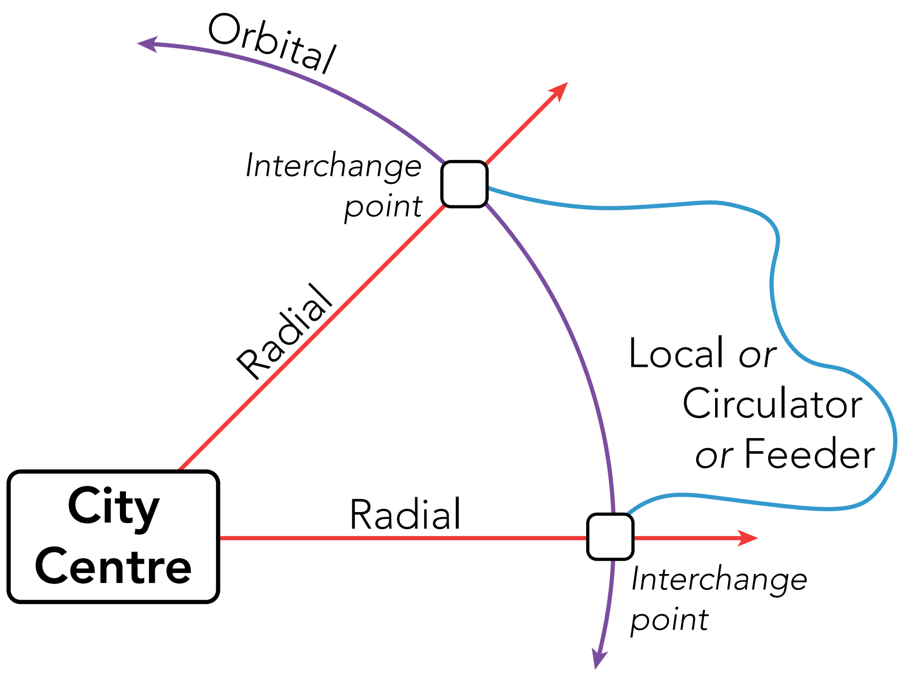
These two factors are interrelated. The most efficient way to grow the bus network without growing bus volumes in the City Centre is to vastly improve orbital services, so that fewer people are forced through the City Centre when it is not their destination.

In this report, we will refer frequently to the three main kinds of public transport line:

- ***Radial** lines connect the City Centre to neighbourhoods and suburban areas. (Radial lines that continue across the City Centre, serving radial paths on opposite sides, are called **Cross City** lines in Dublin.)*
- ***Orbital** lines connect key neighbourhoods and suburban centres to each other, without traversing the City Centre.*
- ***Local** or **Feeder** lines travel shorter distances within neighbourhoods and suburbs, typically connecting to radial and orbital service at an interchange point.*

*A fourth type, the **Express**, may have any shape but typically runs nonstop for a long segment going to or from a major destination.*

Figure 4: The three main types of public transport line are called radials, orbitals and feeders.



Immediate Changes in the City Centre

Finally, some near-term events require changes to the network as early as 2018:

- The **Luas Cross City** project, which is nearing the beginning of trial running, will extend the Luas Green Line north from St. Stephen's Green across the City Centre to Broombridge (see Figure 5). This line will cause changes to both bus demand and to the streets that buses can use.
- The **College Green Civic Plaza** project will close the east end of Dame Street to vehicle traffic, severing the bus link between Dame Street and O'Connell Street. This will reroute large numbers of buses via the Quays, and require rethinking the affected lines in this new context. Figure 6 shows a conceptual rendering of the College Green project.

Figure 5: Map of the Luas Cross City alignment.

Figure 6: Proposed design for the College Green Civic Plaza. The path accross College Green linking O'Connell Bridge and Dame Street will be closed to all vehicles, including buses. Approximately 120 to 150 buses per hour currently use this path.

Where the Bus Network is Going

Network Redesign: Study Year 2018

in the immediate, this network design study focuses on changes that could be implemented quickly, as early as 2018.

This short-term focus is not in conflict with rational long-term planning. Through the Transport Strategy for the Greater Dublin Area, NTA has already established the long term pattern of core transit services, and also many of the key permanent bus corridors. This study builds on the intentions of the Strategy, and considers how short term changes can move in the direction that they define.

In addition, this study may identify new frequent bus corridors and infrastructure needs that may have long-term impact. The study will recommend that these findings, if any, be considered in the next round of long-range planning. In this way, long term and short term planning support one another.

Medium Term: the BusConnects Program

The Bus Network Redesign is the first step in a series of transformative changes to Dublin's bus network over the coming years. The next steps in achieving this transformation include:

- building a network of **"next generation" bus corridors** on the busiest bus lines to make bus journeys faster, predictable and reliable;
- introducing **Bus Rapid Transit**, a higher quality of bus system, on three of the busiest corridors;
- developing a **state-of-the-art ticketing system** using credit and debit cards or mobile phones to link with payment accounts and making payment much more convenient;
- implementing a **cashless payment system** to vastly speed up passenger boarding times;
- a **simpler fare structure**, allowing seamless movement between different bus services without financial penalty;
- a **new bus livery** to integrate bus vehicles of different operators and types, and providing a modern look and feel to the new bus system;
- **new bus stops** with better signage and information and increasing the provision of additional bus shelters; and
- transitioning to a new bus fleet using **low-emission vehicle technologies.**

Long Term: Transport Strategy for the Greater Dublin Area

The NTA's long term strategy for Greater Dublin provides direction on four layers of the network, as shown in the figures on page 9. The following services are envisioned by 2035:

- The most important Core Orbital and Core Radial corridors are slated to receive significant infrastructure and service improvements.
- The five busiest Core Radial corridors are envisioned to operate as a three-line Bus Rapid Transit service.
- A Metro line is envisioned, first connecting the City Centre to the airport. In a second phase, a southern Metro line will replace the current Luas Green Line south of City Centre.
- Further Luas lines are contemplated, including a new line to Liffey Valley and Lucan, an extension of the Green Line to Bray, an extention of the Luas Cross City to Finglas, and an extension of the Red Line to Poolbeg.
- High frequency DART service is expected to grow with the addition of western lines, to Dunboyne, Maynooth and Celbridge.

This study will be strongly guided by these ideas, with the goal of moving the redesigned bus network in the direction they indicate. However, new considerations arising in this study may also suggest refinements to the details of the core bus services in the strategy.

Figure 7: BusConnects includes making speed and reliability to bus corridors, developing cashless fare systems, and using low-emission vehicles.

Figure 8: Long Term - Comprehensive Regional Rail Network

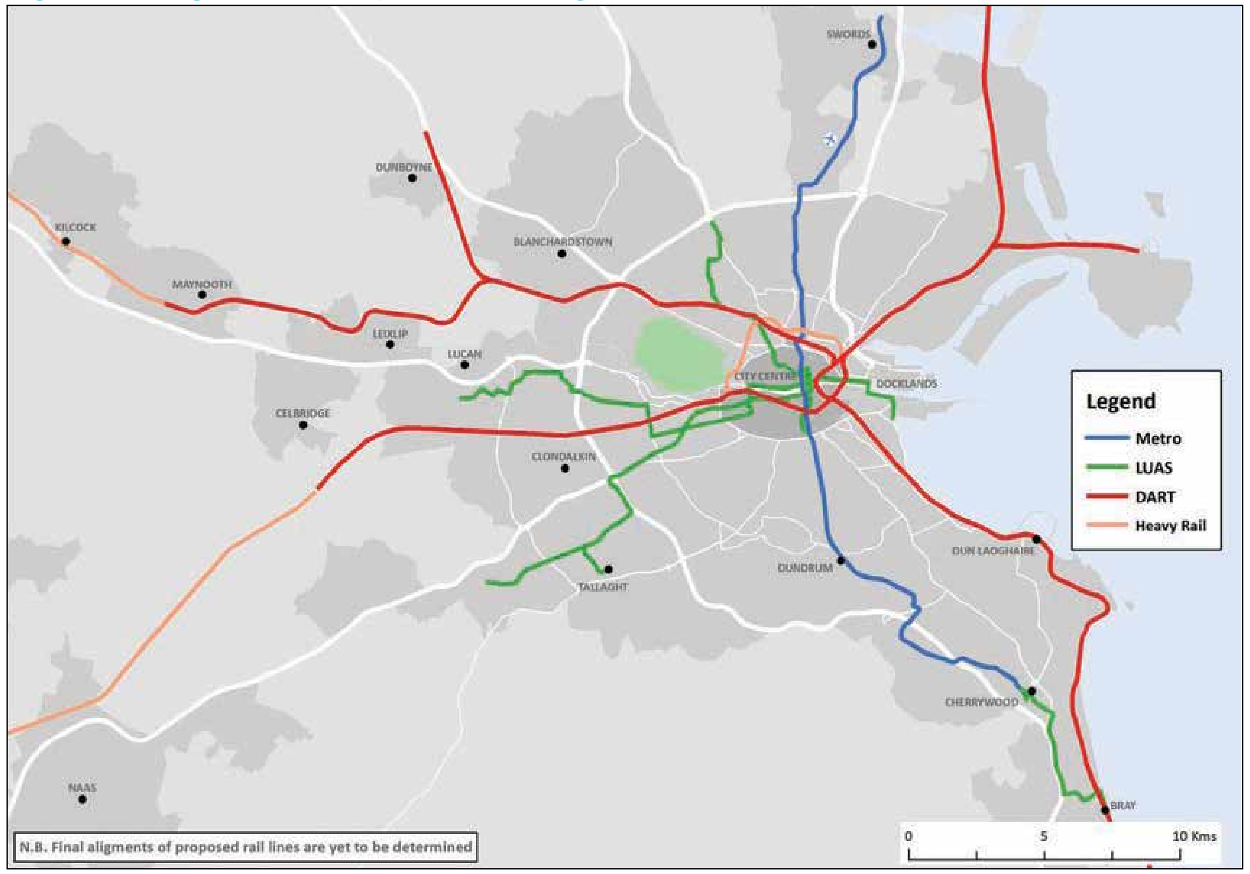


Figure 9: Medium Term - Bus Rapid Transit Corridors

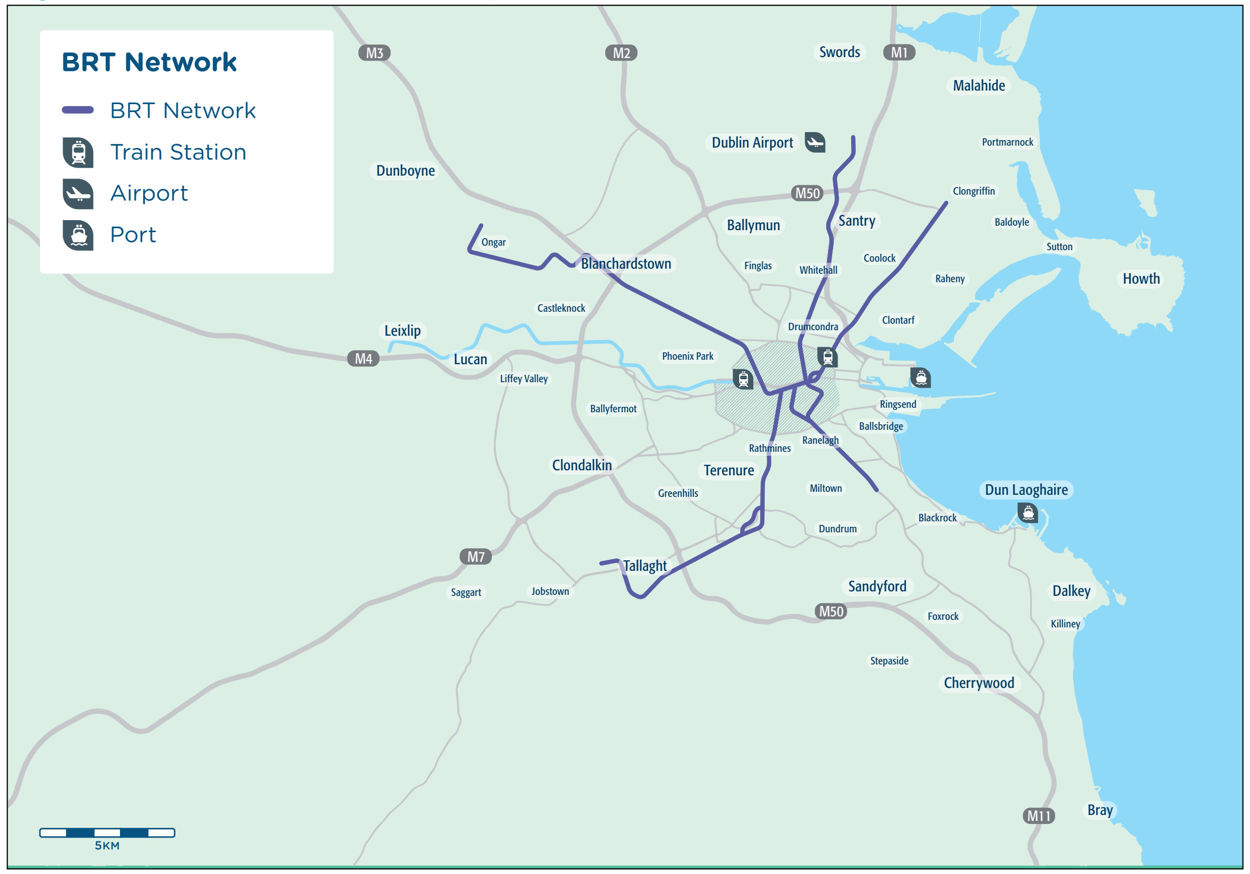


Figure 10: Medium-Term - Core Radial Bus Corridors

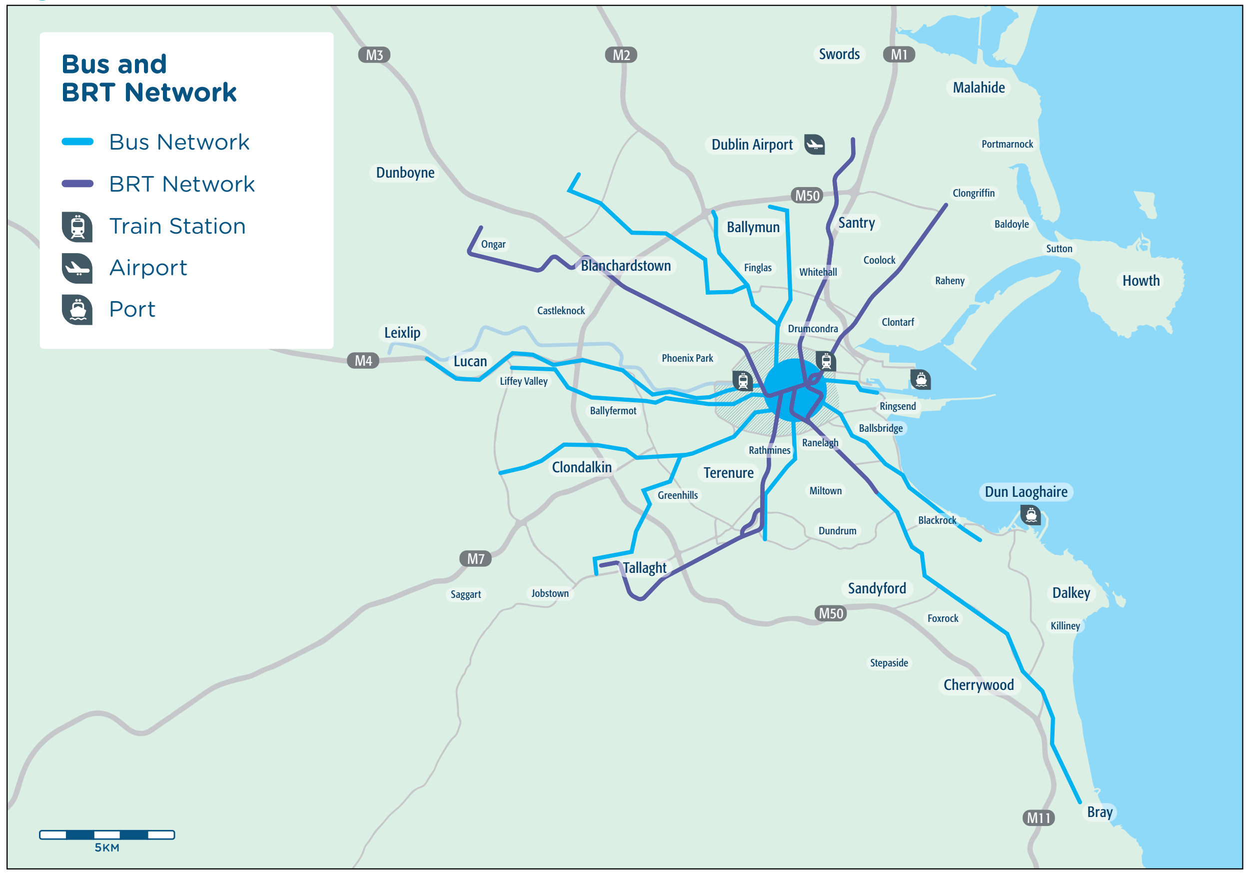
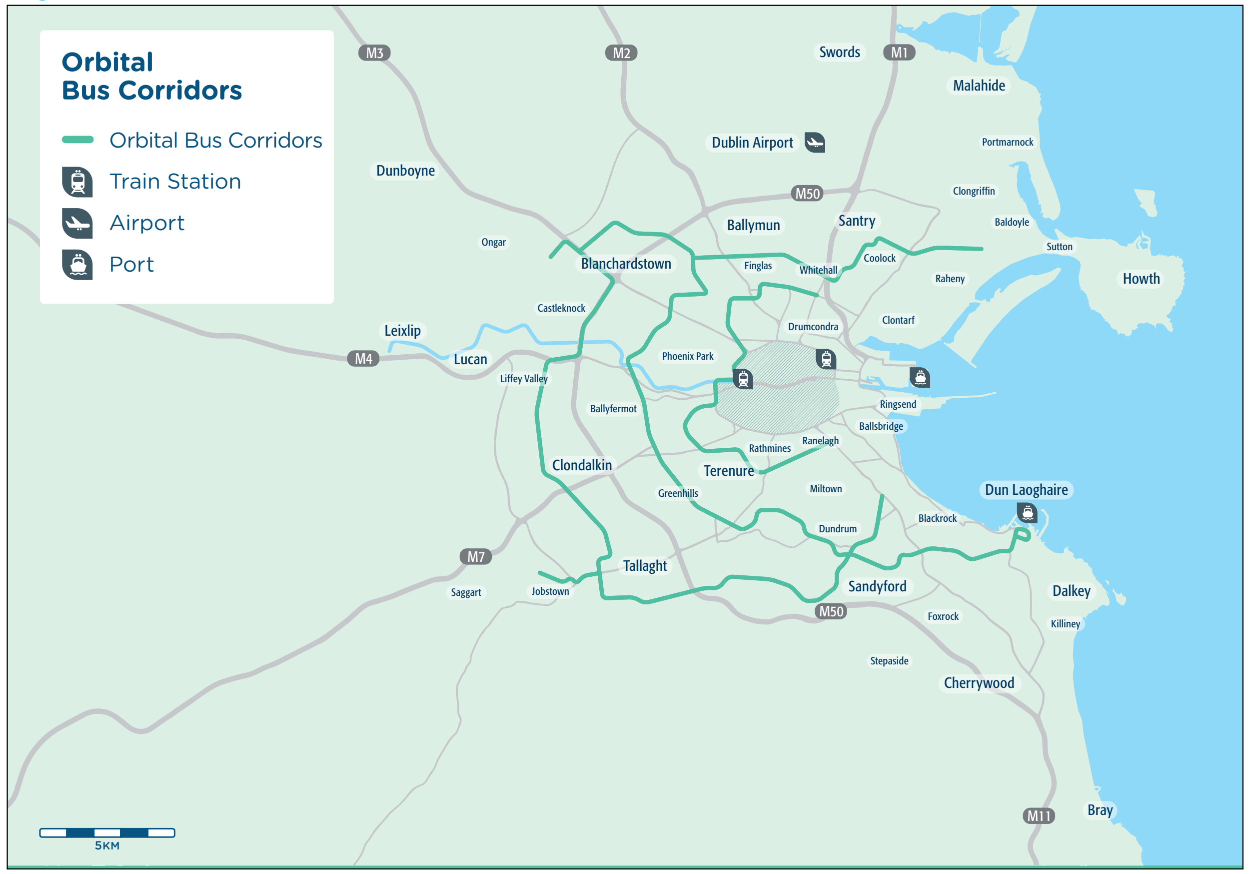


Figure 11: Medium Term - Core Orbital Bus Corridors



2 The Geometry of Useful Public Transport

Patronage Arises from Usefulness

The Dublin Area Bus Network Redesign intends to produce a bus network that can achieve significantly increased patronage over time, and increases the overall regional mode share for public transport and other sustainable transport modes.

Patronage is an important goal for many reasons other than fare revenue. It measures how many people benefit from the service, and how effective it is at providing alternatives to the private car.

Public transport patronage arises from service that is useful to as many people as possible, for as many trips as possible. There are some geometric facts about how networks do this, which this chapter briefly reviews.

A helpful way to illustrate the usefulness of public transport is to look at where one could get to, from a particular point, on public transport plus walking. This diagram, called an isochrone (see Figure 12), is a simple example. From the selected point, the diagram shows where someone could be, on public transport combined with walking, in 30, 45, or 60 minutes.

A more useful service is one in which these shapes are bigger, so that each person is likely to experience it as useful for more purposes. We can roughly measure this by looking at how many destinations – jobs, shopping, etc. – are inside each blob, and how that number grows or shrinks depending on the network design.

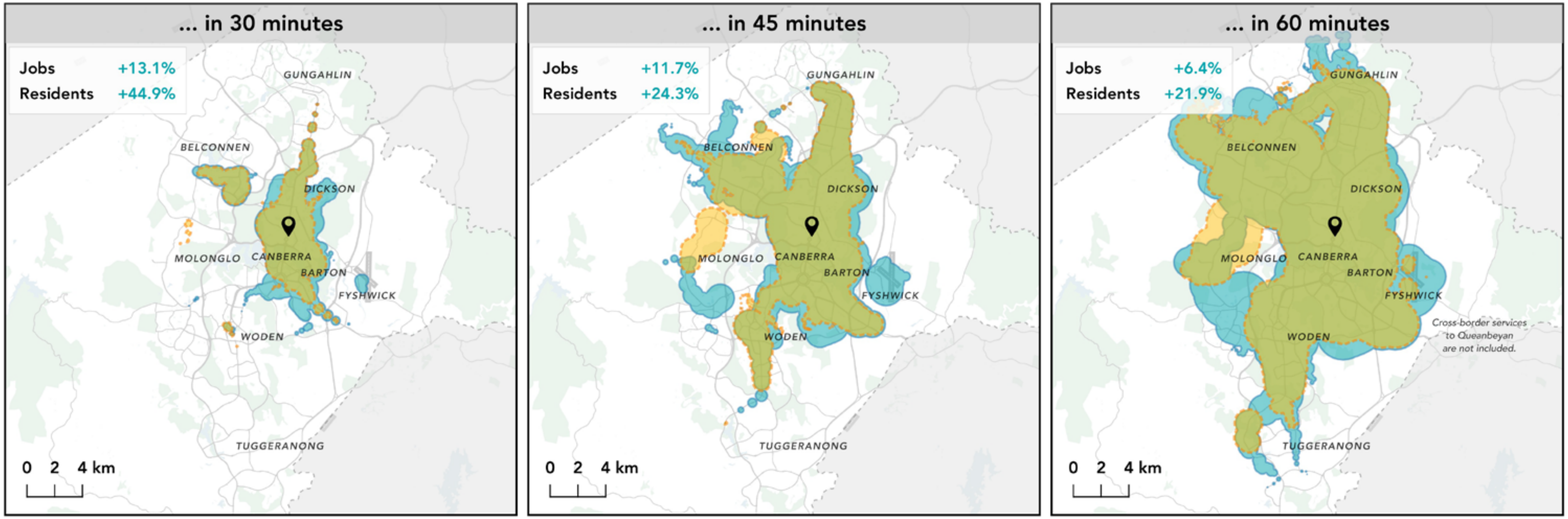
Even beyond usefulness, these diagrams show the level of personal freedom and opportunity afforded by the public transport network.

The potential to expand this freedom and opportunity is the foundation for the increases in patronage that a network design can achieve. This does not strictly predict patronage, because patronage also varies with external factors including prosperity, the costs of car ownership, petrol prices, and the availability of alternative services.

Nonetheless, calculating freedom and opportunity in terms of the numbers of people, places and jobs that can be reached in a certain amount of time does summarize the aspect of patronage that network design influences. This calculation can be made without recourse to assumptions about human culture or behaviour, whose effects may not be reliably predictable. It is for these reasons that we focus on it.

> *To **maximise liberty and opportunity** for the greatest possible number of people:*
>
> - *one must deploy **frequent service;***
> - *with optimal **speed** and **reliability**; and*
> - *following **favorable patterns in the built environment**.*

Figure 12: The isochrones below compare how far one can travel using Canberra, Austrailia's existing network (yellow) versus the proposed network (blue) in the indicated amount of time.



Why Frequency Comes First

Patronage responds to many features of a service, including speed and reliability, but the dominant factor is frequency. Frequency is the elapsed time between consecutive buses (or trains, or ferries) on a line, which determines the maximum waiting time.

People who are used to getting around by private vehicle often underestimate the importance of frequency, because there isn't an equivalent in their experience. A private vehicle is ready to go when you are, but public transport isn't available until it comes.

High frequency means public transport is coming soon, which means that it approximates the feeling of liberty you have with your private vehicle – namely that you can go anytime. Frequency has three independent benefits for the passenger:

- **Frequency reduces waiting**, which is everyone's least favorite part of a trip. The basic sensation of being able to go when you want to go is the essence of frequency. (A smartphone can tell you when the bus is coming, but still does not reduce the wait or get you where you want to be.)
- **Frequency makes connections easy**, which makes it possible for a cluster of public transport lines to become a network. A public transport line without good connections is useful for travelling only along that line. A network of frequent lines can make it easy to travel all over the city. This massively expands the usefulness of each line.
- **Frequency is a backup for problems of reliability.** If a vehicle breaks down or is late, frequency means another will be along soon.

We can see the effect of frequency by looking at how existing services perform.

Figure 13 shows a dot for each Dublin Bus line, with the x-axis indicating frequency and the y-axis indicating productivity, which is patronage divided by the quantity of service provided. High frequency means a low elapsed time between consecutive trips, so it is to the left on these diagrams. Quantity is measured in vehicle hours, where a vehicle hour is one bus operating for one hour.

Adjacent Figure 14 shows a similar graphic for hundreds of lines in 24 North American cities. In both cases, **higher frequency is generally associated with higher productivity**.

The larger dataset shows the pattern very strongly, including the upward curve indicating an exponential payoff of very high frequencies.

The same effect is visible but less obvious in the Dublin data. This is probably because many infrequent lines tend to run long distances on the same streets, so that people can sometimes take whichever comes first. This effect causes higher frequency, and thus higher patronage, on lines that are technically infrequent.

These graphs are more remarkable than they first look, because higher frequency means a higher quantity of service. **This illustrates the power of frequency to deliver more patronage than would be expected by the increase in service hours.**

Figure 13: Frequency vs. productivity (boardings per hour) on bus lines in Dublin

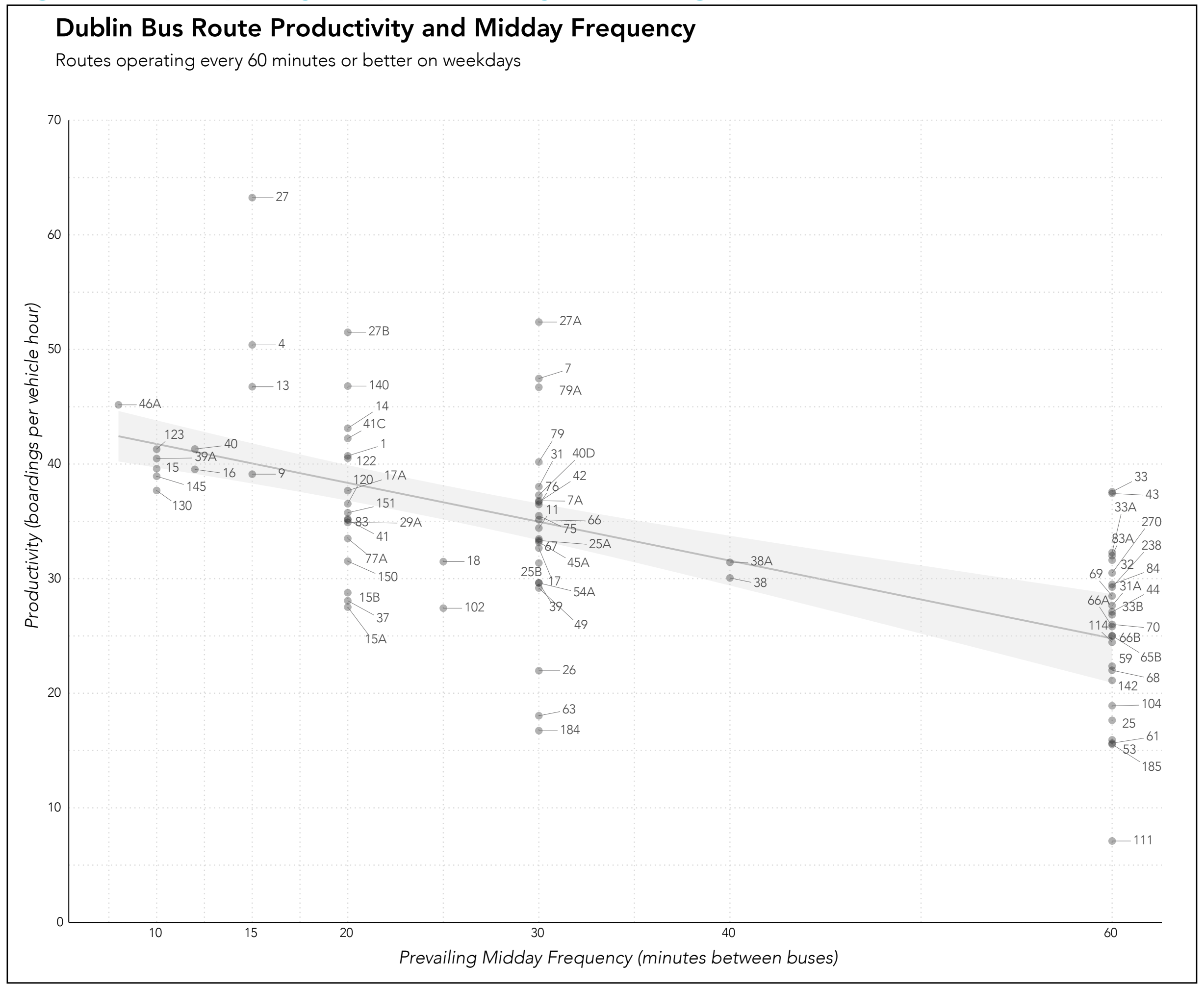
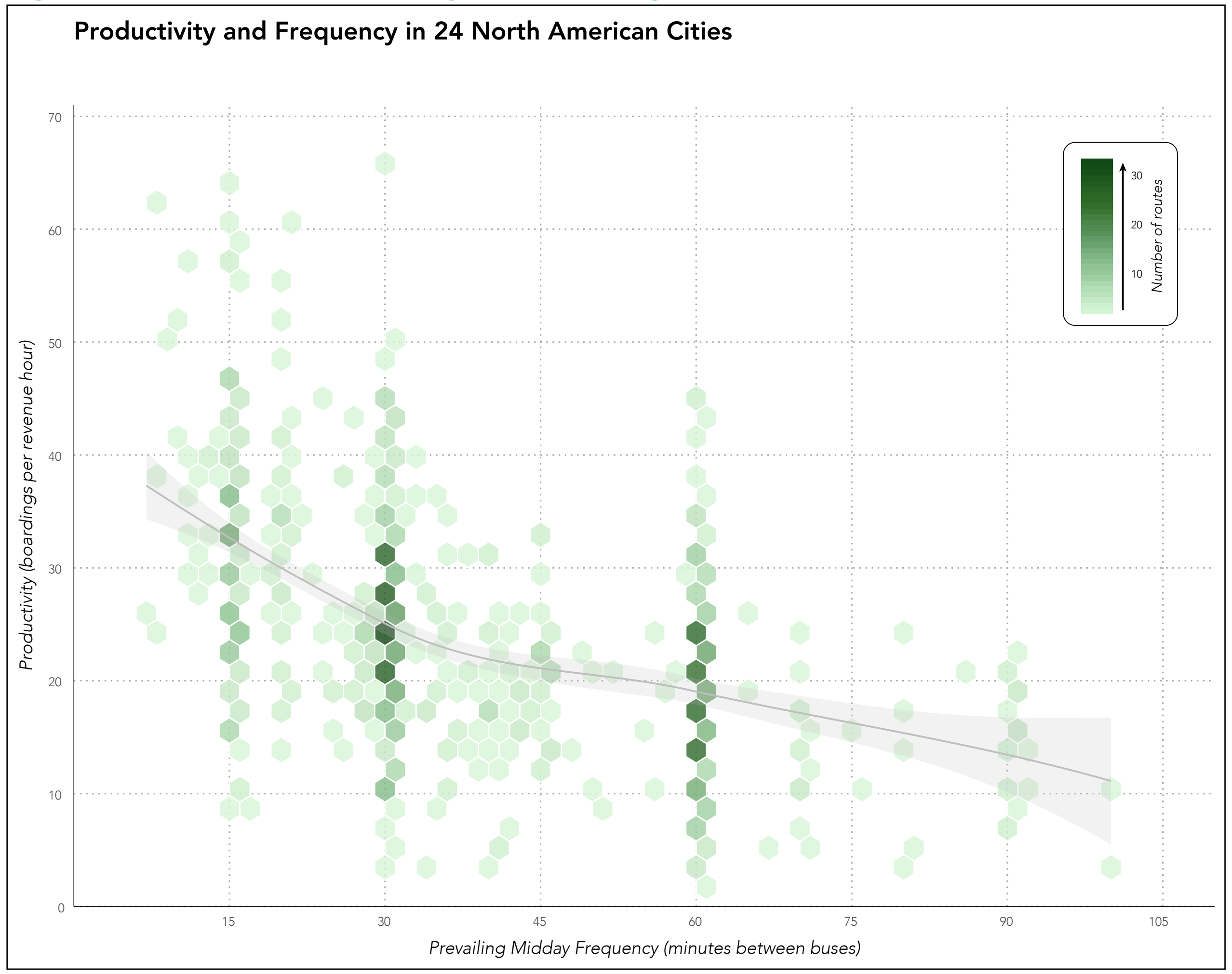


Figure 14: Chart of productivity vs. frequency in 24 North American cities



Patronage Depends on the Built Environment

Service quantity and quality are necessary but not sufficient to create a high-patronage network. To achieve sustained high patronage, A public transport service must also focus on places that are geometrically favourable to its success.

The following factors are critical:

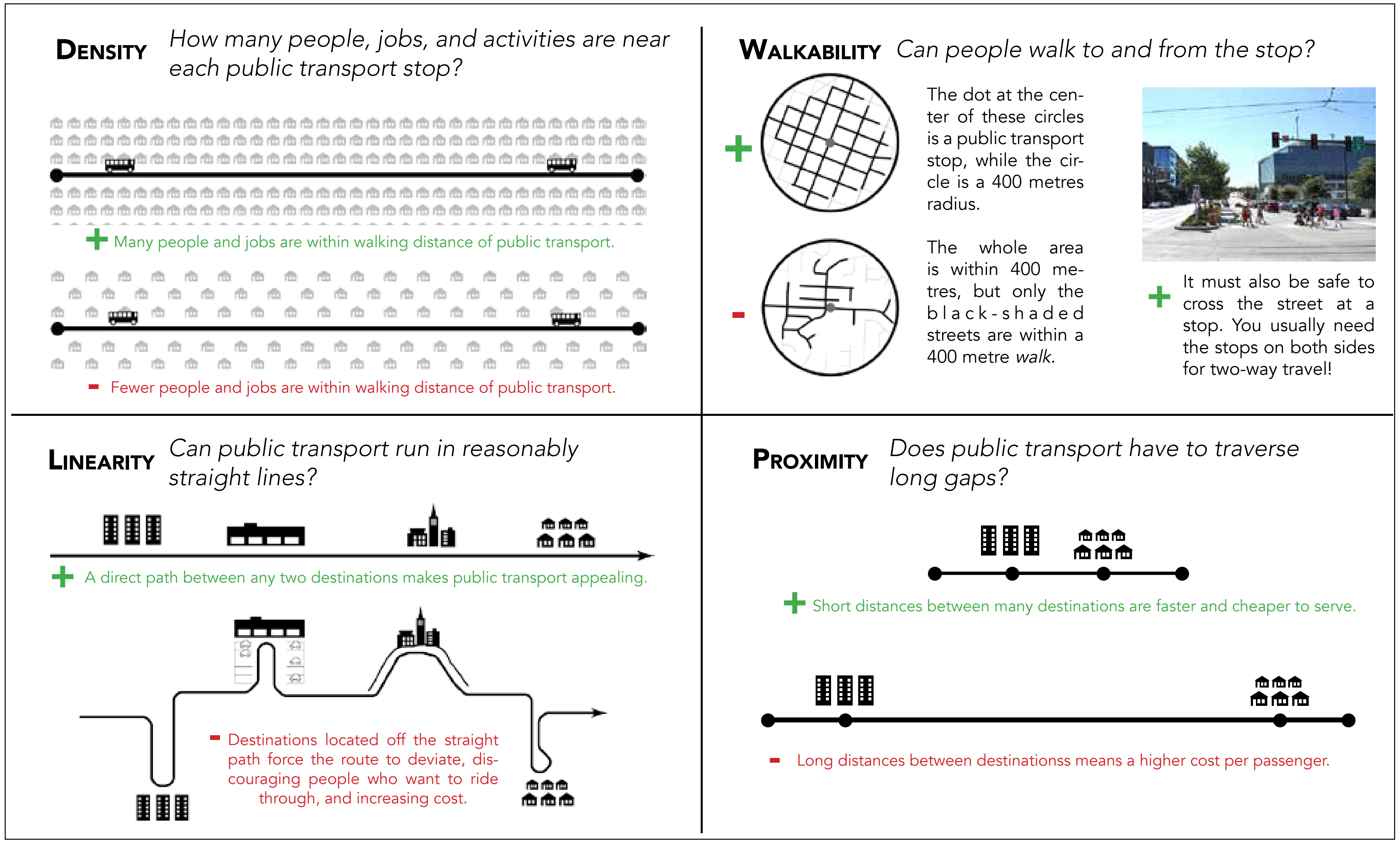
- **Density.** Density determines the number of people and destinations near any public transport stop, which is the first-order estimate of the stop's potential market.
- **Walkability.** If more people can safely and comfortably walk to a bus stop (and cross the street to access both directions of service), the service becomes useful to more people.
- **Linearity.** Where a bus can reach major destinations by running in straight lines (rather than weaving into and out of neighbourhoods), bus service is faster, and less expensive to operate, and less frustrating for customers.
- **Proximity/Continuity.** Where there are fewer gaps in demand, more people will use the service per hour and per kilometre of service provided.

The next pages show how these patterns operate in Dublin.

These geometric facts present us with potential conflict between goals, because the optimal way to maximise patronage could be not to serve certain areas where the geometry is unfavourable.

However, in this study, we stipulate that all areas now covered will continue to be, and focus on maximising patronage within that constraint.

Figure 15: Aspects of the built environment contribute to public transport patronage.



Note: Walkability and Linearity are both associated with ***permeability****, the notion that direct paths of travel are available through neighbourhoods.*

- **Lack of neighbourhood permeability reduces walkability.** *If there are no walking paths connecting subdivisions, pedestrians must take much longer walks to reach a public transport stop, reducing the area with access to that stop.*
- **Lack of road network permeability impacts linearity of bus service.** *To serve certain areas, buses are required to make long and expensive deviations in and out of cul-de-sacs.*

Examples from Dublin: Density and Walkability

Because dense areas often support multiple land uses in close proximity, density and walkability often go hand in hand. The aerial imagery shown here contrasts two areas at the high and low end of the spectrum for both

- **Higher density and walkability:** The vicinity of Drumcondra Station features a mix of terraced houses and apartment buildings, as well as small commercial and large institutional uses (see Figure 16). The area is connected by a dense network of narrow streets and alleys that make it easy to walk to stops on Drumcondra Road from any point.
    - » This means that many people are likely to be present near any bus stop, and that it is likely to be a relatively short distance from any point to the nearest bus stop.

- **Lower density and walkability:** The area located between Rathfarnham and Terenure Road is dominated by semi-detached and detached houses, with almost no commercial uses present (see Figure 17). The blocks are long, with relatively few street intersections, and the street network is bisected by the much wider floodplain of the River Dodder. This makes it relatively inconvenient to walk to Rathfarnham Road.
    - » This means that far fewer people are likely to be near any bus stop, and that walks from any point to the nearest bus stop are probably longer and more circuitous.

> *Because of the inherent **density** and **walkability** of these two areas, **any public transport service going through Drumcondra will attract higher patronage** than a comparable service south of Terenure Road, even if those two services operate at the same frequency, for the same hours, and serve all of the same other places.*

Figure 16: The area around Drumcondra Station features both high density and high walkabililty.

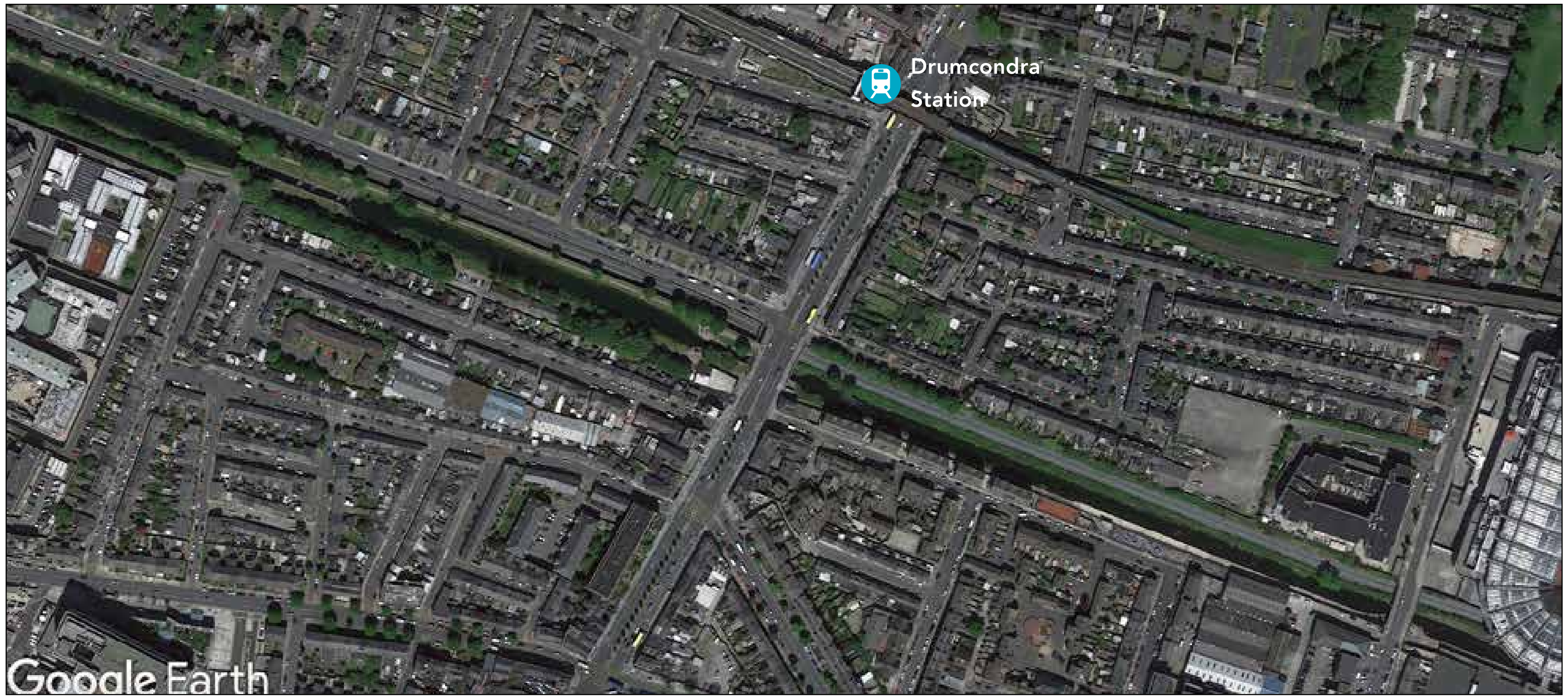


Figure 17: The area between Terenure Road and Rathfarnham features relatively low density and limited walkability.

Examples from Dublin: Linearity

Because of differences in historic land use and road network decisions, some parts of Dublin are served (and servable) by much more linear radial bus services than others. The following examples illustrate this:

- **More Linearity:** southeast Dublin is served by long, straight radial roads and rail right-of-ways that allow for very linear service on corridors such as Merrion Road, Stillorgan Road, the Harcourt light rail right-of-way.
  - » This means it is possible to operate public transport services that are both fast and direct, and as a result are both convenient and cost-effective. And, in fact, the frequent Dublin Bus lines in this area (and the Luas Green Line as well) have some of the highest patronages observed in Dublin.

- **Less Linearity:** the vicinity of Finglas is much more complicated to serve with public transport, due to the geometric facts of the road network and development pattern.
  - » The configuration of the N2 as the Finglas Bypass means that the most direct radial path skips past the area's central destination at Finglas Village. This means any line that focuses primarily on serving the bypass will be fast, but less accessible, like Line 140 today, whose market lies primarily north of Finglas in Charlestown.
  - » Finglas has developed into neighbourhoods oriented away from the bypass. Serving each one of these neighborhoods requires reaching off of the bypass to the local network of secondary roads.
  - » This means any line that tries to solve the bypass problem by entering the neighborhoods is confined to a slower and far more circuitous path, as Line 40 is today.

Figure 18: In southeast Dublin, the network of straight roads allows bus lines to be linear while serving all neighbourhoods.

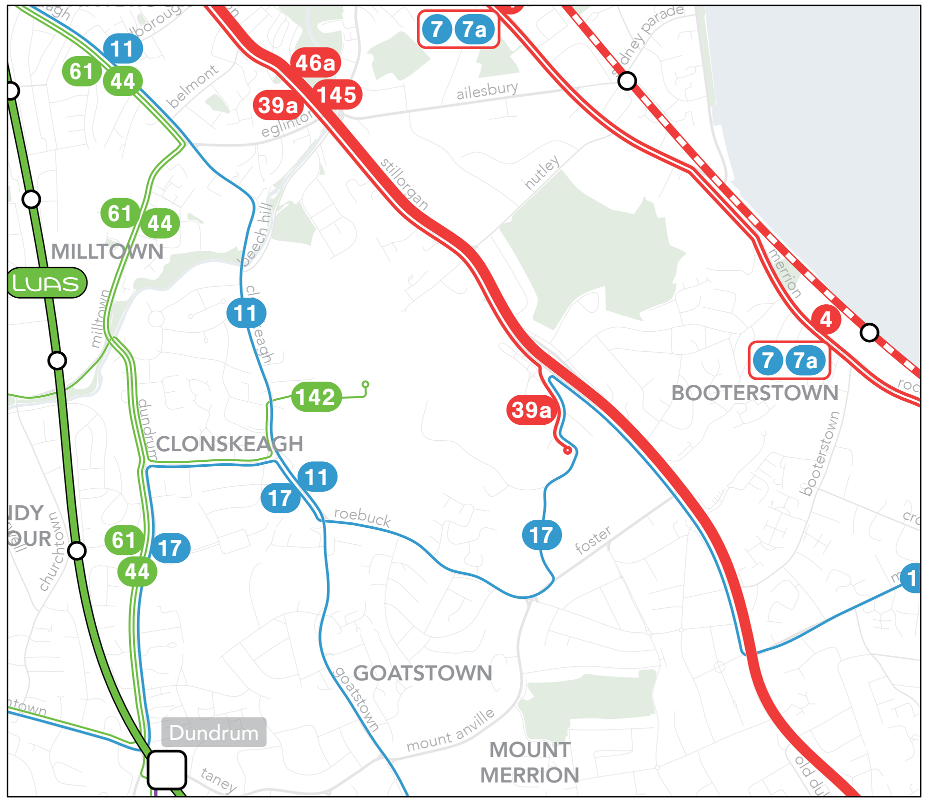
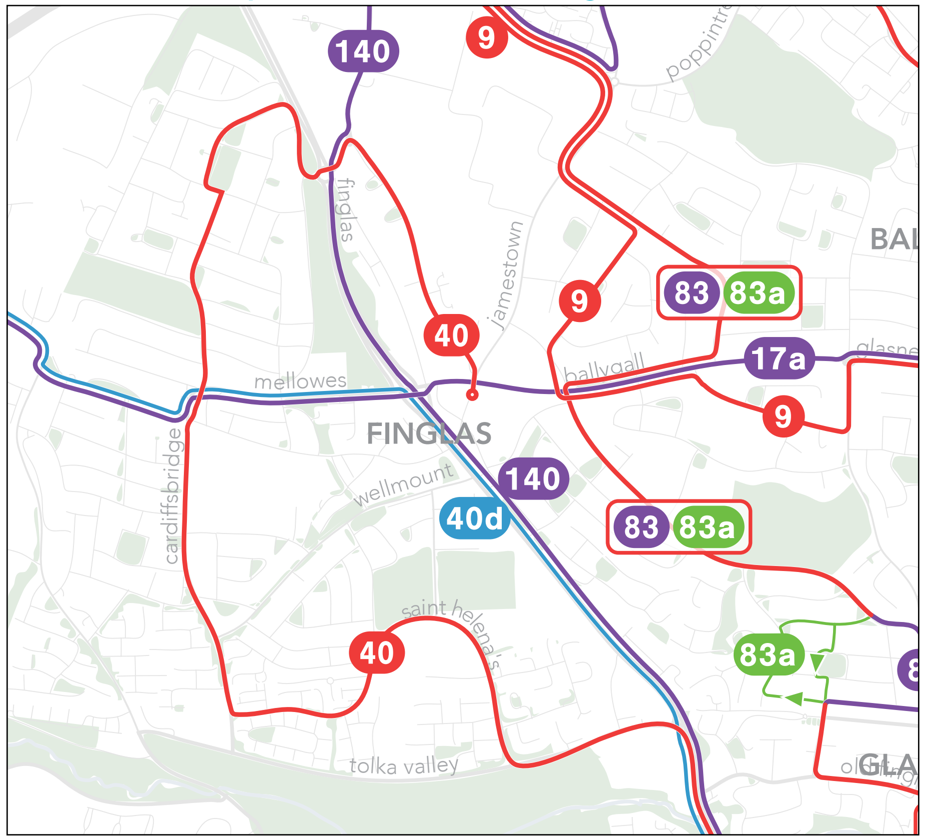


Figure 19: In Finglas, the road network forces bus lines off the most direct path to serve each neighbourhood.



Because of the linearity of the arterial street network, any radial bus line in southeast Dublin is likely to be relatively direct and conveniently accessible.

In Finglas, however, the most direct path to City Centre is taken by the pedestrian-unfriendly Finglas Bypass. This means Finglas' main radial bus lines are constrained to operate on circuitous paths through neighborhoods.

As a result, ***achieving an equivalent level of service will always require more resources in Finglas than in south-east Dublin.***

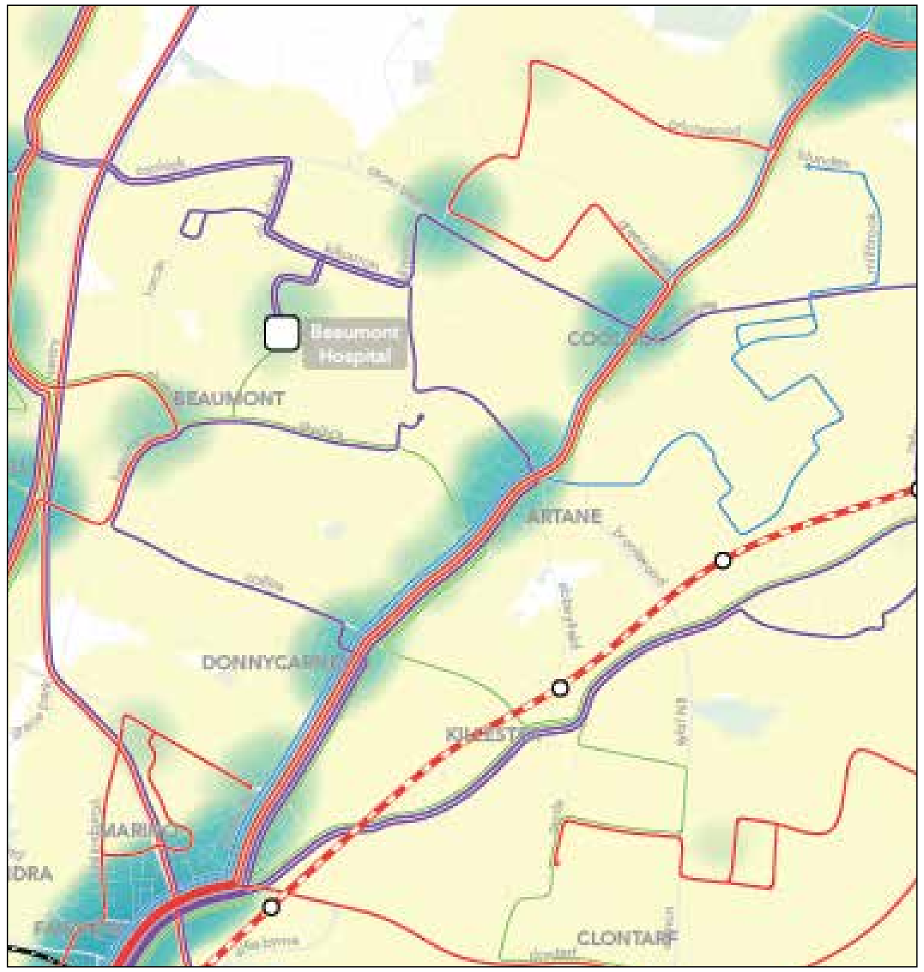
Examples from Dublin: Proximity/Continuity

Whereas certain travel corridors in Dublin are continuously developed and generate demand throughout, others force public transport to traverse large gaps of lower or non-existent demand. The following examples illustrate this:

- **More Continuity:** Based on the measured number of weekday bus boardings, Malahide Road exhibits a steady level of demand from Fairview to Northern Cross. Few of the areas in this corridor have extremely high demand, but there is consistent and significant demand throughout.

- **Less Continuity:** On the other hand, the Navan Road corridor connects strong anchor points with extremely high demand (City Centre and Blanchardstown Shopping Centre), but the local development pattern means that bus lines traverse long stretches with weak demand in between.

Figure 20: The blue dots indicate continuous demand along Malahide Road, based on a count of bus boardings.



Because of the continuous development and steady demand throughout the corridor, any bus line on Malahide Road will serve a higher number of boardings per kilometre than a comparable service on Navan Road, which connects high-demand centres through a long area of low demand.

Figure 21: The same measure shows long gaps in demand along Navan Road, largely reflecting corresponding gaps in development.

Summary

An effective network planning effort cannot simply be data-driven. As we explore the data over the next chapters, it is important to remain mindful of the purely geometric facts about public transport.

For example, frequency and speed on each segment of the network determines the degree of freedom and opportunity a person in a particular place will experience, and it does so based on purely geometric calculations.

In addition, measures of the built environment such as density, walkabilty, linearity and proximity are also geometric facts that determine the efficiency with which public transport can provide useful service.

It is always helpful, when thinking about public transport, to distinguish purely geometric facts – facts that are true always and everywhere – from data-driven arguments about human behaviour that constitute most measurements of public transport outcomes.

Rich data is essential for planning, but observations derived from data are always less certain, and more debatable, than geometric facts. Our focus on geometry in this report is intended to help people see what cannot be changed, so that they can have clearer conversations about what can.

3 Patterns of Demand

Indicators of Public Transport Demand in Residential Areas

The last chapter observed some geometric facts about how and where public transport can provide useful service to many people, efficiently. This chapter looks at Dublin's development pattern and demographics in greater detail.

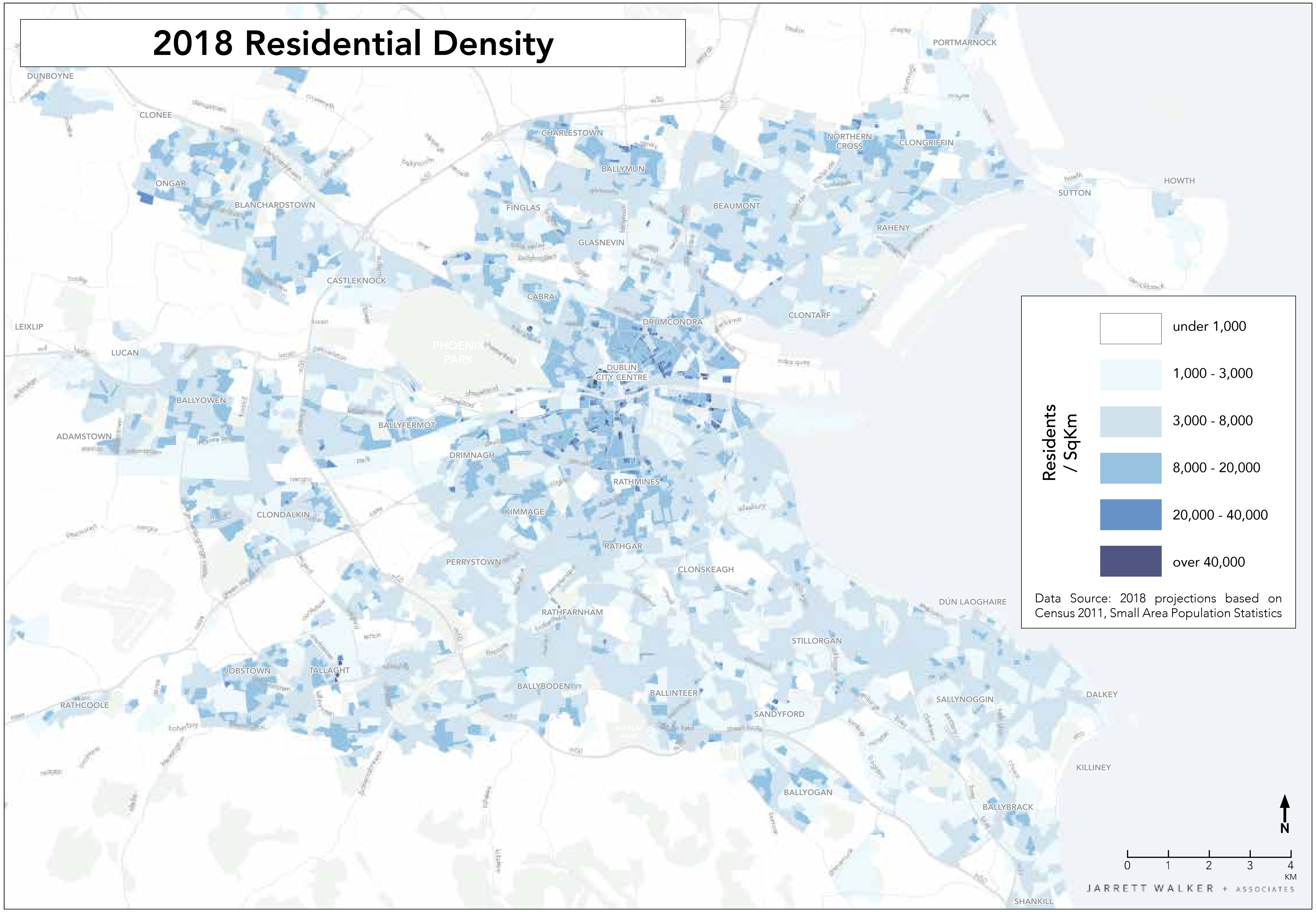
Residential Population Density

As we observed on page 13 above, density determines how many people or jobs are within walking distance of any public transport stop. As a result, density is the most critical first-order measure of the size of the potential market.

The adjacent map of residential population density shows the number of people per square kilometre residing in different parts of Dublin. It is based on the Census Small Area data, projected to expected population in 2018. All other things being equal, the higher the number, the higher the likely demand for public transport.

Note that maps such as this one are sometimes distorted by the shapes and patterns of zones used in the Census Small Area data. For example, if a dense area happens to share a zone with a low-density or empty area, the high-density area may not appear because we see only the average area of the entire zone. This is an important caution for viewing all of these demographic maps.

Figure 22: Residential population density in Dublin, projected for 2018. Residential density is a primary indicator of public transport demand.



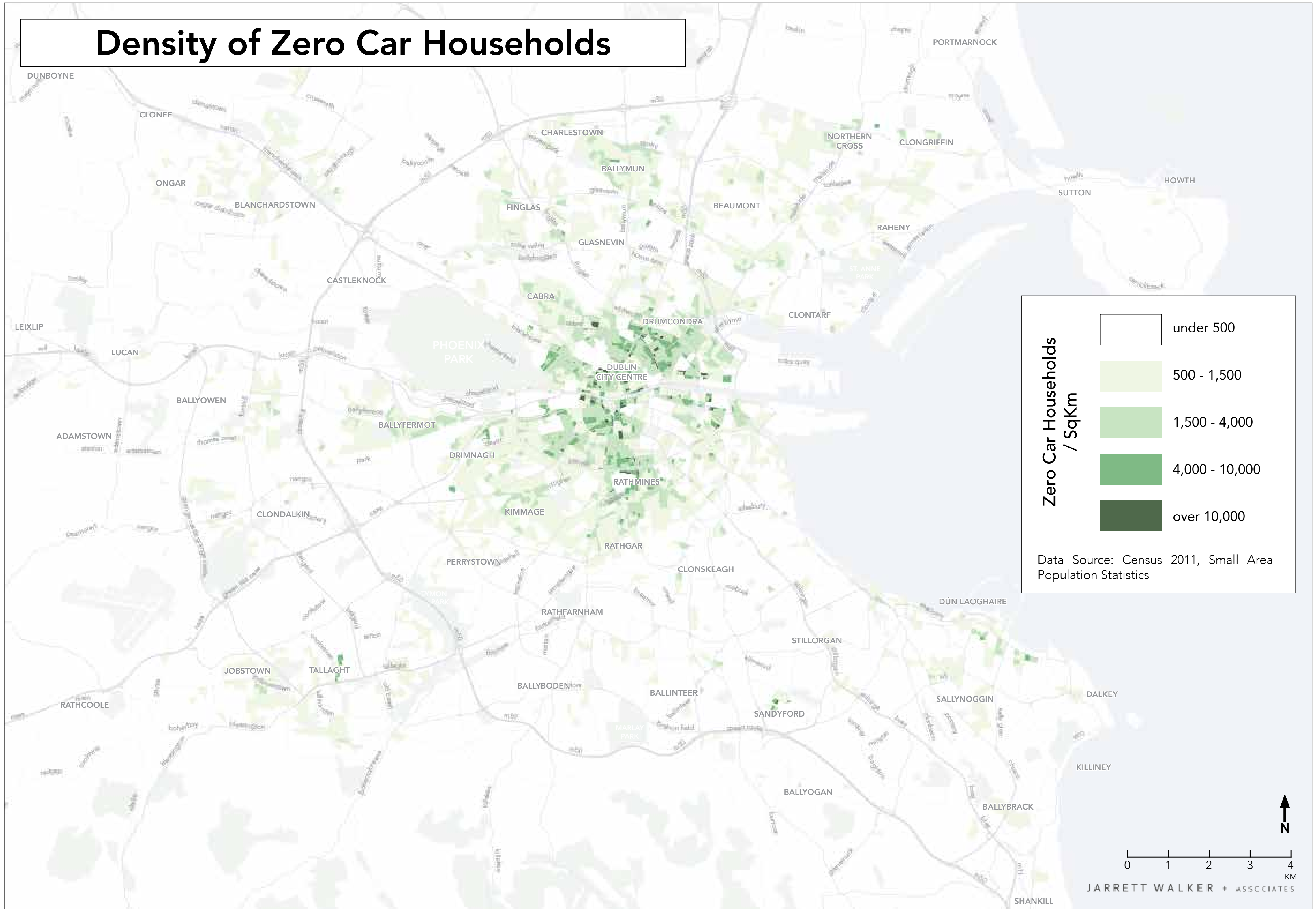
Density of Households with No Vehicles

People with less access to a private car are less likely to rely on a private car for their daily travels, and more likely to rely on public transport.

This is true of anyone living in a household with fewer vehicles than adults, but even more so in households that own no vehicles at all.

The adjacent map shows the density of those with the least access to a car. Although there is clearly a higher concentration of such households in and near the City Centre, certain suburban areas also figure prominently such as Ballymun, Finglas, Ballyfermot, and parts of Tallaght and Dun Laoghaire.

Figure 23: Density of households without a car in 2011. This is also a strong indicator of public transport demand.



Household Deprivation Index

The adjacent map shows a measure of average level of poverty in different parts of Dublin.

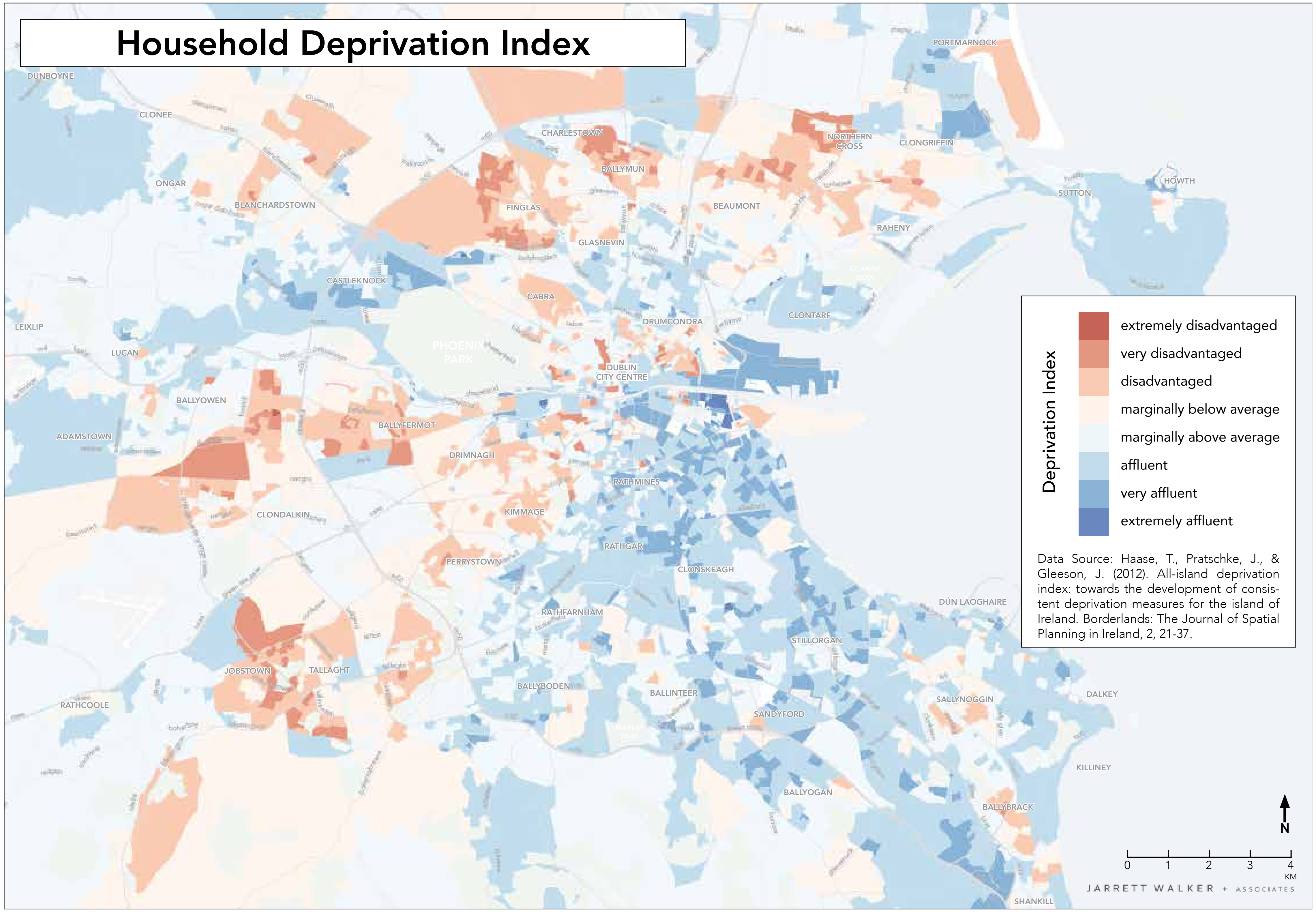
Unlike the other maps in this chapter, this data is available to us as a rate, rather than a density. Zones that show up here as having high poverty may have few people, so the effect may be exaggerated.

Poverty is at best a marginal indicator of public transport demand in Dublin, with significantly less power to predict patronage than other factors presented in this report.

This map also dispels the notion that poverty is the only reason not to own a car. Zero-vehicle households correlate with deprivation in many outer areas but not in the City Centre or in other dense, walkable places such as Dun Laoghaire's town centre.

- In areas that are less geometrically favourable to public transport (in terms of density, walkability, linearity or proximity) zero-vehicle households are explained mostly by deprivation.
- In areas that are more geometrically favourable (which tend also to be places where many of life's needs are in walking or cycling distance) it is relatively easy to have a rich life without owning a car, and people of diverse incomes choose to do so. These people become public transport customers regardless of income.

Figure 24: Map of household deprivation, based on an index of Census measures. This is not a strong indicator of public transport demand in Dublin.



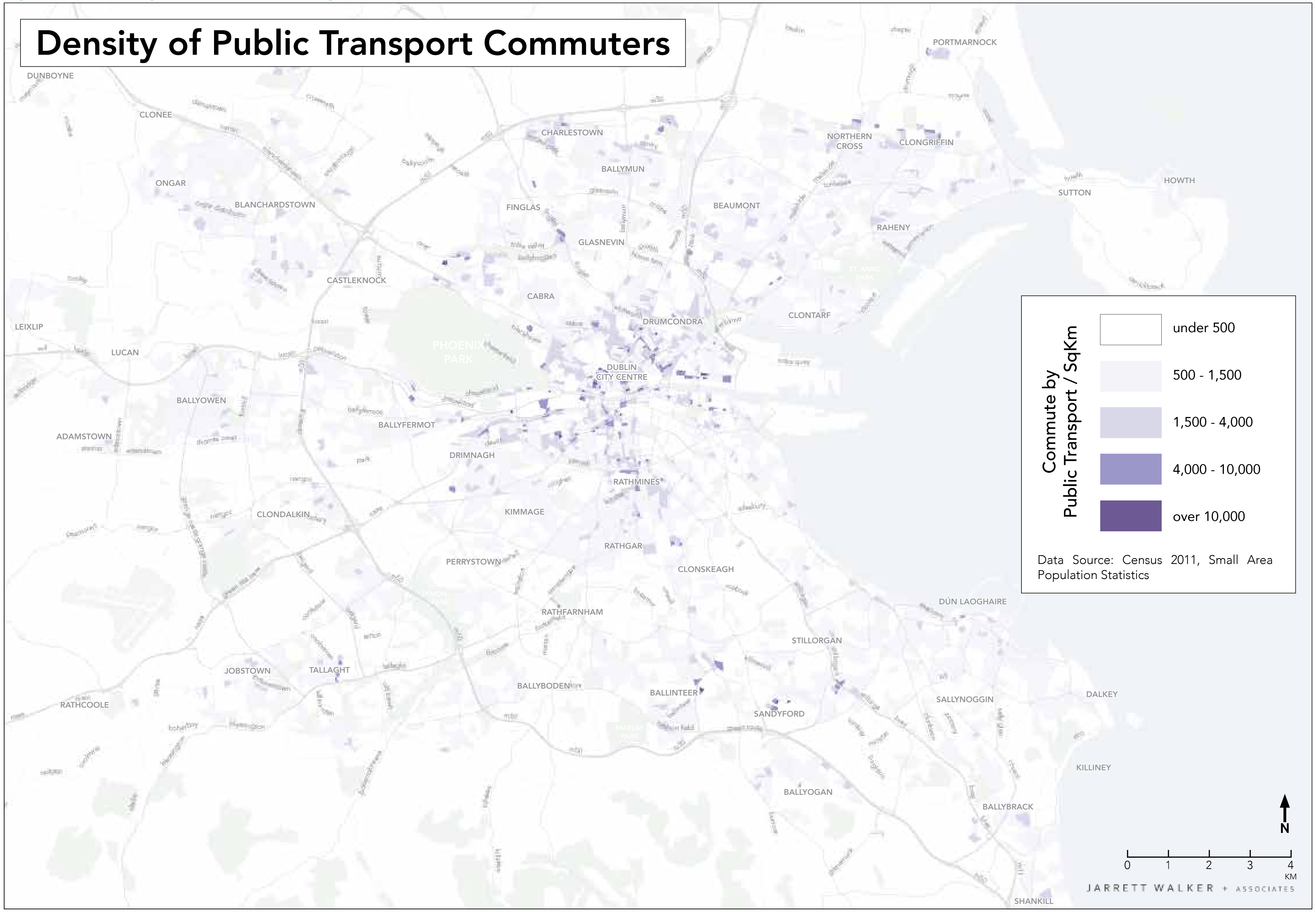
Density of Public Transport Commuters

This map shows the density of persons who indicated that they commute to work by public transport in response to Census 2011.

Although existing commute behaviour can be a good indicator, this data should not be construed as an absolute measurement of public transport use, for a variety of reasons:

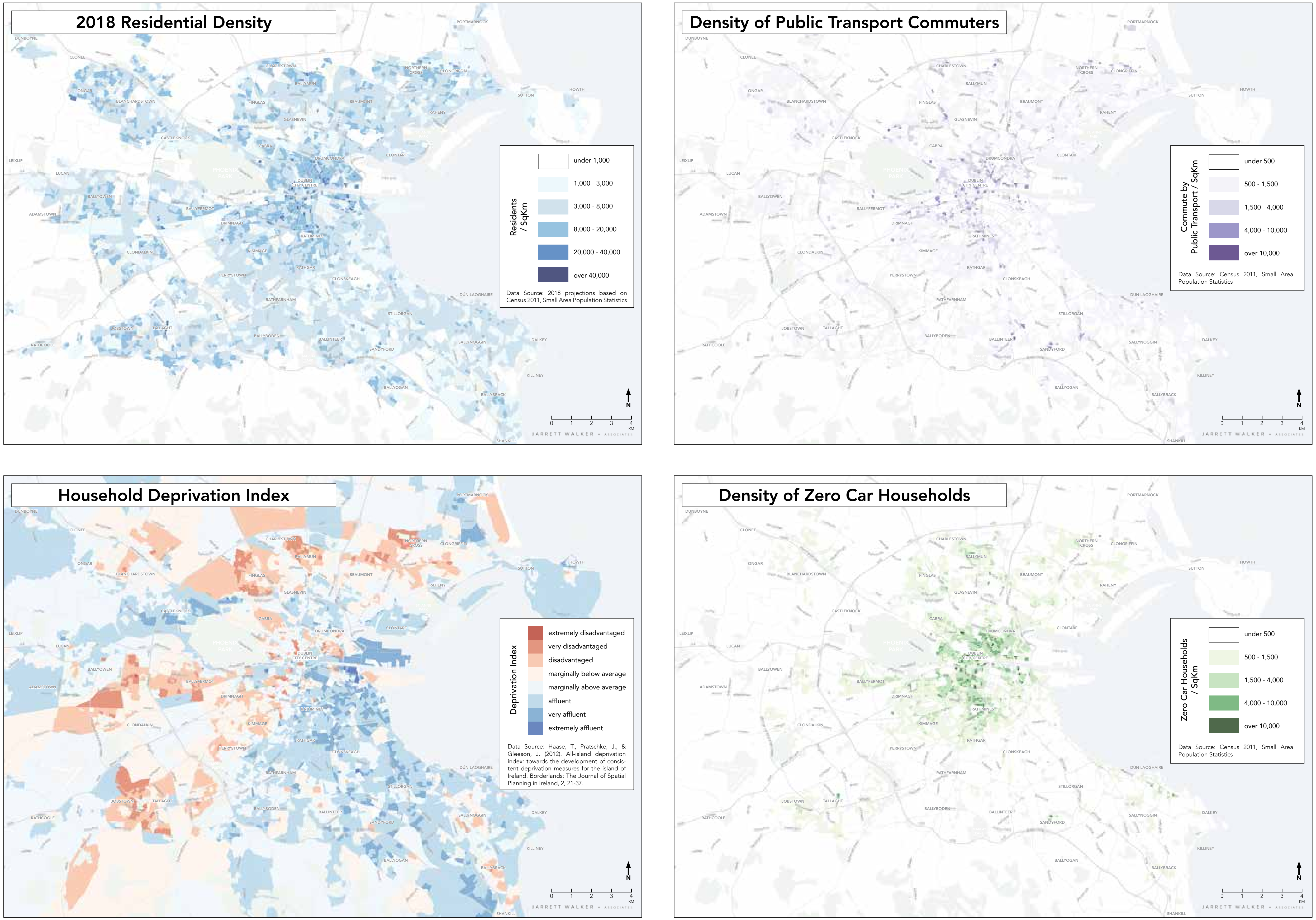
- This map shows only the home end of work commute trips: the commuters captured by this data are all headed to work somewhere else, and will also generate demand there.
- The journey to work is only one of the average person's daily trips, and not everyone takes this trip. Commute-related trips may be as few as 20% of total trips.
- Many people combine their commute with a variety of different purposes such as shopping, appointments, socializing, school, and many others. Public transport can be useful for all of these.
- Existing public transport riders are people for whom the existing network works well. There may be others for whom it could work if the network were different.
  - » For example, implementation of Network Direct changes in 2012-2013 may have opened new paths of travel not reflected in Census 2011 data.

Figure 25: Density of commuters using public transport in 2011



Where there are more people, there is higher demand – Part 1

Figure 26: Comparing the four maps presented shows us that sheer **residential density is the strongest indicator of the density of public transport commuters** in Dublin. In other words, how many people there are near a bus stop matters more than the details of their situations.



Identifying Regional Centres of Demand

Employment and Student Enrolment Density

The measures we have examined so far focus exclusively on the location of people's residences.

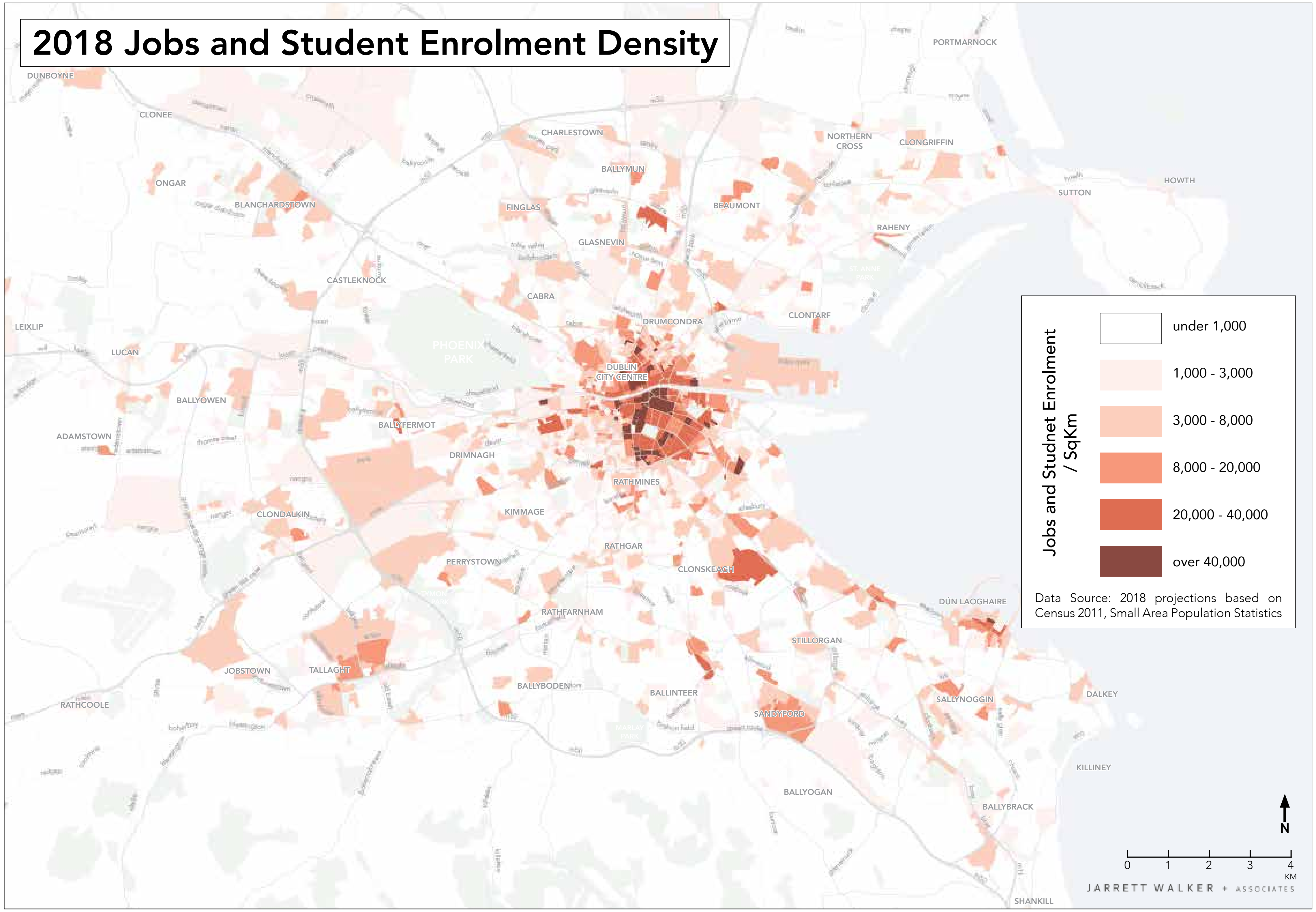
From a transport perspective, this means we have only examined the beginning and end of everyone's day. To understand what is happening in the middle of the day, it is useful to map the density of jobs and student enrolment, as we have done in the map in Figure 27.

This map shows that locations of employment and student enrolment are much more geographically concentrated than people's residences.

The greatest concentration of employment by far is found in the City Centre. Nonetheless, there are strong suburban centres at Dun Laoghaire, Sandyford, Dundrum, Tallaght, and (beyond this map) at Dublin Airport and Swords.

Concentrations of students obviously identify the major universities throughout the Dublin area, but especially at Trinity College, University College Dublin, Dublin City University, and (beyond this map) at Maynooth University. Note that planned consolidation of Dublin University of Technology campuses at Grangegorman may not be fully reflected in these data.

Figure 27: Density of jobs and student enrolment, projected for 2018. This is also a primary indicator of public transport demand.



Combined Activity Density

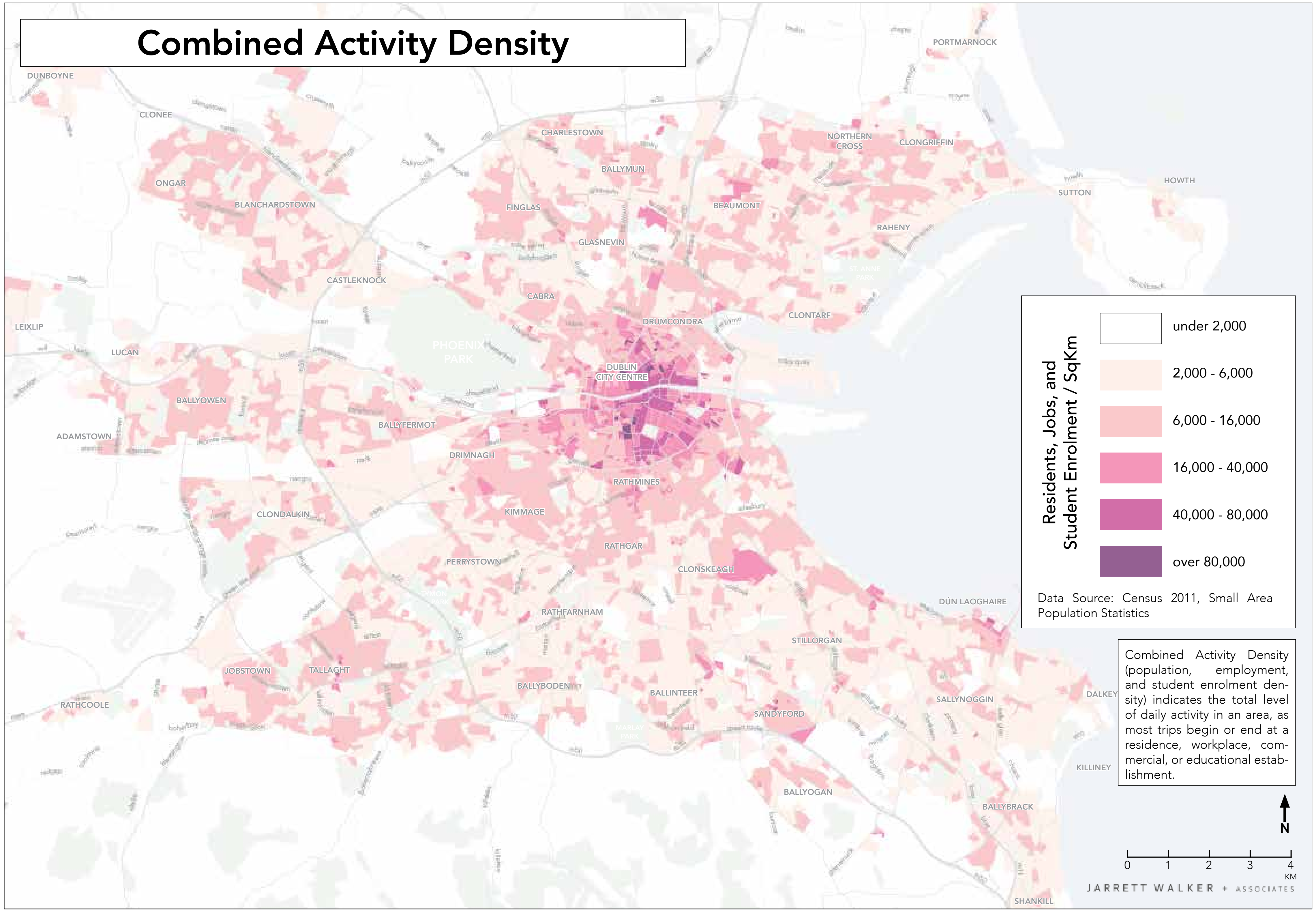
Figure 28 combines residential, employment, and student enrolment densities to approximate the total effect of all densities in forming the public transport market.

Because they are so much more concentrated than residences, centres of employment and student enrolment dominate this map.

Note that employment density is also a proxy for many other trips that a destination attracts. Retail jobs, for example, also imply customers.

However, while residential density is less prominent in this image, it remains a critical element of the best public transport markets.

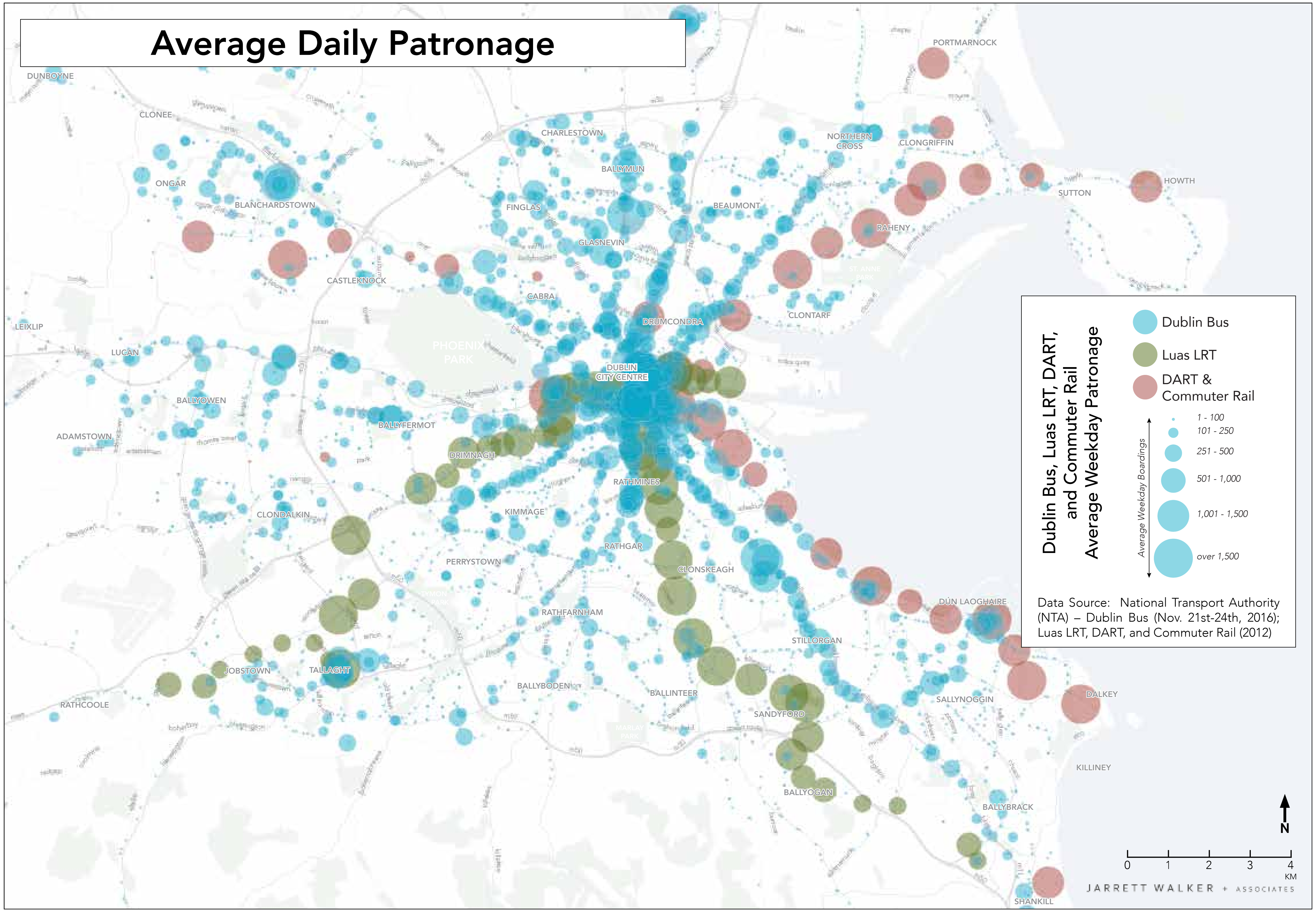
Figure 28: Activity density combines residents, jobs, and student enrolment for a more complete indicator of all-day public transport demand.



Observed Demand – Weekday Boardings on Public Transport

The adjacent map in Figure 29 shows observed average weekday patronage at every public transport stop in Dublin, including locations served by Dublin Bus, Luas, DART and Commuter Rail.

Figure 29: Map of average daily public transport boardings at bus, Luas, DART and Commuter Rail stops.



Observed Demand – Bus Patronage Heatmap

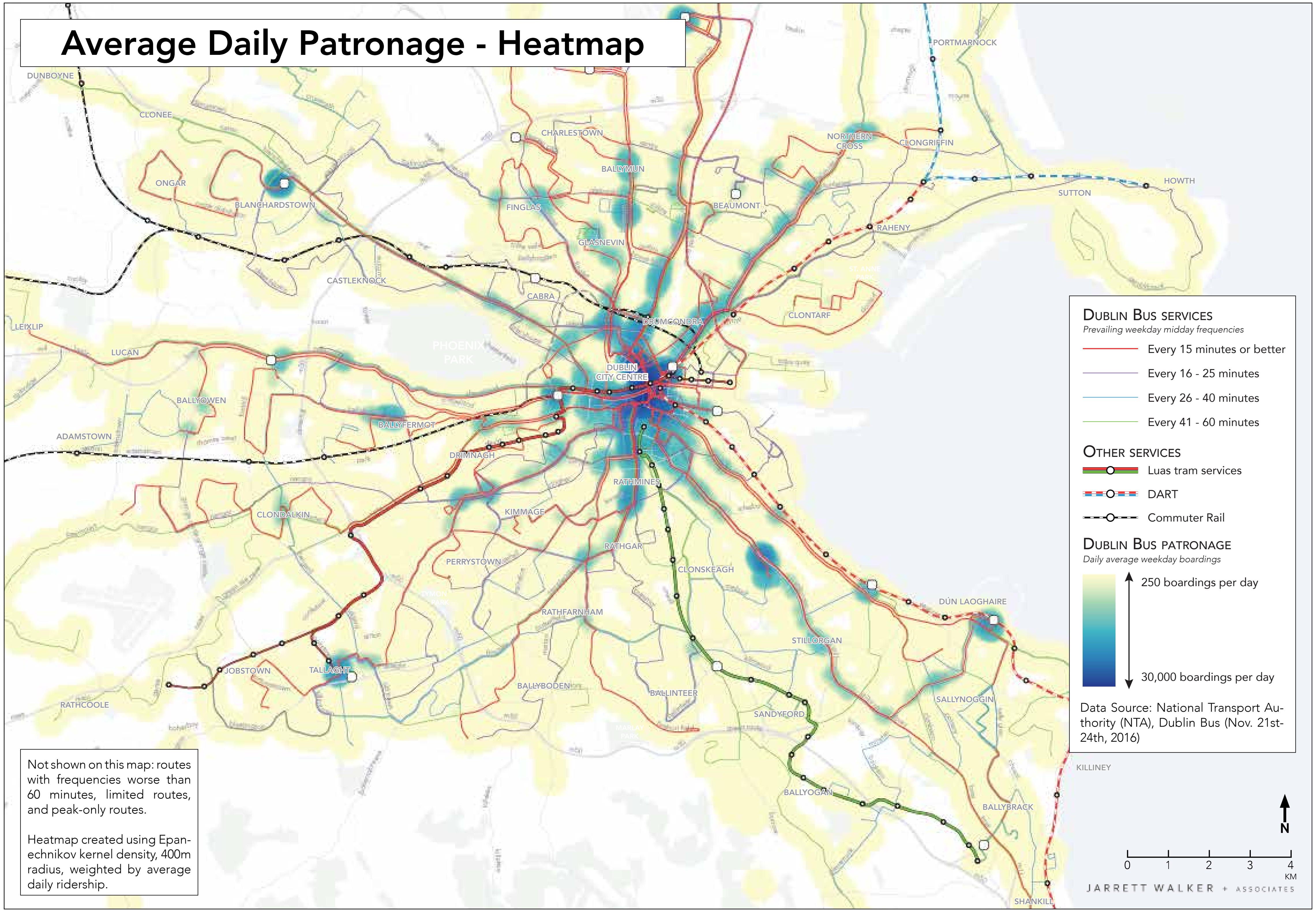
The previous image, showing bus boardings by exact location, is useful for detailed planning but not ideal for seeing a bigger picture.

To show the patterns of patronage more vividly, and remove distractions arising from the number and scale of stop-by-stop dots, we can show the same data as a heatmap, as in the adjacent map in Figure 30.

Heatmaps aggregate stop-level data by showing the number of boardings in each unit of area. As a result, the larger geographical patterns of patronage become clear. The heatmap also enables us to make a direct comparison between observed demand and combined activity density, as is done on the following page

This map also shows the lines of the existing bus network according to their typical frequencies in the middle of the day. The data show the extent to which existing patronage is driven both by frequency of service and density of demand.

Figure 30: Map comparing the density of bus boardings to the level of public transit service available.



Where there are more people, there is higher demand – Part 2

Comparing the activity density map to the bus boardings heatmap shows that the **patterns of observed demand for bus services are very close to the patterns of demand suggested by density.**

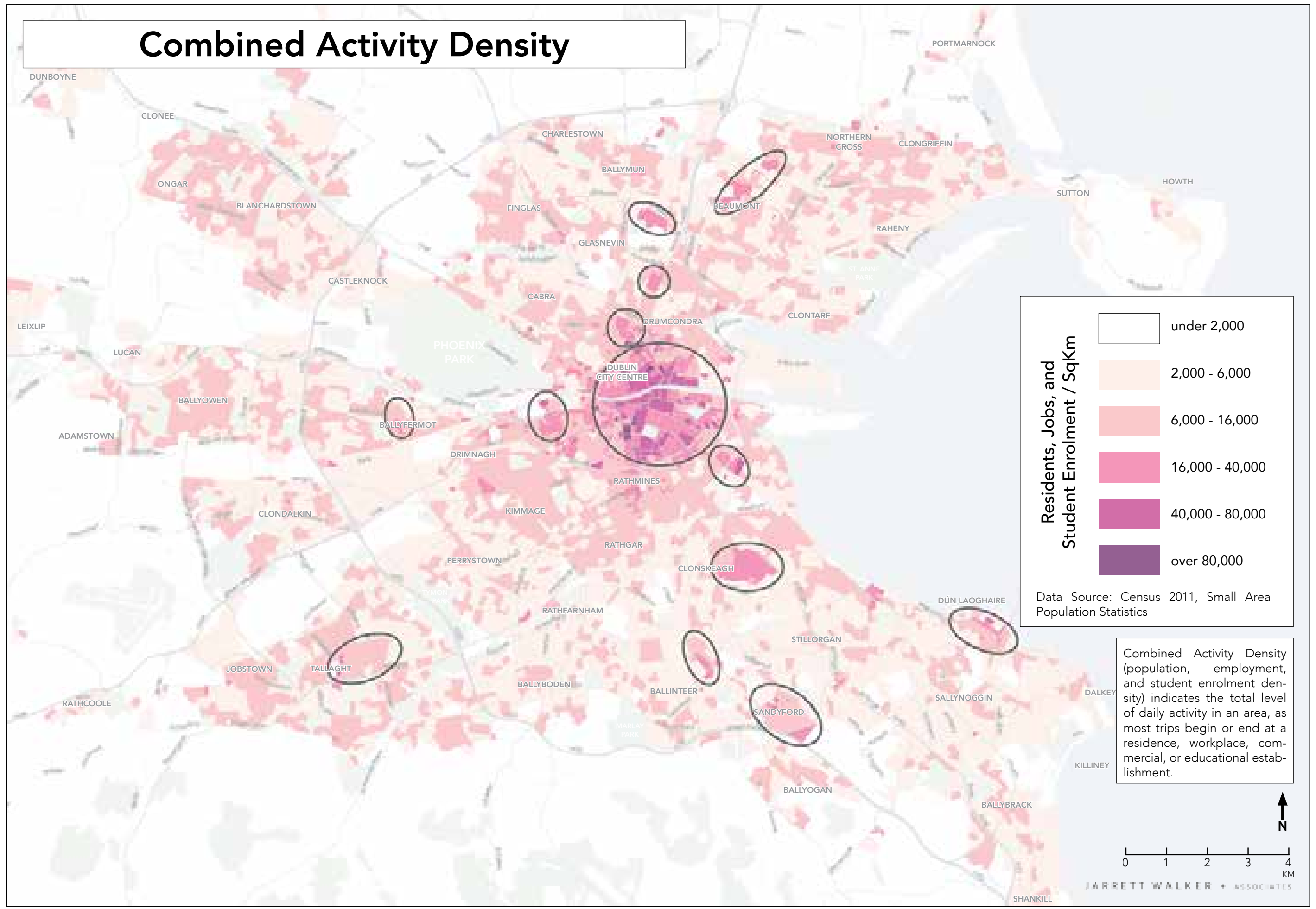
Note that the heatmap does not show patronage on the DART and Luas lines, where high frequency rail services provide the vast majority of existing public transport trips. This explains some apparent low patronage around those corridors, such as at Sandyford and Dundrum.

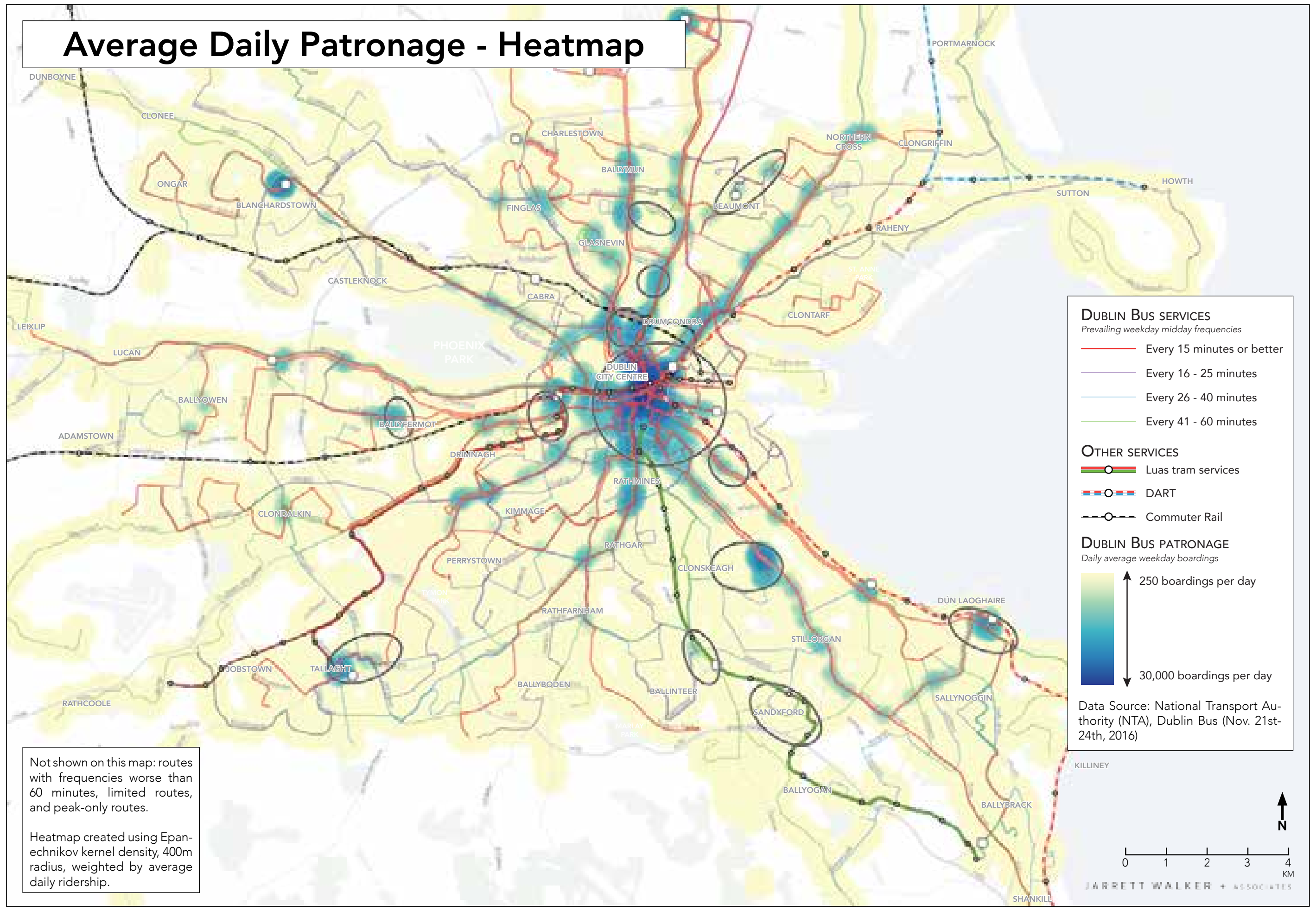
In general, though, the disparities between the two maps illustrate problems of linearity in the development pattern.

For example, Dublin City University's main campus generates patronage mostly 700m to the west on Ballymun Road. This reflects the fact that the campus faces onto an orbital road rather than a radial one, and the current service design does not emphasise frequent orbital service. As a result, the most frequent services, which are logically following linear radial corridors, skirt the far edges of the campus instead of passing the main gate.

Beaumont Hospital is a dramatic example of a major destination where public transport service is hampered by extremely poor linearity and proximity. Serving this location requires threading circuitous roads, and it is relatively isolated from other centres of demand. Because of these difficulties. As a result, Beaumont Hospital has only medium-frequency services, and patronage is lower than the site's very strong employment density would suggest.

Figure 31: The map on the left compares the expected centres of demand while the map on the right shows how the network attempts to meet that demand.





On weekdays, service is proportional to patronage

In Dublin, as in many cities, public transport patronage is strongest during the morning peak, when the school and work commutes occur simultaneously. Patronage then drops in the middle of the day, before rising again in mid-afternoon when schools let out.

The afternoon peak is less intense and longer than the morning peak, as people leave schools, universities and work at different times, and then spend the afternoon and evening embarking on multiple trips to socialize, complete various errands, and return home.

This pattern expresses itself very clearly in daily patronage on Dublin Bus, as is shown in Figure 33**.** Figure 34 and Figure 35 show that this pattern of peaking holds largely true on Luas and DART/Commuter Rail as well.

Although the pattern of peaks and troughs in demand throughout the day is not unique to Dublin, the intensity of both the morning and evening peaks is notable. Figure 32 shows us that existing Dublin Bus services ramp up considerably during these peaks to meet demand. Because peak-only service is expensive to provide, the service peak does not fully match the boardings peak.

Figure 32: Bus service responds to the morning and afternoon patronage peaks with extra service.

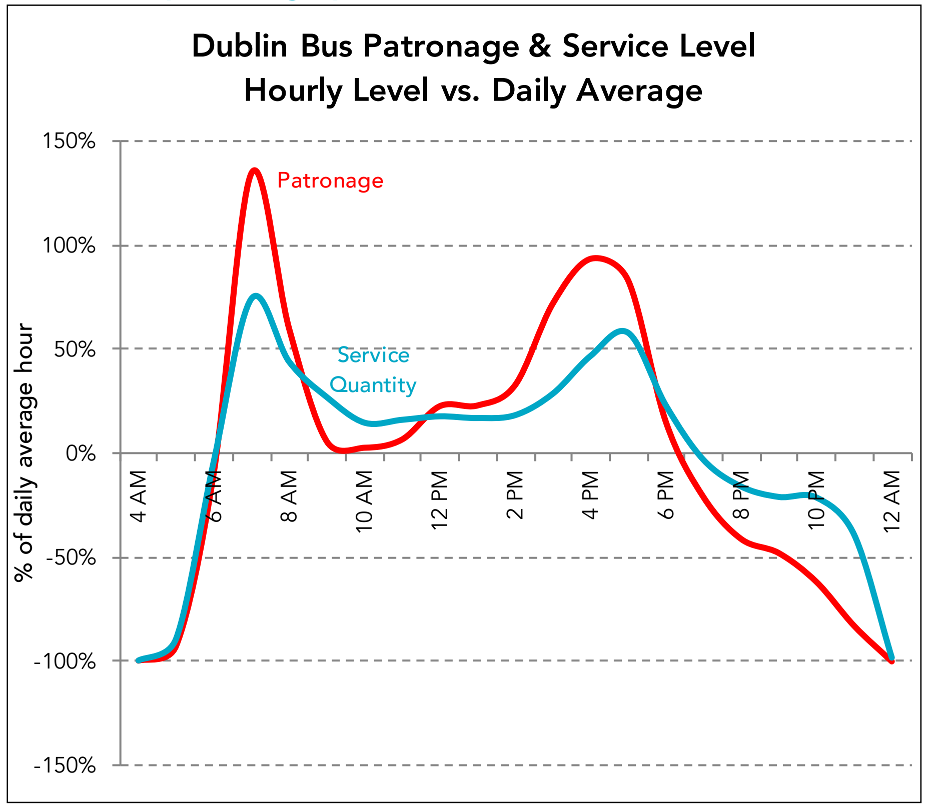


Figure 33: Daily patronage by hour for Dublin Bus

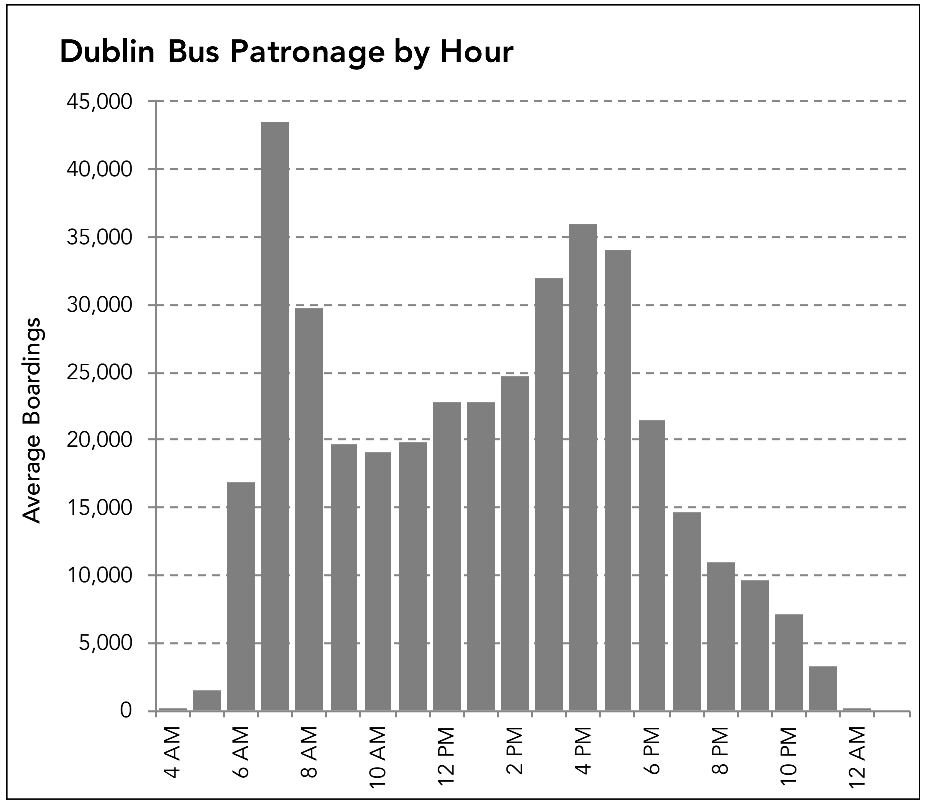


Figure 34: Daily patronage by hour for the Luas lines

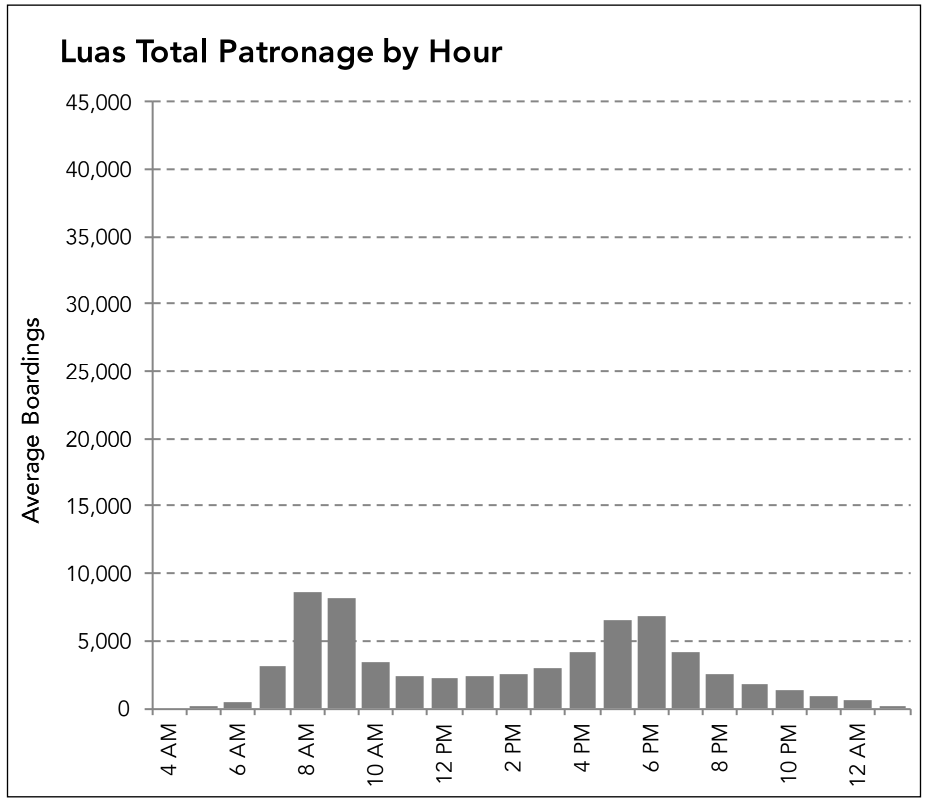
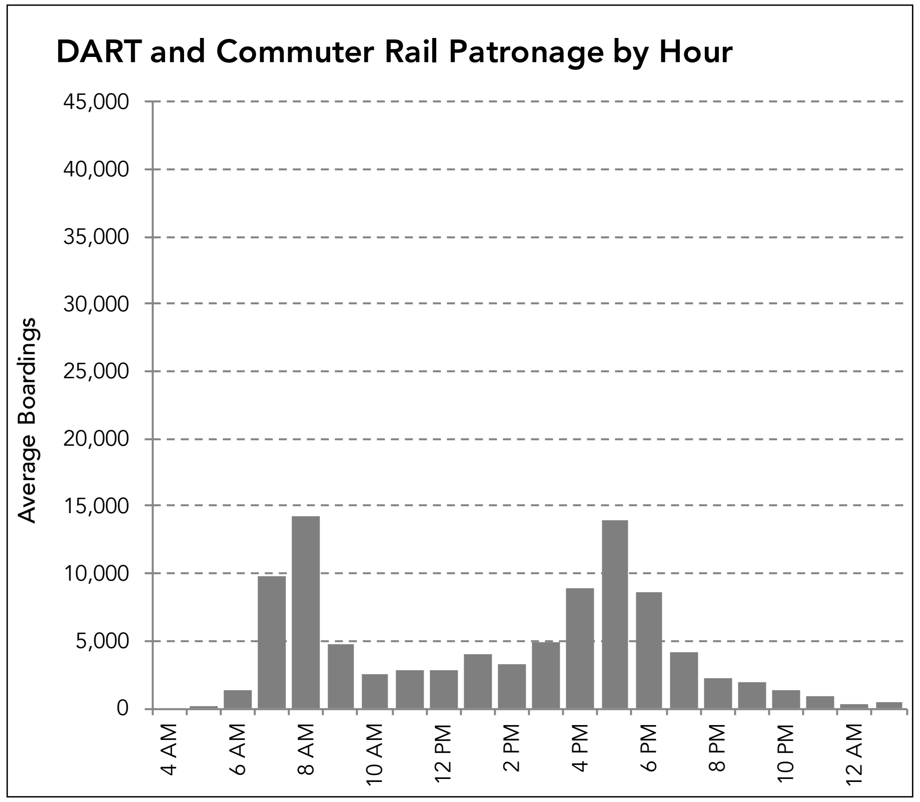


Figure 35: Daily patronage by hour for DART/commuter rail



On weekends, patronage may be suppressed by low service

In the existing bus network, weekday patronage is higher than Saturday patronage, which is much higher than Sunday patronage.

On the surface, this could appear to be lower demand reflected in lower service quantity. Dublin Bus runs approximately 11,000 vehicle hours on weekdays, but only 7,400 vehicle hours on Saturdays, and 4,500 vehicle hours on Sundays.

However, higher levels of service typically generate higher productivity in terms of boardings per hour. In this case, **system productivity is similar on Saturdays and on Sundays as it is on weekdays, despite much lower levels of service.** Some lines even have distinctly higher productivity on weekends.

While this is not decisive, this finding is consistent with there being some suppressed demand on weekends. Over recent decades, the level of activity on weekends has increased considerably, so there may be vestiges of out of date assumptions about weekends in the existing service.

Figure 36: Chart showing patronage by day of week

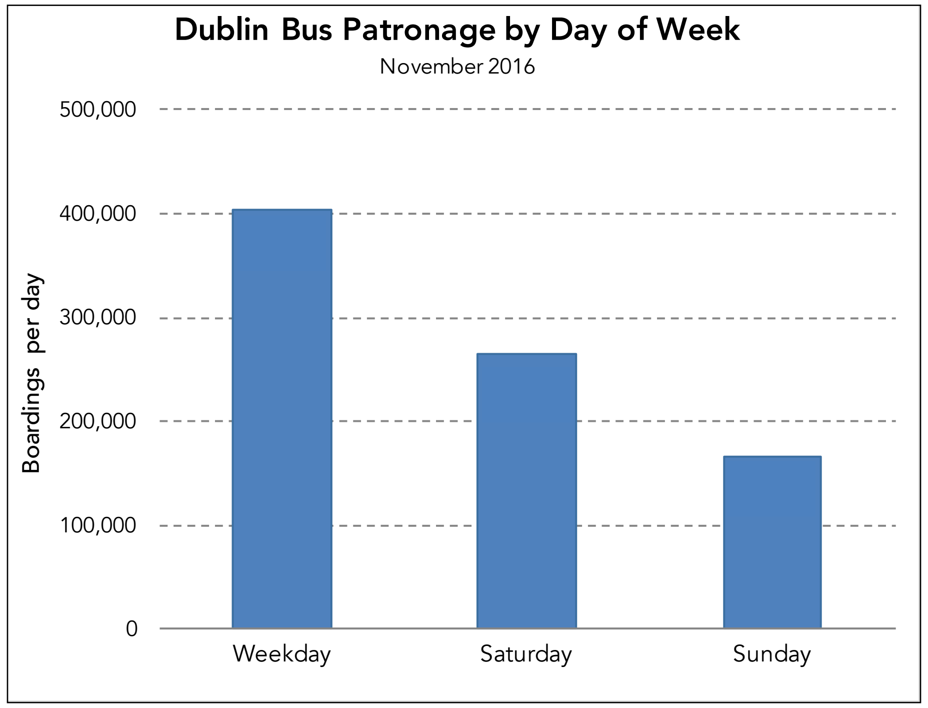


Figure 37: Chart comparing productivity by day of week

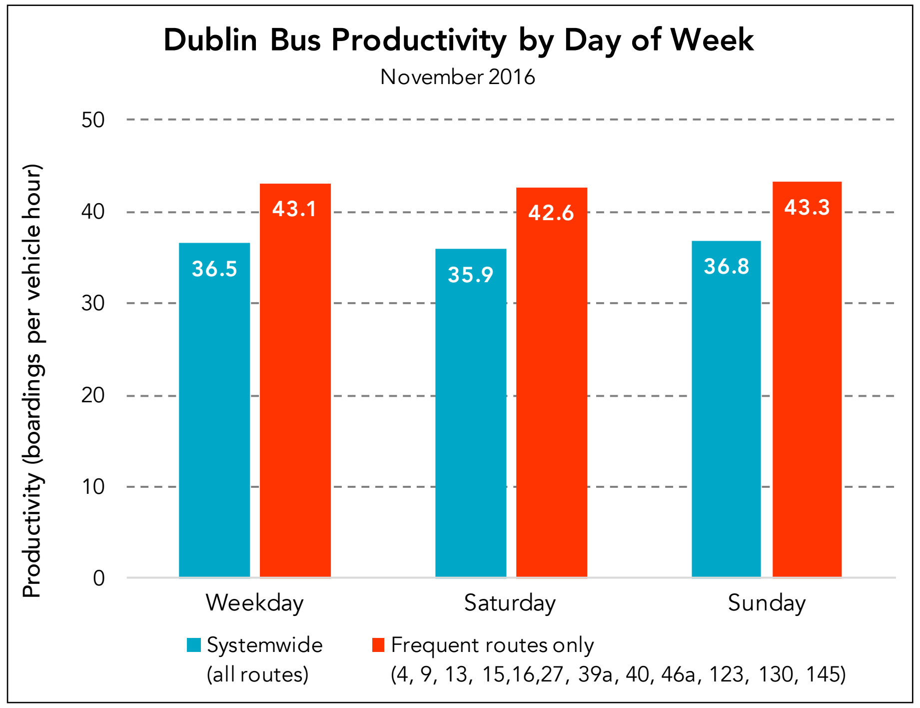
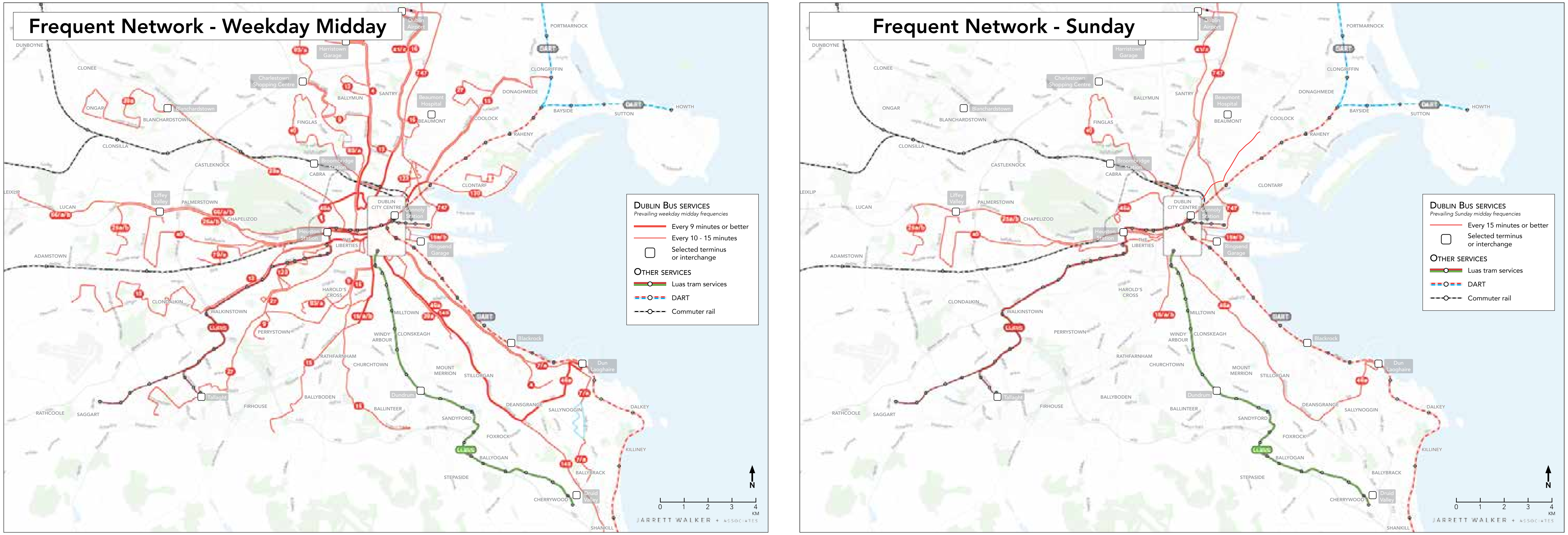


Figure 38: These maps compare frequent service (every 15 minute or better) on the weekdays vs. Sundays. The smaller number of frequent routes on Sunday is a reflection of lower service.



4 Structure of the Existing Bus Network

Underlying Conditions – Regional Transport Infrastructure

An effective public transport network requires both service and infrastructure. The Bus Network Redesign is focused on service, and will propose service changes mostly in the context of existing infrastructure. It is therefore useful to understand the general state of the infrastructure underlying the bus network today.

The underlying infrastructure is mostly strong, with known gaps and plans for improvement.

In Dublin, buses rely entirely on roads for rights-of-way. There are no roads fully reserved for public transport. This may change in future, with the continued improvements on Core Radial and Core Orbital corridors, and the introduction of Bus Rapid Transit on the highest patronage lines in line with the BusConnects project.

Nonetheless, even today, a combination of measures taken by the National Transport Authority and the City and County Councils have resulted in a regional network of bus lanes and shared bus/bike lanes. Although the network of bus lanes network still has many gaps and interruptions, there are bus lanes in every major radial corridor and on some orbital roads as well. This is visible in the map in Figure 39.

It is worth noting that some outer orbital roads have bus lanes but not much bus service; this is not a problem, as these lanes help create the conditions for effective orbital services in the future.

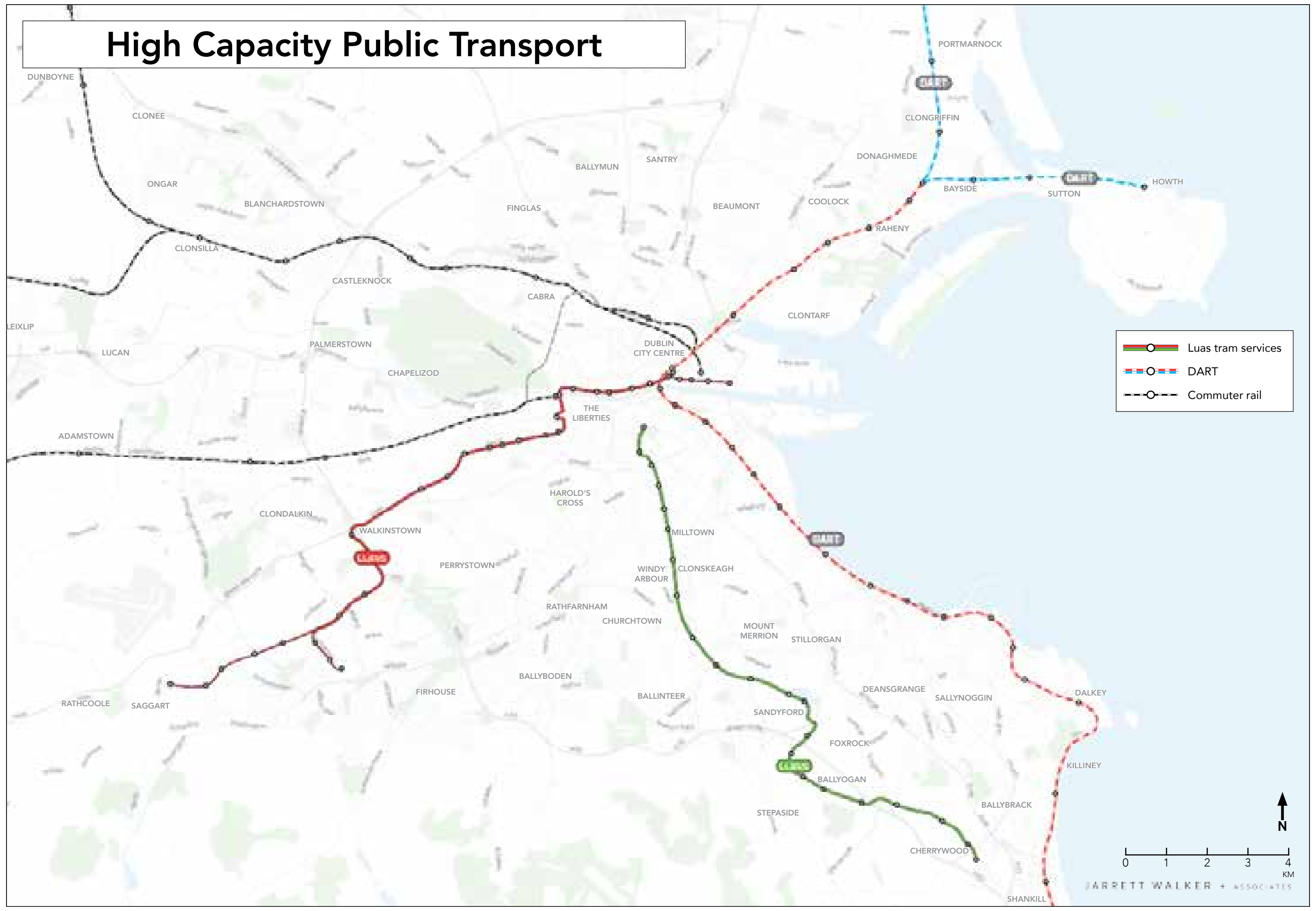
One issue potentially impacting the effectiveness of bus lanes is the number of vehicles that are allowed to use them. For example, in Dublin, taxis are allowed to use most bus lanes. This is not necessarily a problem in outlying areas, but may exacerbate speed and reliability problems in central areas where many bus lines converge (see Figure 41 on page 33).

In addition, the bus network is mutually supportive with the regional network of high-capacity all-day rail lines, in particular Luas and DART. The service on these rail lines relieves pressure in some of the highest-demand corridors, and in the City Centre.

At the moment, the most pressing gap in the rail system is the termination of the Luas Green Line at St. Stephen's Green, before it would connect with the Red Line, DART or regional rail. This problem is being addressed by the Luas Cross City project (see page 7).

Figure 39: Map of bus lanes

Figure 40: Map of existing high capacity public transport - Luas, DART, and commuter rail



The network is comprehensive, but highly radial

Service extends throughout Dublin Metropolitan Area

As can be seen by the series of maps below, existing PSO bus service reaches into all developed parts of the Dublin Metropolitan Area. Beyond the extent shown, several other bus lines extend its reach further into Fingal, as well as Counties Wicklow, Kildare and Meath.

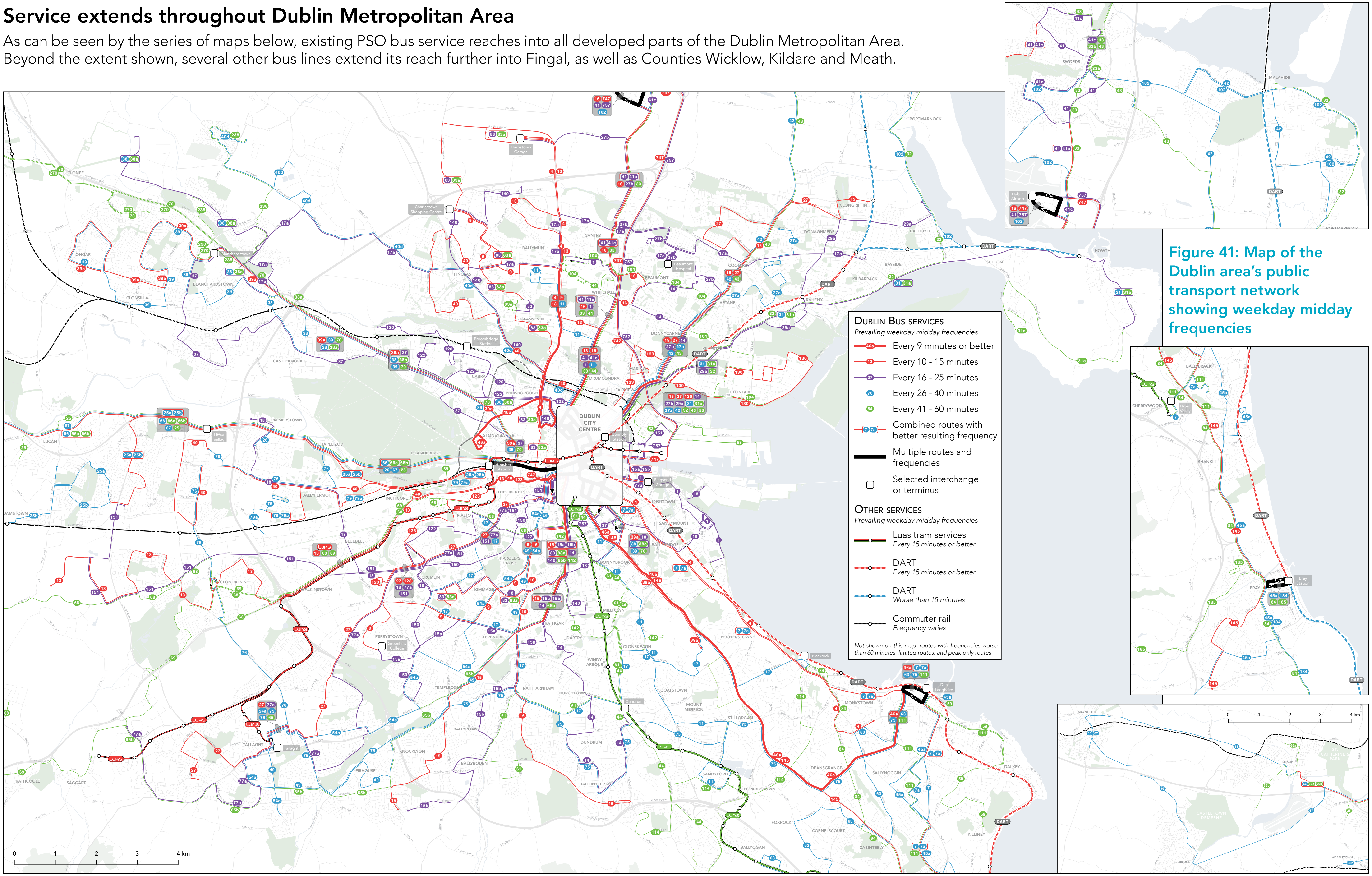


Figure 41: Map of the Dublin area's public transport network showing weekday midday frequencies

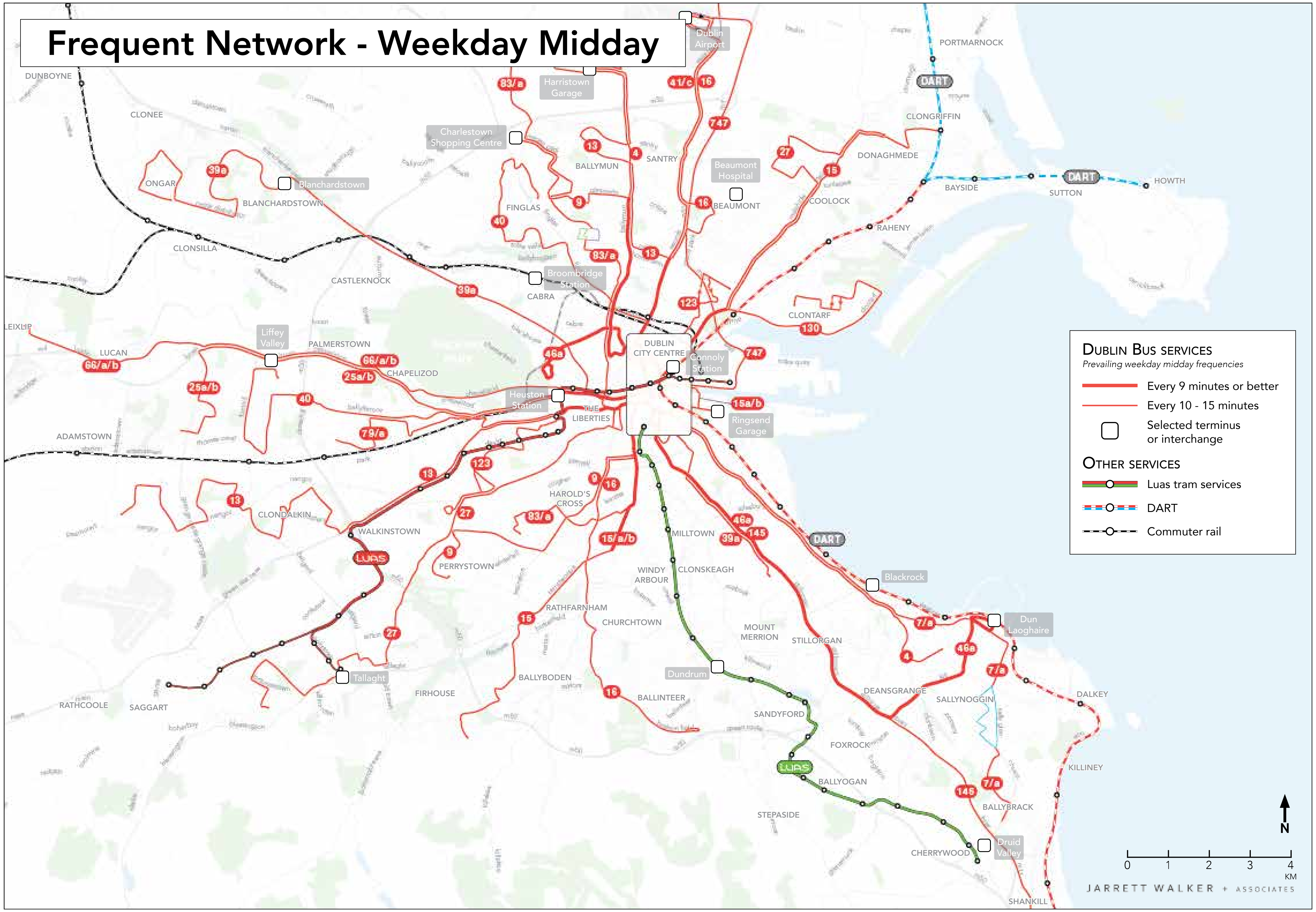
The frequent bus network is entirely radial

The adjacent map shows the extent of Dublin Bus lines that provide all-day service every 15 minutes or less on weekdays. Every single line meeting this standard is radial, i.e. it connects outlying areas to the City Centre.

Many of these are Cross City lines, which connect different suburban locations by traversing the City Centre. Cross City lines were significantly expanded by the Network Direct effort, and have significantly improved suburb-to-suburb connections between areas on different sides of the River Liffey.

Nonetheless, this pattern means that if you want to travel orbitally between outer centres on the same side of the city – Tallaght to Dundrum, for example – the only frequent way to travel is to go into the City Centre and back. As the outer centres grow, the absence of high-frequency orbital service will become an increasing barrier to public transport's ability to serve those places.

Figure 42: Map of the frequent network (routes that operate every 15 mnutes or better) during weekdays at midday



Orbital bus lines are few and infrequent

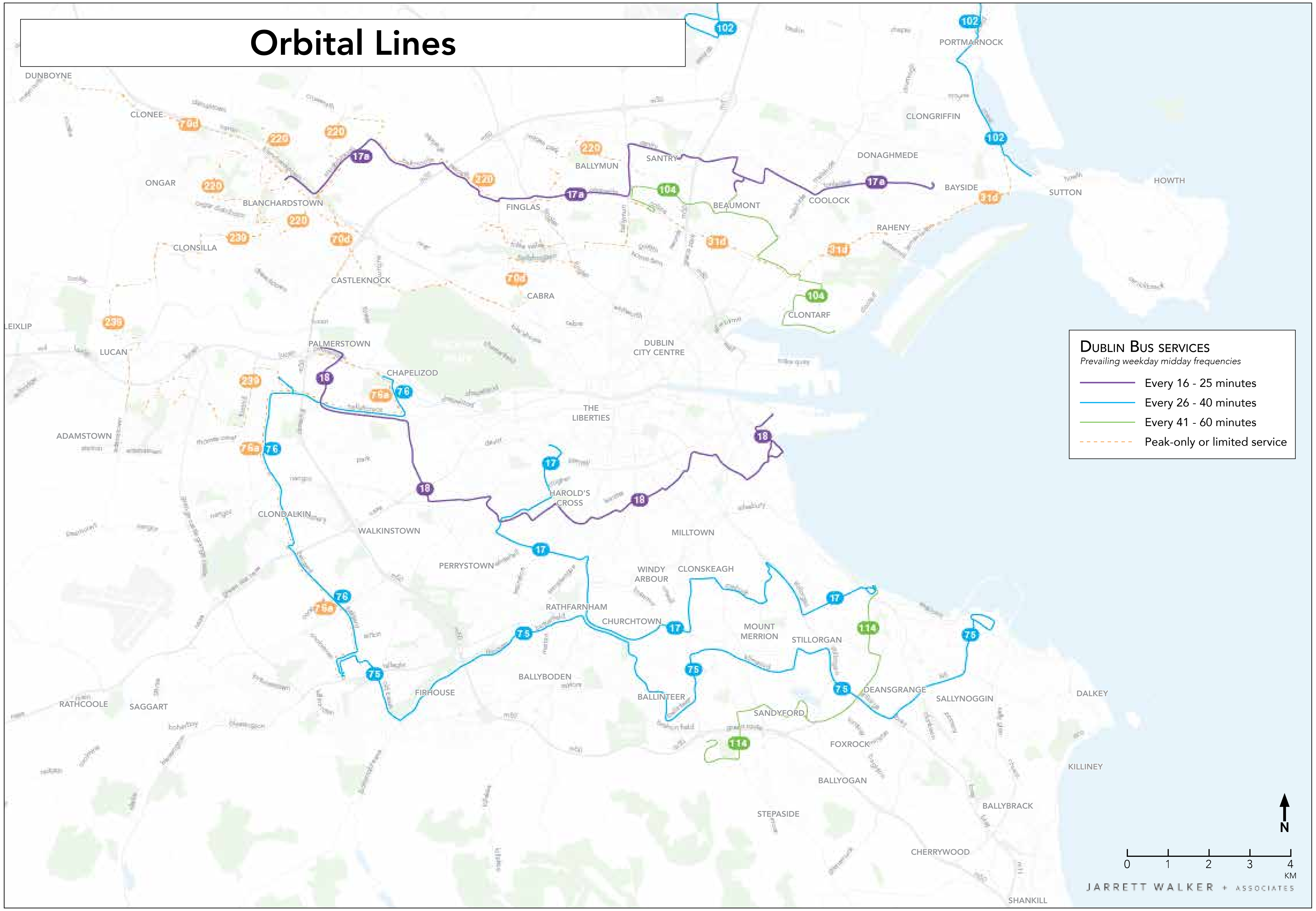
Radial networks like Dublin's tend to develop in cities with strong centres. They are also a natural consequence of the outward growth of cities. When cities grow outward, the tendency is to extend the existing transport network to newly developed areas.

Radial networks tend to have weak orbital service, which is service that connects outlying or suburban areas to each other, bypassing the City Centre.

As shown in the adjacent maps, this is also the case in Dublin, where there are relatively few orbital bus lines, and none of them are frequent outside the peak commute period.

We are not the first to observe this. NTA has already undertaken studies of frequent orbital services, whose ideas will be incorporated into the current study's recommendations.

Figure 43: Map of existing orbital lines in Dublin's bus network.



The radial network was highly efficient, up to a point

A radial network, with the possibility of passenger interchange in the Centre, can be a very efficient way to distribute trips throughout a city. This is because:

- Radial lines generally follow the most concentrated paths of demand (suburb to City via suburban centres).
- When all lines meet in one central area, a passenger can travel from any point A to any point B with a single interchange.

This is most true in small and mid-size cities, and was true for most of Dublin's history. However, when an urban area expands beyond a certain size, radial networks start encountering a variety of issues:

- Radial lines get more distant from each other as they get farther from the City Centre. In large cities like Dublin, this means that frequent bus lines are spaced too far apart to serve the middle of outer neighbourhoods.
- As new suburban centres develop, passengers on suburb-to-suburb trips must travel further and further out of direction through the City Centre.
- The radial network of streets and roads that characterizes the city may not reach the farthest suburbs. Where the street network itself is not radial, it is hard to create and maintain efficient radial bus lines.

Two notable but problematic patterns of bus routing have arisen in the face of these issues: Orbital Compensation and Radial Distortion.

Orbital Compensation

Orbital compensation is an awkward process of trying to use radial bus lines to serve places where the street pattern is more orbital than radial. There are many examples in Dublin, but here are two:

- In **Beaumont**, lines 14 and 16 deviate through the middle of the neighborhood, ensuring residents access to both Swords Road and Malahide Road. This makes both routes somewhat circuitous for traveling to points further out. (While Line 14 ends just beyond Beaumont, Line 16 proceeds all the way to the airport.)

- Multiple radial lines weave on and off of **Ballymun Road** to provide orbital access to Balbutcher Lane (line 13), Finglas (line 9) and Drumcondra Road (lines 11 and 13).

  Because service is spread out among multiple orbital movements, the frequency of the radial mainline service on Ballymun Road (line 4) is limited to a bus every 15 minutes on weekdays, when the corridor as a whole might support service every 5 minutes.

In each case, frequent orbital services, running east-west in these images, would not need to twist and turn as much as radials must do to serve the same areas.

Figure 45: Lines 14 and 16 near Beaumont

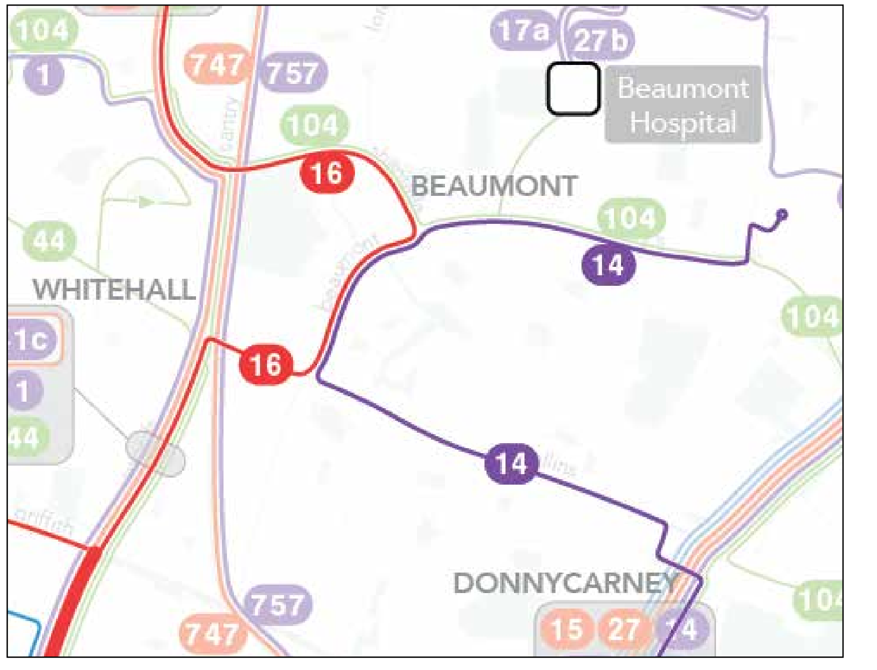
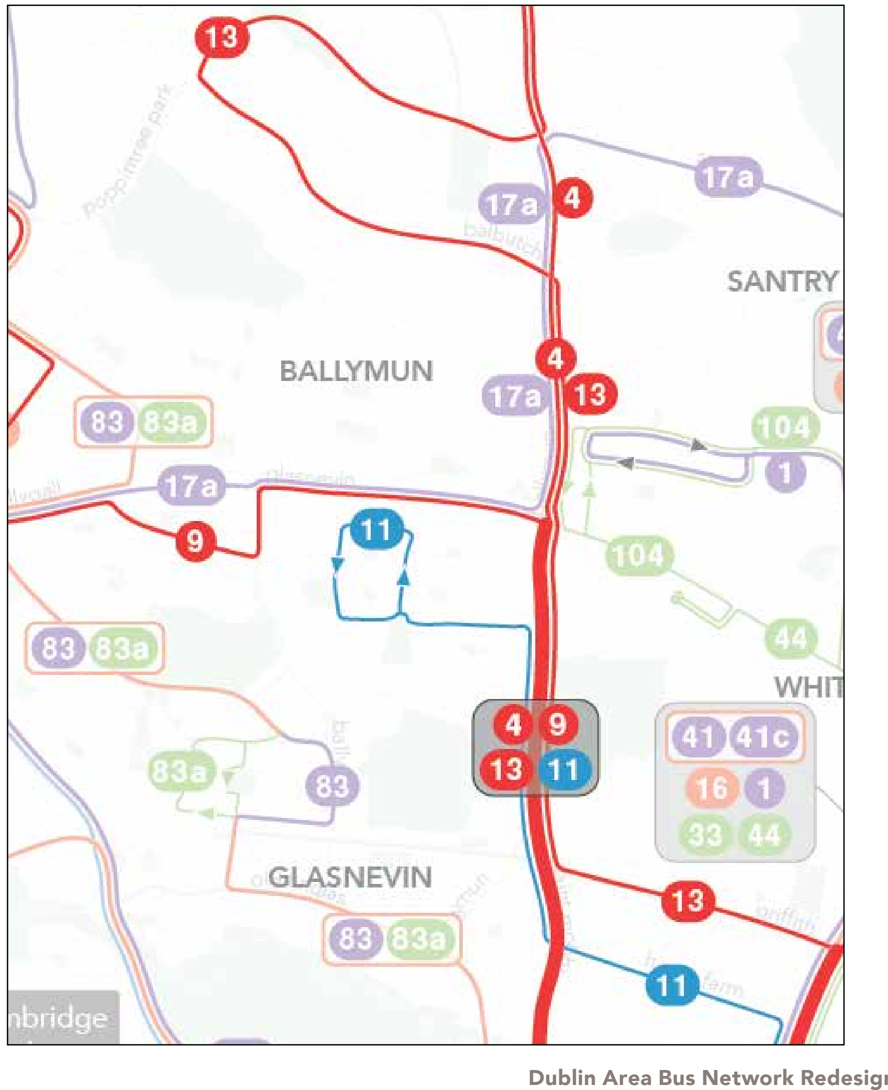


Figure 44: Lines 9, 11, and 13 near Ballymun Road



Radial Distortion

In most areas inside the M50, the arterial road network in Dublin is oriented to draw traffic into and out of the City Centre. This road network structure works well with the radial bus network structure.

In outer suburban areas, the street network operates differently, drawing traffic out of suburban neighbourhoods and onto motorways that eventually feed into the M50.

As a result, there are very few bus-operable roads connecting neighborhoods. In some cases, there are direct obstructions to traffic from one neighborhood to another.

This is a massive problem of linearity, as Chapter 2 defined the term. In addition, it is also in some cases an issue of permeability, in cases where the road network is specifically designed to avoid connecting adjacent neighborhoods to each other, preferring to connect them only to the nearest freeway feeder.

All this means the road network works against a radial bus network, because it forces radial lines to find circuitous paths to capture patronage. Circuitous paths make for longer travel, which reduces the demand for public transport relative to other modes.

One approach to this problem is to focus more on connecting these areas to major suburban centres, in a local feeder pattern, and then connect those centres to the city. Chapter 5 reviews this possibility.

Some examples of this phenomenon in Dublin are the following:

- **Blanchardstown: Lines 39 and 39a** travel from Ongar through most of the length of Blanchardstown in highly circuitous patterns, largely because the most direct paths between neighborhoods are blocked to vehicle traffic.

- **Clondalkin:** Frequent **Line 13** takes a highly circuitous path through the highest demand areas, causing major delay to passengers further out. The less frequent Line 151 has a direct radial path, but there is much less demand along this path, so it cannot support such a high frequency.

- **Lucan/Ballyowen: Lines 25a/b** deviate and split to reach all the areas in the vicinity of Grange Castle Road.

- **Liffey Valley:** As **Line 40** approaches Liffey Valley Shopping Centre from the east, it actually turns away from it to ensure service to Neilstown Road and Foothill Road. This creates a frustrating journey to the shopping centre from the high-density areas just to the east, such as Ballyfermot.

Figure 46: Lines 39 and 39a through Blanchardstown

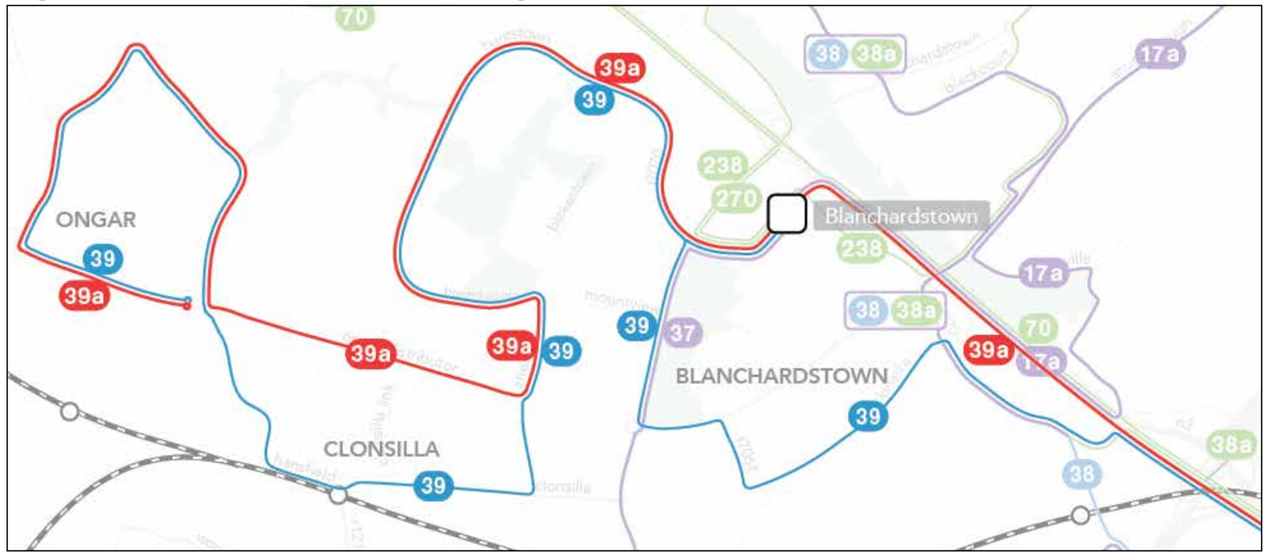


Figure 47: Line 13 near Clondalkin

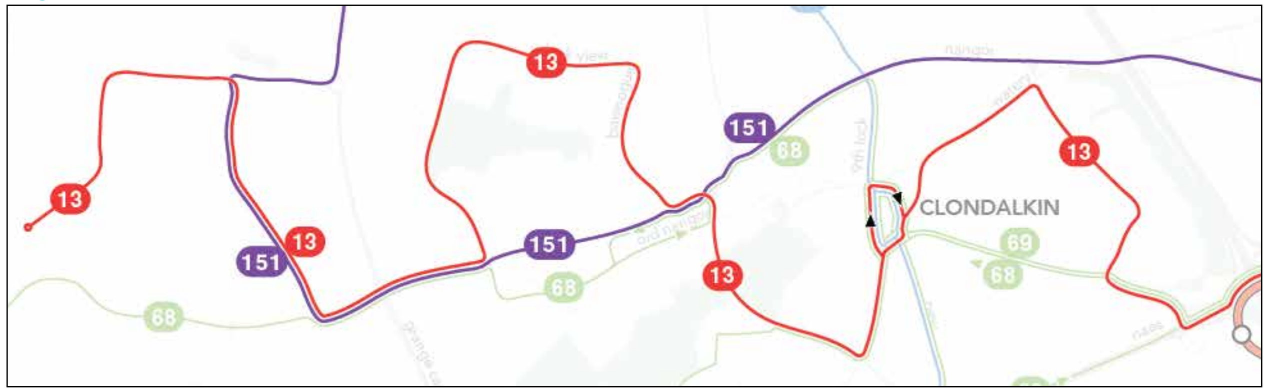


Figure 48: Lines 25a/b in Ballyowen; line 40 north of Liffey Valley

The radial network makes buses converge in the centre

The geographic pattern of bus volumes during the AM peak period is portrayed in Figure 49. A similar pattern prevails at other times, with less extreme contrasts.

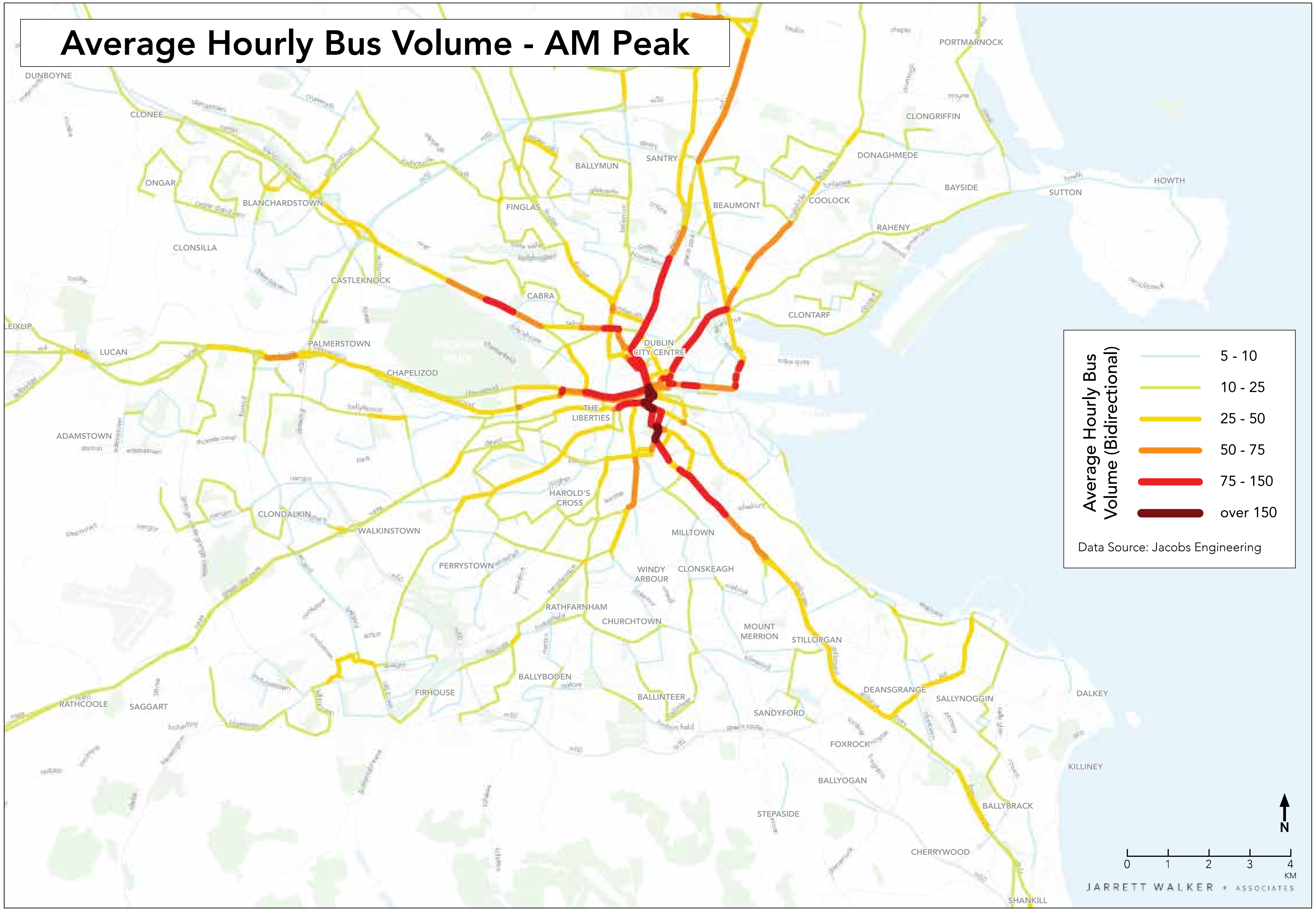
Because Dublin's bus network is so radial, bus lines converge on a limited number of key roads as they approach the City Centre. This pattern is even stronger in the City Centre itself, where a very limited number of paths is available to traverse from north to south, or east to west.

Up to a certain point, this is a good thing, as the result is very high frequencies that are very attractive to customers.

But in some places, the bus volumes are so high, and the paths so constrained, that buses start delaying other buses due to congestion, even in bus-only lanes.

Dublin City Centre will always be the convergence point of many extremely frequent public transport corridors, so ample bus-only facilities are needed, but it is not clear that such an extreme volume of buses is necessary. To some extent this may be an artefact of the network's radial history rather than an ideal pattern for the future.

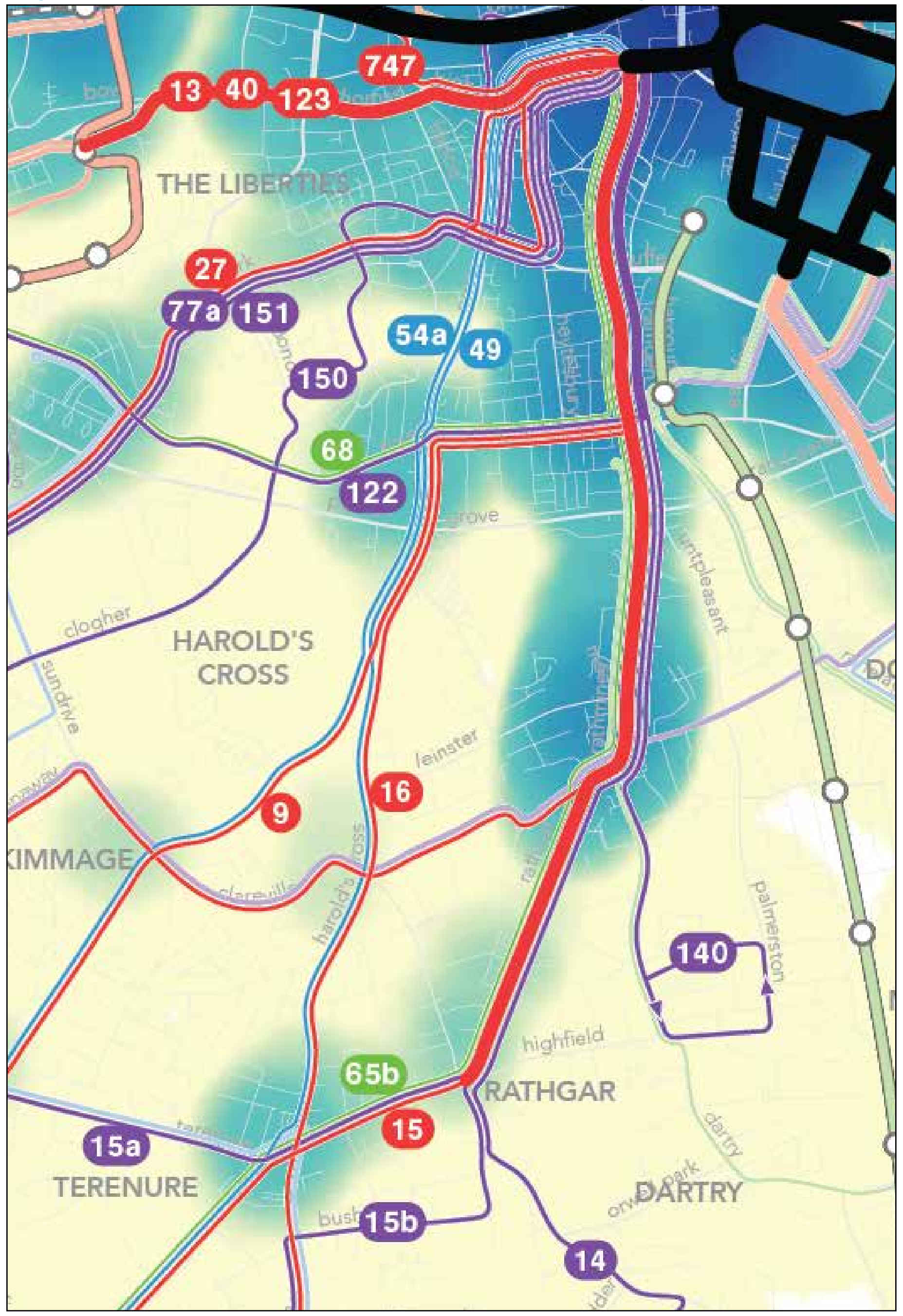
Figure 49: Map of AM peak bus volumes



Sometimes bus volumes converge to meet high demand

In many cases, convergence of multiple bus lines is positive and consistent with the overall demand pattern: demand for bus service is generally stronger in inner, denser neighbourhoods, so it helps for frequency to increase there. One example of bus volumes logically converging to provide super-frequent service to a high-demand area is from Rathmines Road to Aungier Street (see Figure 50).

Figure 50: Map of Rathmines/Camden/Aungier corridor



Sometimes bus volumes converge through areas of very low demand

However, in other cases, the strong radial pull of the network forces very large volumes of buses through areas that have no demand at all, or very low demand. In these cases, there is an imbalance between service frequency and demand in more central areas, which constitutes waste. Chapelizod Road is a clear example, as can be seen in Figure 51. In these cases, using suburban hubs to consolidate passengers onto fewer buses may save considerable resources.

Figure 51: Map of Chapelizod Road and Bypass showing low patronage demand

The existing Cross City line pattern minimizes the need for interchange...

As in many cities, the Dublin network design includes many features designed to reduce the need to interchange.

This is most evident in the design of the Cross City radial corridors. Major radial corridors are generally oriented to use multiple overlapping lines to:

- Distribute service to a broad fan of suburban areas on one side of the city.
- Extend through the City Centre to serve multiple corridors on the other side.

Drumcondra Road and Malahide Road both present good examples. In both cases, multiple lines provide frequent service to a long segment, while lines fan out to provide broader coverage in outer neighbourhoods. At the same time, the lines on both corridors aim in different directions on their way south through the City Centre. This is portrayed in Figure 52 and Figure 53.

It should be noted that along some corridors, Dublin Bus offsets the schedules of the overlapping routes so as to create the best possible combined frequency. This is a good practice, but there is no way to extend it to the patterns crossing the City Centre – where short trips are most sensitive to frequency – because the overlapping routes that form each corridor are separating and recombining in this area.

Figure 52: Map of all-day routes on the Drumcondra Road corridor

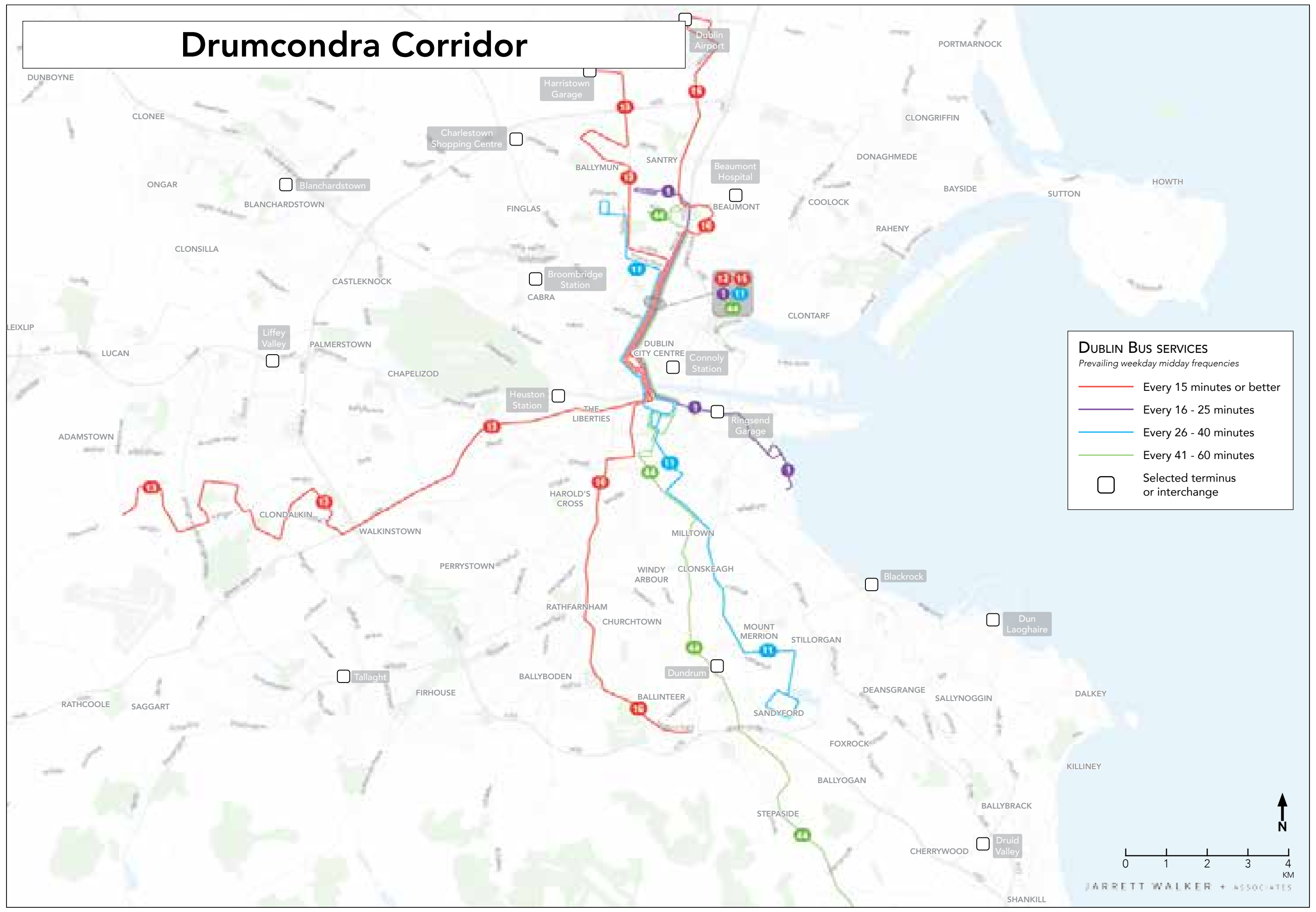
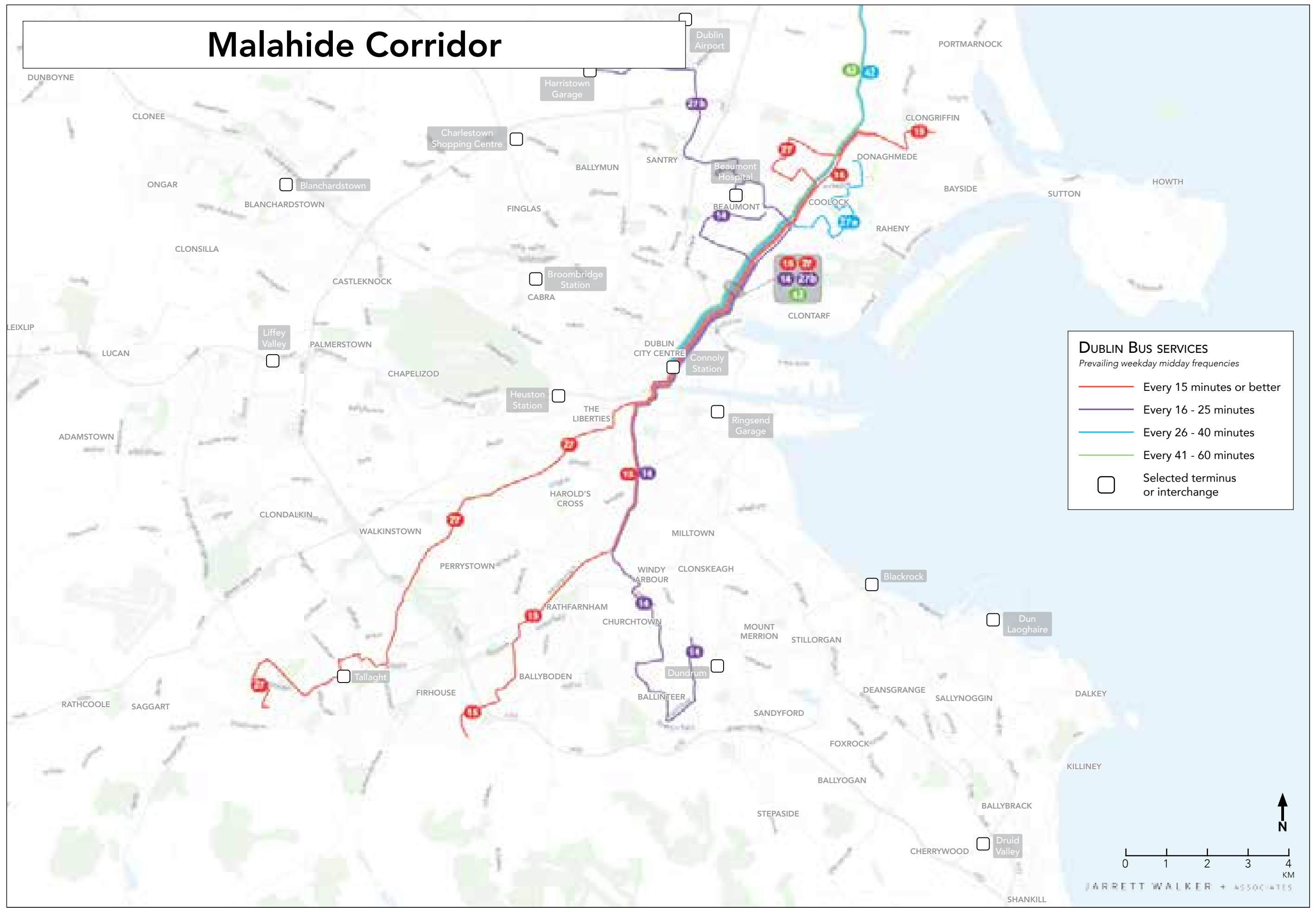


Figure 53: Map of all-day routes on the Malahide Road corridor

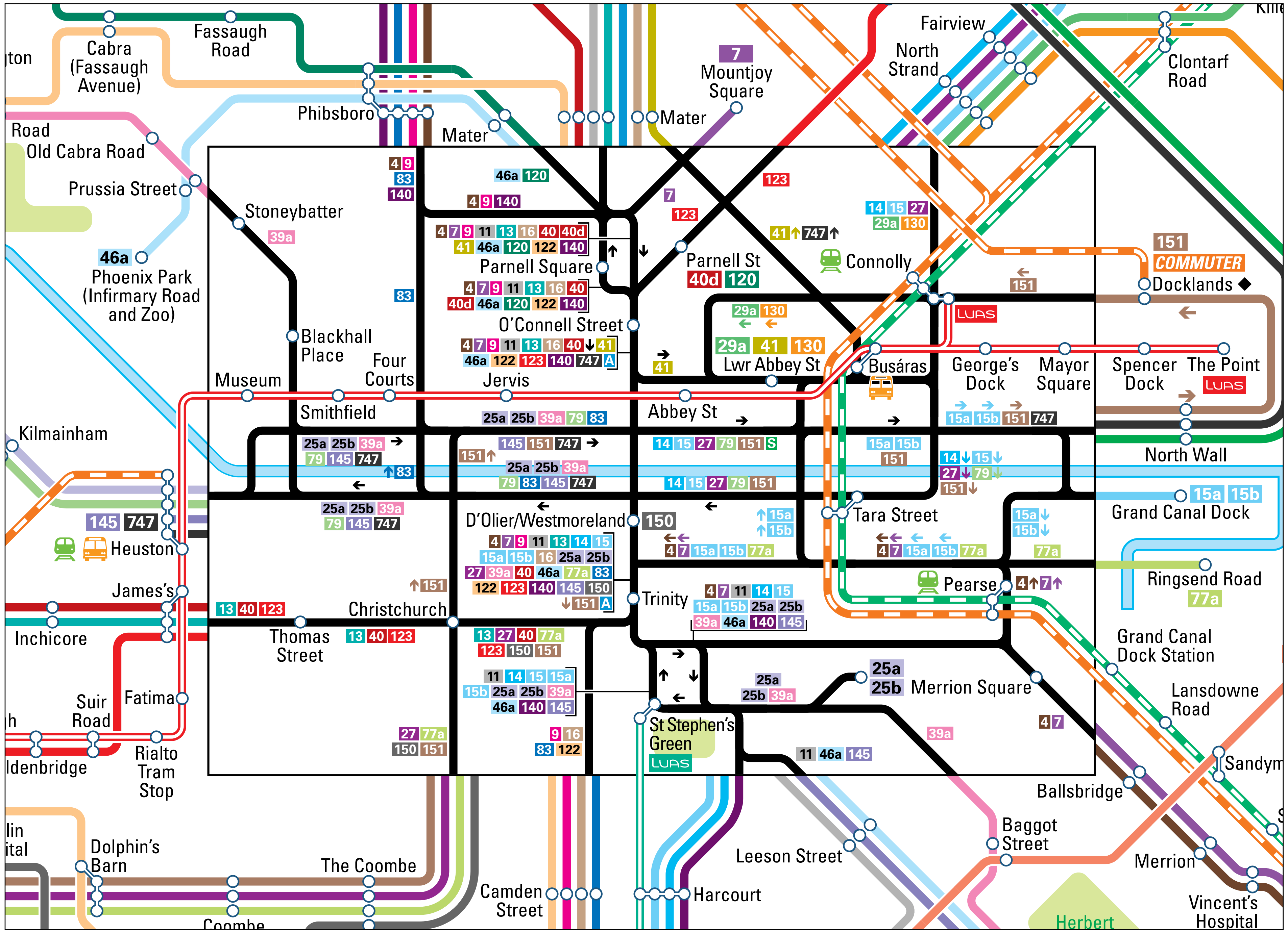


…which makes the network very complex, and more difficult to use

The through-routing pattern described above means that it is possible to take a one-seat ride between numerous areas, minimizing the need for interchange. This is convenient for some users, but it comes at a cost:

- The line structure is necessarily complex and difficult to read, requiring many individual line and branch numbers to describe different levels of similarity and difference between lines.
- Because cross-city buses weave in all directions as they connect different corridors to each other, the City Centre network is so complex that we have found no record to date of a map that successfully shows all the bus routings through central Dublin.
  - » The closest approximations focus either on (a) listing City Centre stops where one can catch the bus to various suburbs, or (b) displaying the streets where buses operate, but focusing only on certain bus lines.
  - » For example, the image in Figure 54 shows only streets where frequent lines operate, but even so the complexity is almost overwhelming.
- This is not just a mapping issue, though. In a city with a large centre like Dublin, if a user cannot understand the network, they are likely dissuaded from using it between different parts of the City Centre despite the very high quantity of service.
  - » Easy legibility is crucial to attracting the occasional user, including the tourist, who is not motivated to learn much complexity to make a desired and often spontaneous trip. This feature, routine in rail services, can also be brought to bus services through careful network design and branding, options explored in Chapter 5.

Figure 54: With a complex City Centre, even a map showing just a subset of lines is difficult to follow.



The fare structure reinforces avoidance of interchange

Even in cases where interchange might result in the most efficient trip, passengers are discouraged from changing buses by the price structure of public transport in Dublin.

This problem is not unique to Dublin Bus, but affects Luas and Irish Rail as well. The following are examples of price challenges inherent to interchange:

- It is always more expensive to use a second mode (bus-to-rail, or rail-to-bus), even when it saves time or results in a shorter journey.
- Unless one holds a Taxsaver pass or comparable discounted pass, it is also always more expensive to board a second bus.
- When paying with a Leap card, an interchange results in a 1 euro discount on the second fare, but only if taken within 90 minutes of the initial boarding.
- The daily cap available on the Leap card is 7 euro if one uses only the bus in a given day, but rises to 10 euro if a rider switches between bus and rail at any point.
- In either case, the Leap daily cap is over 3 times the cost of a single boarding.
- Dublin Bus, Luas, and Irish Rail each have different weekly or monthly unlimited pass options, but no single operator's pass is transferrable to any other operator.

Because the NTA is working on fare issues in parallel through the BusConnects plan, **the network plans explored in this study will presume that fare barriers to interchange can be removed**, to illustrate the benefits, in terms of patronage potential, that could arise from doing so.

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 lines,** each with their own frequency, prevent buses from being evenly spaced to minimize waiting. Along with low frequency on some lines, this means many people wait longer than they need to.
- **Complexity.** The sheer number of lines 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 produce major delay by 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.

The foundation of many of these problems is 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 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.__ It is too early in the study to be proposing anything. 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.

How Connections Improve Travel Time: Theory

Imagine a simple city that has three primary residential areas, along the top in the diagram to the right, 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 lines, as shown in Figure 55. Suppose that we can afford to run each line 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 line between every residential area and every activity center, we run a direct line from each residential area to a single activity centre, but we make sure that all the resulting lines connect with each other at a strategic point, as in Figure 56.
- Now we have three lines instead of nine, so we can run each line three times as often at the same total cost as the Direct Service option. So instead of service every 30 minutes, we have service every 10 minutes. Let's call this the **Connective Option**.

Figure 55: Example of direct service from each residential area to activity centre

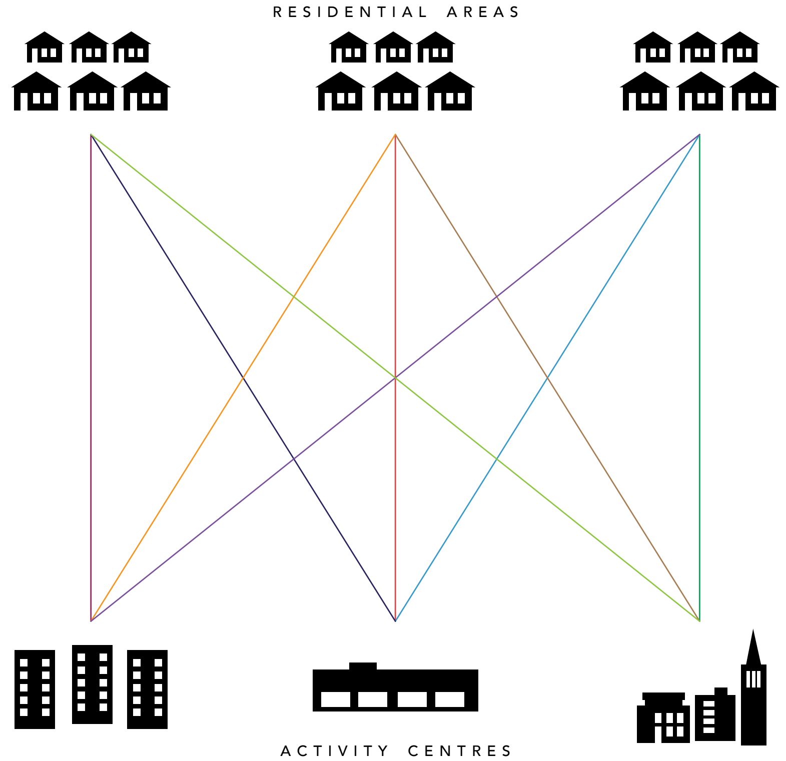
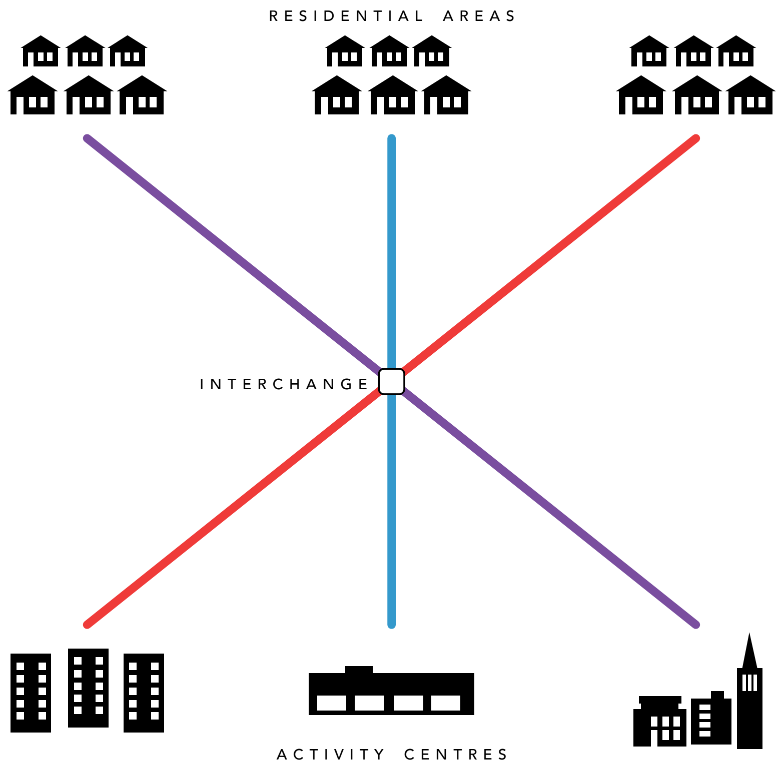


Figure 56: Example of frequent connective service to a central transfer point



The Direct Service option seems to be the obvious solution. But if we want to maximize people's ability to get places with our fixed budget, we should prefer the Connective option.

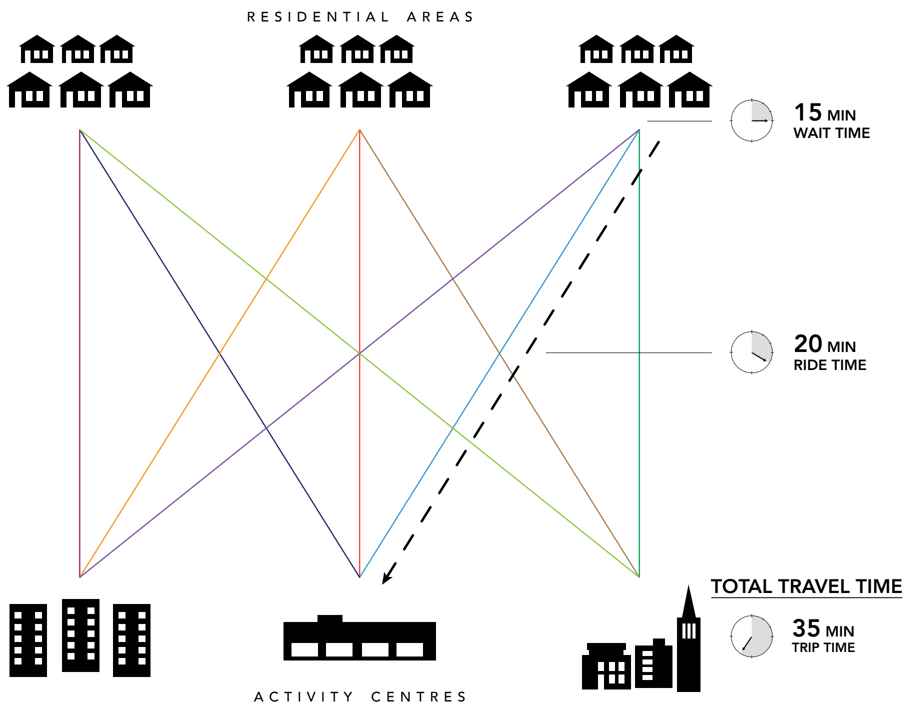
Consider how long a typical trip takes in each scenario, from the standpoint of a person whose needs to leave or arrive at a particular time. **For example, let's look at trips from the rightmost Residential Area to a given Activity Centre.** For simplicity, let's also assume that all lines, in all scenarios,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

Figure 57: Example of a trip taken with direct service from a residental area to an activity centre



Now look at the **Connective Option.** We leave the same residential area on its only line, 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 to it 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:

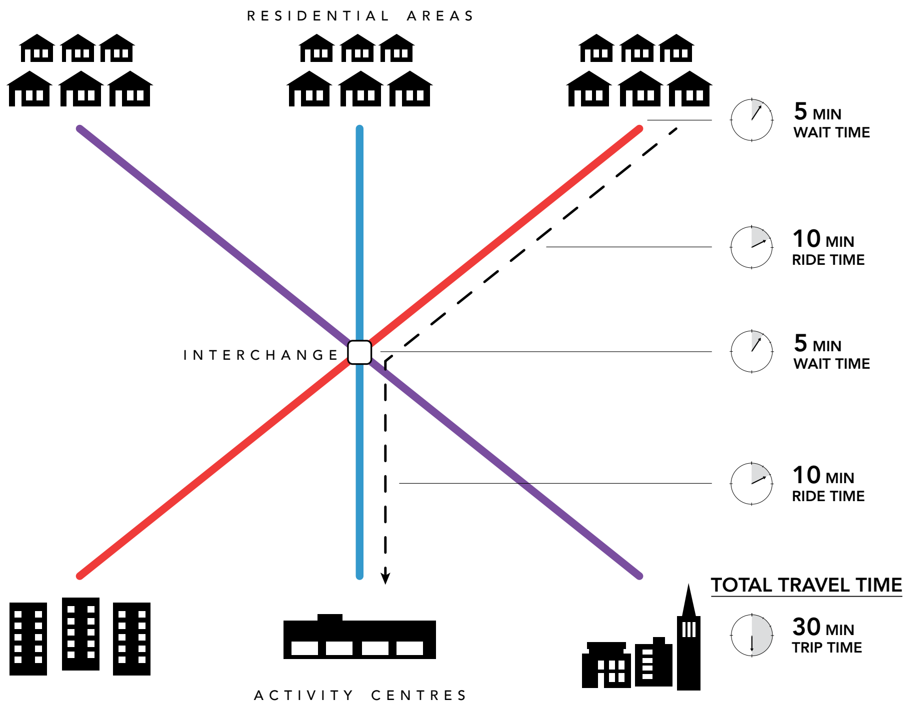
Wait 5 minutes + Ride 10 minutes

+ 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.

Figure 58: 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 lines, 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 modeler 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 modeling approach assumes that the inconvenience of interchange is something different to, and separable from, the time that the interchange takes.

There is considerable documentation[1] 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 (as illustrated by Figure 12 on page 11) is greatest if you are willing to interchange as needed, rather than allowing the interchange experience to dissuade you.

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 go catch the train whenever it is going. Many people do treat schedules in this way, especially when making regularly scheduled commutes that can be planned into a work day's 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 at your destination before your work shift starts, time you would probably rather have spent in bed. 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 for simplicity we have presented this example in terms of commutes to work, but of course, a good public transport system 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, there are several other reasons to prefer Connective networks over Direct Service networks.

- Average travel time is better than the worst-case time calculated above. In the Direct Service network, everybody's trip takes 35 minutes. In the Connective network, two-thirds of the market has a 30 minute trip, but one-third of the market (those still served by a direct line) has an even faster trip.
- The Connective network is made of more frequent services, triggering the cubed benefit of frequency discussed in Chapter 2 The Geometry of Useful Public Transport.
- The Connective network is simpler. A network of three frequent lines is much easier to remember than a network of nine infrequent ones. Marketing frequent lines as a Frequent Network can enhance the patronage benefits of this simplicity.

Most transit networks start out as Direct Service networks with relatively little interchange, but as the city grows bigger, Direct Service networks become massively complex. At some point, cities make a transition from a Direct Service network to a Connective one, a transition that often requires severing direct links that people are used to in order to create a structure of very frequent service that is more broadly useful and legible.

Disadvantages of Connective Networks

We do not want to imply, however, that connective networks, which require more interchanging, have no downsides. Here are the most common reasons to dislike connective networks.

The largest disadvantage 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. The walk will be very short, and the high frequencies mean that the wait will be short as well. Excellent shelter and information will also be provided. But it will still be an inconvenience. The level of effort may also be 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 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. Again, NTA is working on a parallel project to improve reliability throughout the network.

Assumptions for this Study

In evaluating the concepts below, please assume that:

- **Fare penalities for interchanging are removed**. Your fare would not depend on whether an interchange is required.
- **The network does not increase overcrowding.** In detailed planning we will ensure that adequate service is provided to meet capacity needs.
- **Adequate shelters and information are found at every interchange stop**.
- **Any walk required for the interchange is safe, efficient, and short**.
- **Reliability continues to improve,** through added bus lanes and other tools that reduce disruption and delay.

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

Four Strategies for a More Useful Network

The next phase of this study will develop a Redesigned Network Proposal based on the theory and data presented in this report. The proposal will consider greater reliance on interchange to increase usefulness and shorten travel times, but the degree to which it does so depends in part on public response to this Choices report.

While the design of the Redesigned Network remains to be done, here are the four major strategies that will be pursued.

- **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 in Figure 59 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.

Still, there is a choice in the degree of adoption of each of these strategies. And it's possible that some of these strategies are more or less appealing than others to Dubliners on the whole, because of their corresponding disadvantages.

For example, restructuring existing services would likely inconvenience some existing riders, and a few would experience longer travel times, even if far more riders experience improvements. This means that any change will be controversial, as those who find the existing system more convenient can be expected to defend it.

That is why this report is called a Choices Report. **The reader is encouraged to think about the trade-offs each of these strategies represents**, and express a view during the comment period. The final network will reflect public comment on the strategies outlined below, and particularly on the question of how far to go in the direction of the network design concept.

Figure 59: Table of four strategies to address four problems

TOOL	PROBLEM ADDRESSED: Poor orbital service	Complexity	Low frequency	Buses in City Centre
1 Standardize Service Categories	**Yes.** Categories make planning efficient services easier, releasing resources for orbital service.	**Yes.** Frequency and span are apparent from the category, without looking at timetables.	**Yes.** Service 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.** Vast reduction of complexity, especially in City Centre	**Yes.** Much 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 grid 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 area.	**Yes.** Feeder networks support consolidating service to City Centre on fewer routes.

Possible Strategy #1: Standardize Patterns of Frequency and Span

In the existing network, a bus line may have any frequency. Although there are tendencies, such as higher frequency at peak, there is no fixed pattern as to 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 lines you know, because you can easily see what the service level of a line would be by its category.

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

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

Figure 60: Typical frequencies and spans for Frequent Network standards in various cities compared to some of Dublin's frequent lines

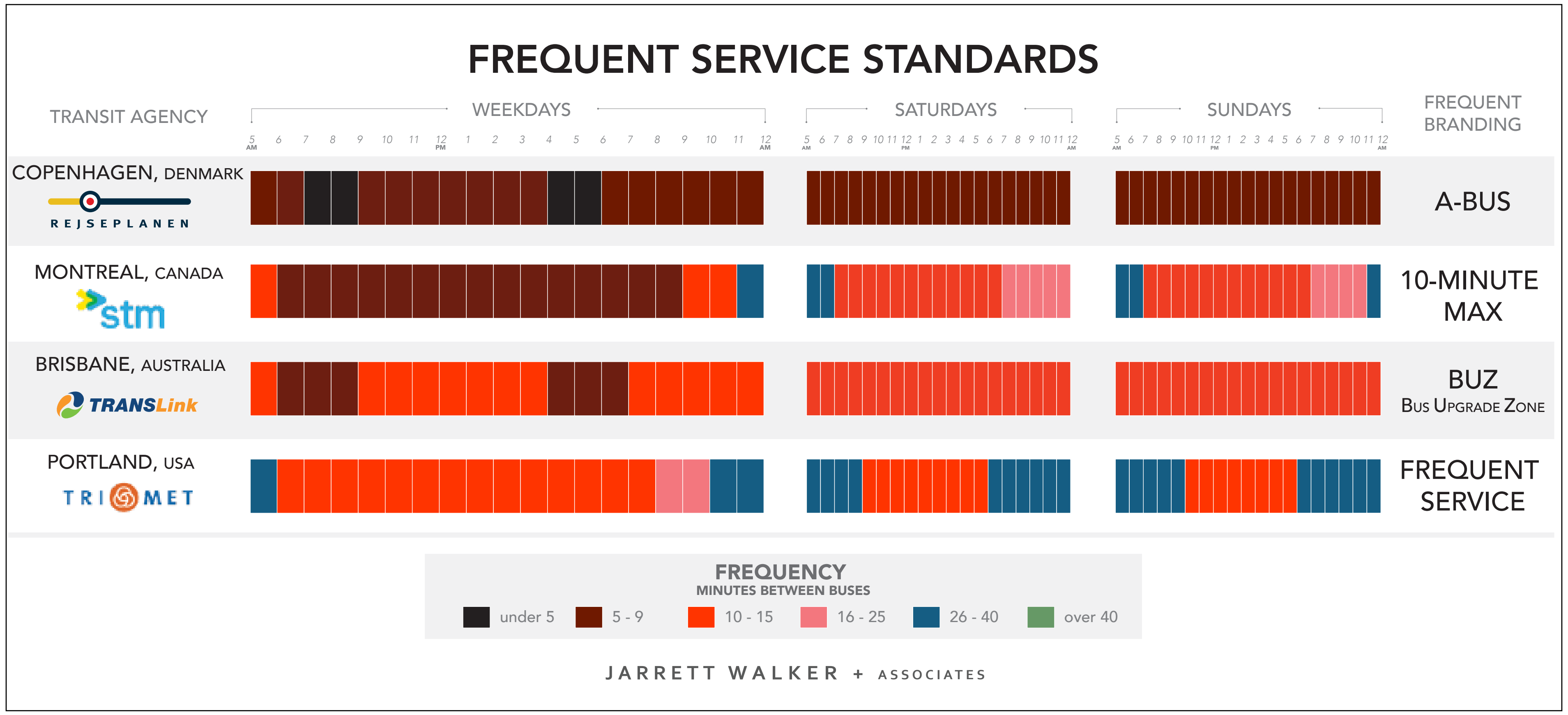


Figure 60 shows some examples of typical frequencies and spans for Frequent Network standards in other cities.

Figure 61 and Figure 62 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 61: Portland, United States - "Frequent Service" bus stop pole and network diagram

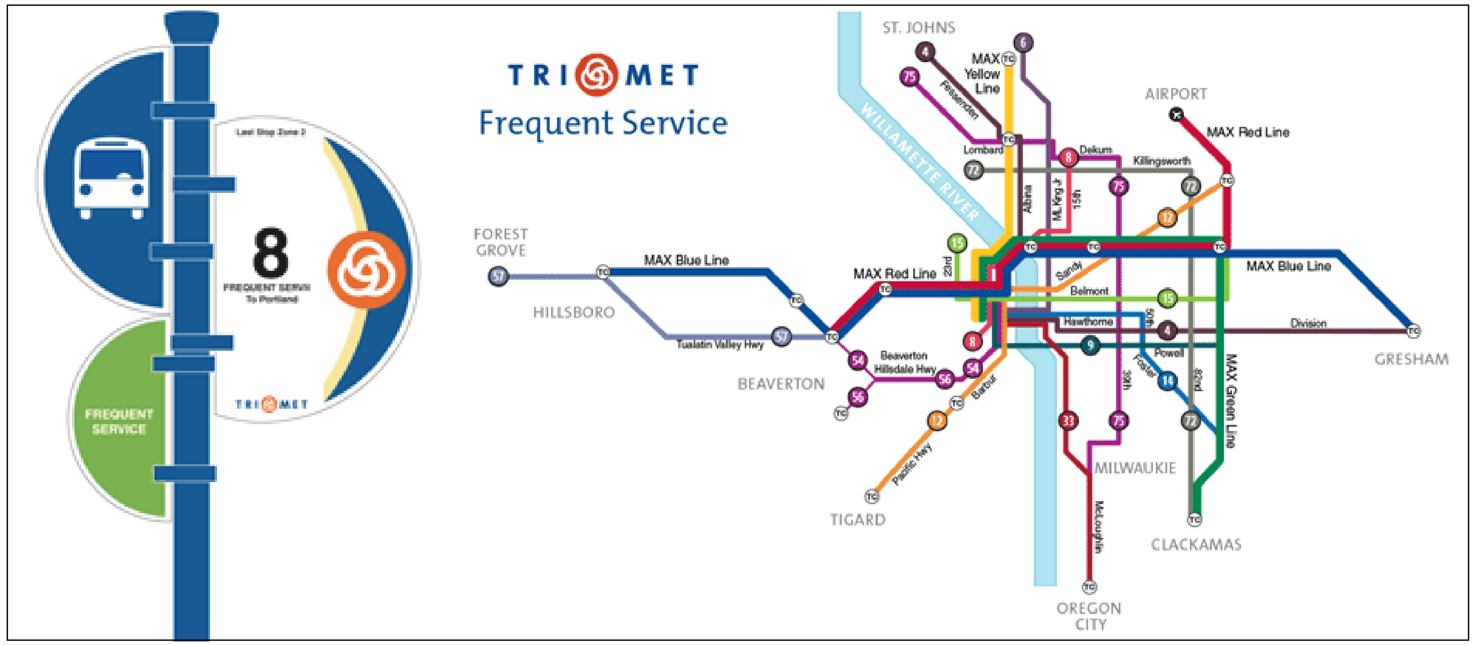
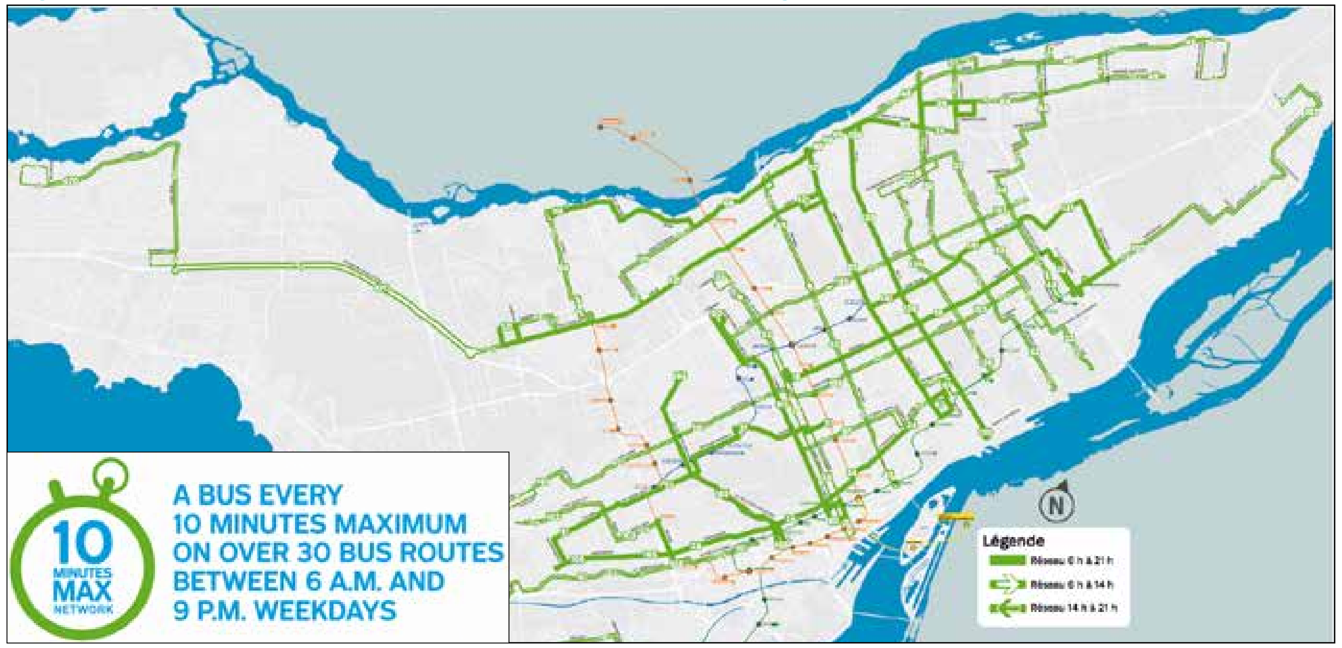


Figure 62: Montréal, Canada - "10 Minutes Max" logo and frequent network map



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

Existing Radial and Cross City Pattern

Figure 63 is a simplified diagram of how radial bus lines are organised along the highest-volume corridors in Dublin. As detailed in Chapter 4, each major corridor has several overlapping bus lines, which do different things on the opposite side of the City Centre.

For example, two overlapping frequent lines from Ballymun approach the City Centre from the north, but one continues to Harold's Cross while the other continues toward Blackrock. 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 lines 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 in Figure 64 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 6 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 in fewer bus lines, it becomes easier to adjust bus volume on each line to match real demand.
- **Reduced bus congestion in City Centre.** Fewer frequent lines are easier to schedule so that buses are not obstructing one another. The total number of bus trips traversing the centre would be somewhat lower, without any reduction in service to the customer.

Figure 63: Existing Network. Multiple lines from each corridor cross the City Centre in different directions.

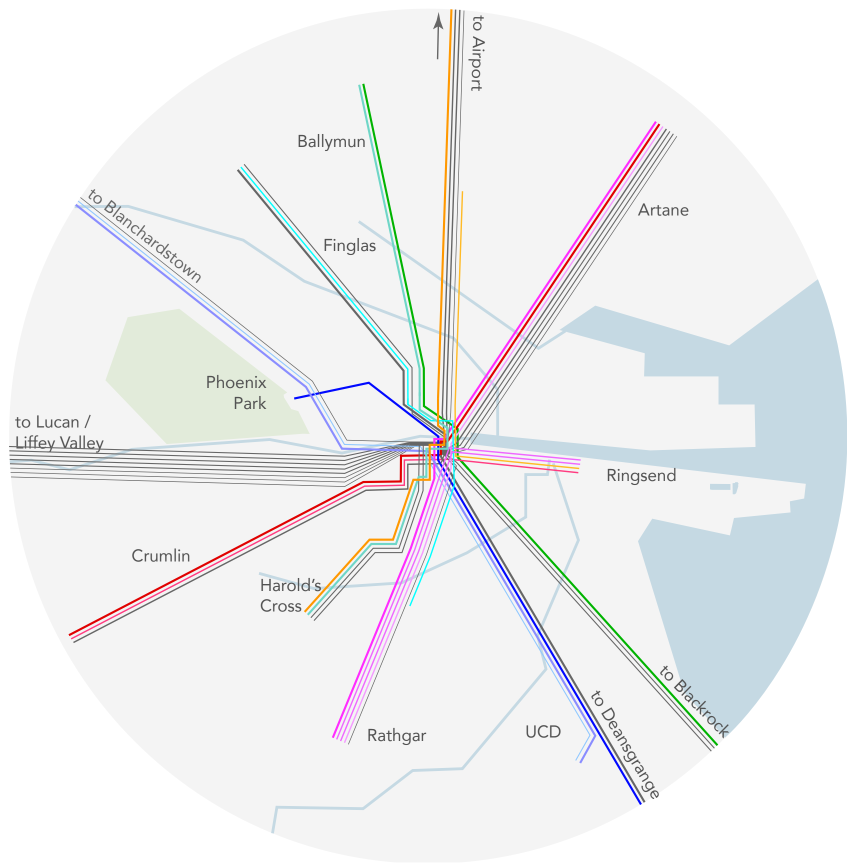
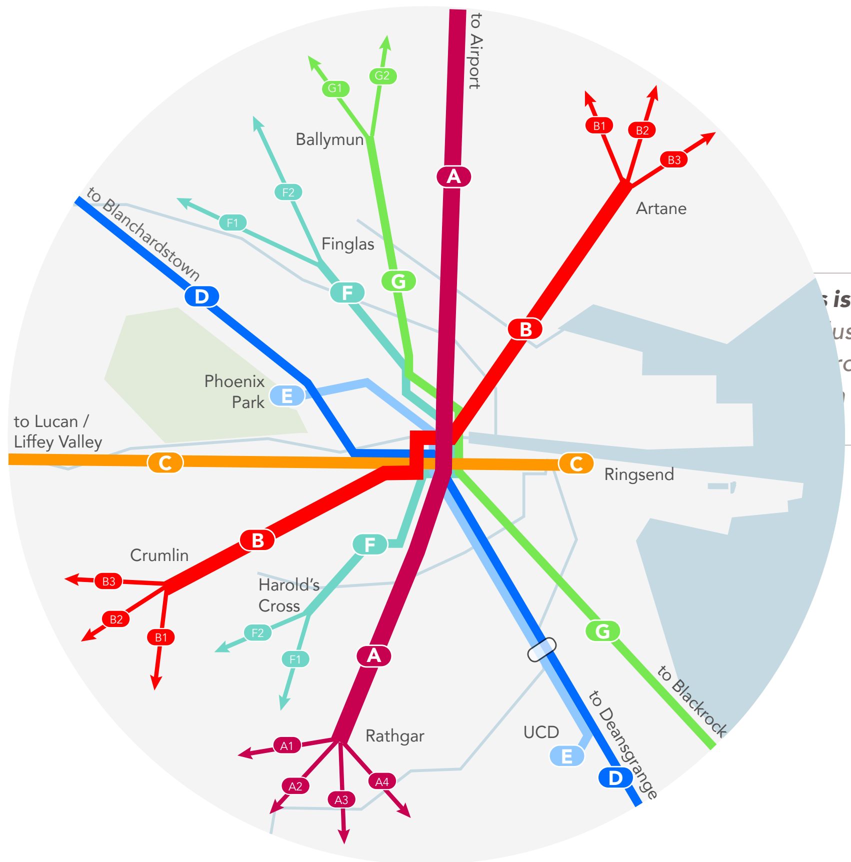


Figure 64: Alternative Concept. Each corridor has a single super frequent route crossing the City Centre on a single path.



Cross City Travel Time Examples

Here a few examples of how cross public transport travel times might change. For simplicity, let us assume that each spine operates at a 4 minute frequency (in other words, a 2 minute average wait). This is possible based on current service volumes.

New Interchange - Harold's Cross (Spine F) to Drumcondra (Spine A)

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

Wait 6 minutes + Travel 34 minutes = **40 minutes**

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

Wait 2 minutes + Travel 24 minutes + Wait 2 minutes + Travel 10 minutes = **38 minutes**

New Interchange - Donnybrook (Spine D) to Heuston Station (Spine C)

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

Wait 5 minutes + Travel 25 minutes = **30 minutes**

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

Wait 2 minutes + Travel 17 minutes + Wait 2 minutes + Travel 8 minutes = **29 minutes**

Restructured Interchange - Lucan (Spine C) to UCD Belfield (Spine E)

In the existing network, this trip would use Lines 39a and 66/a/b:

Wait 5 minutes + Travel 20 minutes + Wait 7.5 minutes + Travel 24 minutes = **56.5 minutes**

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

Wait 2 minutes + Travel 20 minutes + Wait 2 minutes + Travel 24 minutes = **49 minutes**

Still Direct - Ballymun to Blackrock (Spine G)

In the existing network, this trip would use Line 4:

Wait 7.5 minutes + Travel 52 minutes = **59 minutes**

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

Wait 2 minutes + Travel 52 minutes = **54 minutes**

Possible Strategy #3: Build Frequent Orbitals by Reducing Duplication

The existing network features few orbital lines, 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 lines with significant orbital components, as in the example below.

Existing Service - Orbital-Radial Overlap

See Figure 65 at right. Orbital line 18 operates every 20 to 25 minutes in the middle of the day, connecting multiple neighborhoods in the southern half of Dublin City. Line 83 operates every 15 minutes between Kimmage and City Centre. Lines 18 and 83 duplicate each other for a long segment between Kimmage and Rathmines Road.

Alternative Concept - Frequent Orbital

Figure 66 shows another way this could work. The resources currently allocated to Line 83 south of City Centre were allocated to Line 18. It would probably be possible operate Line 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 Line 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 City Centre.

Worst Case Radial Trip - Armagh Road to City Centre

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

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

With a frequent Line 18 and interchange at Rathmines:

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

Figure 65: Existing Service - lines 18 and 83

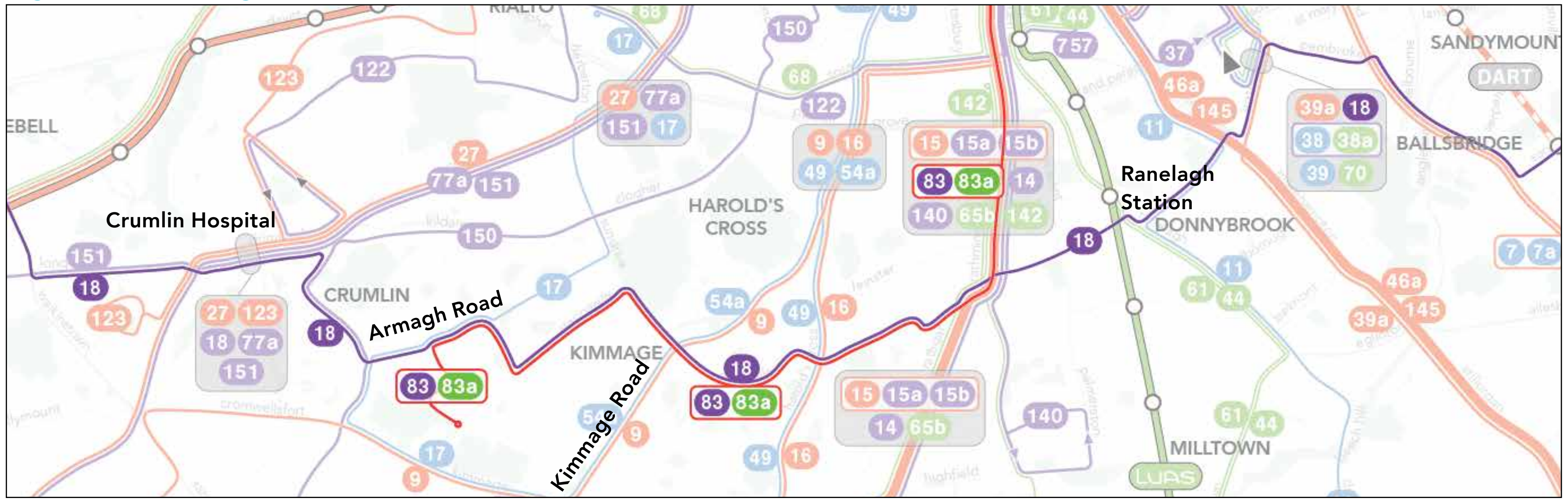
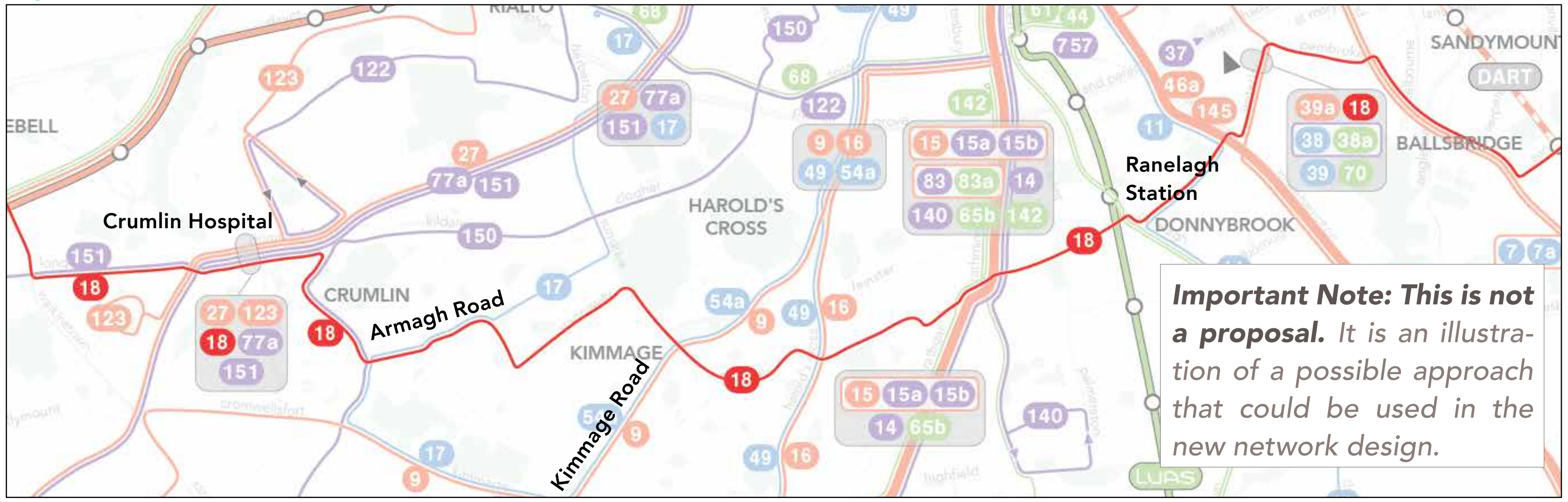


Figure 66: Alternative Concept - frequent line 18



Improved Direct Orbital Trip - Crumlin Hospital to Ballsbridge

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

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

With a frequent Line 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 Line 9, with interchange at Harcourt near City Centre:

Wait 3 minutes + Travel 15 minutes + Wait 7.5 minutes + Travel 12 minutes = **37.5 minutes**

This would change to Luas Green Line and frequent Line 18, with interchange south of City Centre at Ranelagh Station:

Wait 3 minutes + Travel 12 minutes + Wait 7.5 minutes + Travel 12 minutes = **34.5 minutes**

Possible Strategy #4: Grow Suburban Feeder Networks Supporting the Major Lines

Nearly every suburb of Dublin currently has a direct bus service to Dublin 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 lines, 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 Line 70 to City Centre, and Line 270 to Blanchardstown Centre. As shown in Figure 67, both operate very infrequently in the middle of the day, every 60 minutes on average in each direction.

If all resources dedicated to Line 70 were re-allocated to Line 270, as shown in Figure 68, it would be possible to provide service to Blanchardstown Centre every 20 minutes. Passengers headed from Dunboyne to City Centre would connect to frequent radial service at Blanchardstown Centre.

Based on existing schedules, **the increased frequency on Line 270 would greatly reduce average travel times from Dunboyne to Blanchardstown Centre, and would even reduce travel times to City Centre.**

Travel Time Change - Dunboyne to Blanchardstown Centre

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

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

With a more frequent Line 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 Line 70, for the following midday travel time:

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

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

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

Figure 68: Existing Midday Service

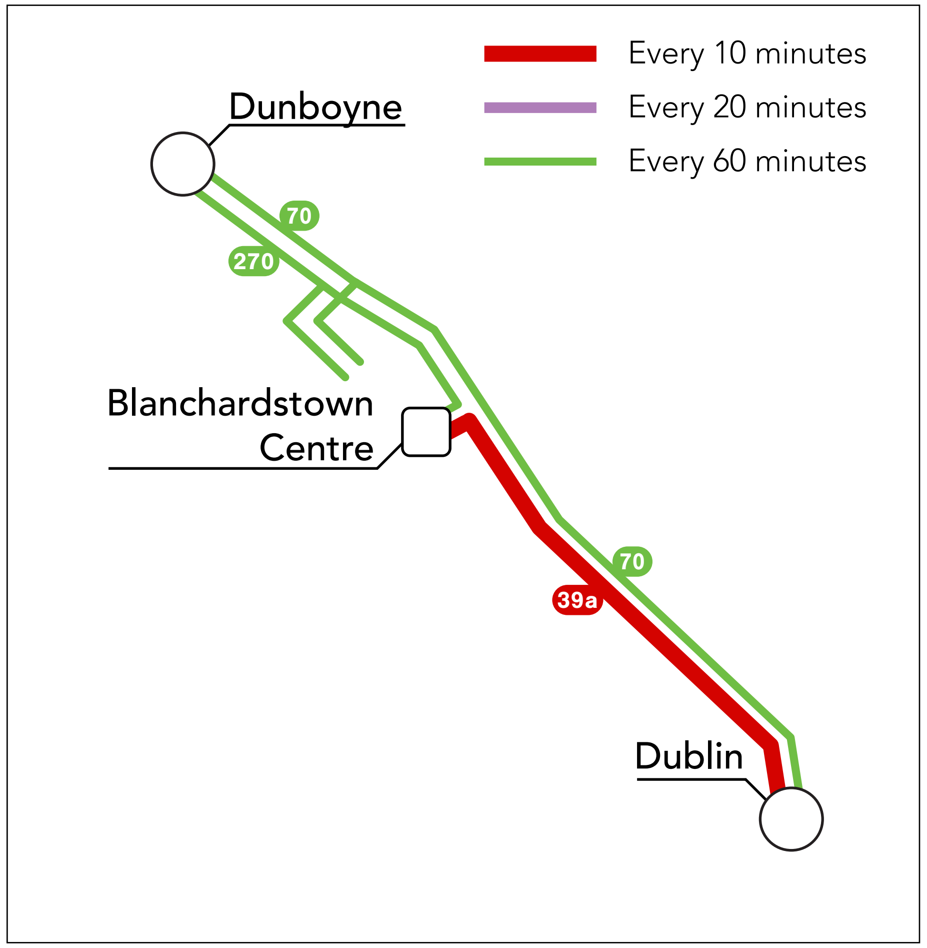
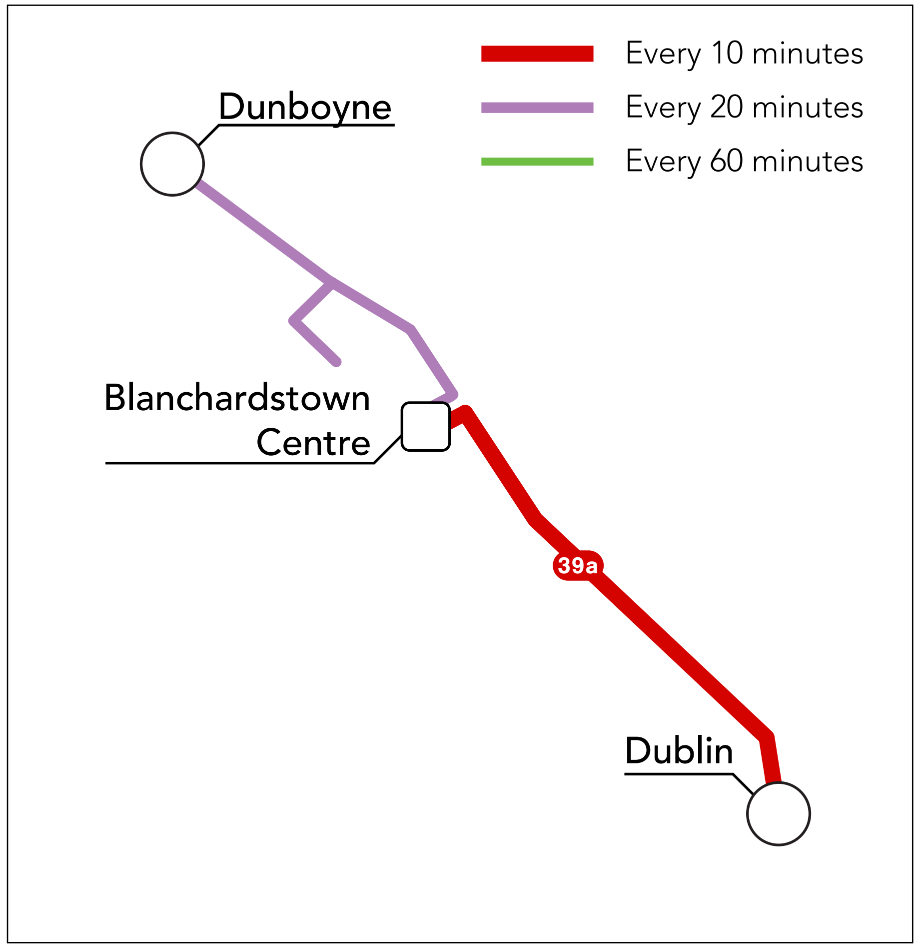


Figure 67: Alternative Concept



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 line into City Centre (e.g. existing Line 39a, or Spine D as described on page 49).
  - » The core radial line may require some additional service may to handle increased loads.
  - » Nonetheless, fewer buses will need to be added to the Core Radial line than are removed from Line 70, because Line 70 passengers will spread more evenly through the hour among the more frequent Core Radial buses.
- **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 that 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.

Still, relying more on interchange is a choice, one that the NTA will need to make based on the advice from the public.

In June 2017, a web survey will ask you to offer your advice on whether NTA should move in the suggested direction, and how far. That survey will be found online, along with information on the broader BusConnects initiative, at **busconnects.ie**.

Providing advice at this stage will be especially helpful and influential, because you will be guiding the plan instead of just responding to it.

Again, when thinking about this choice, please make the following assumptions, which reflect parallel planning processes now underway within the larger BusConnects initiative.

- *Fare penalties for interchanging are removed.* Your fare would not depend on whether an interchange is required.
- *The network does not increase overcrowding.* In detailed planning we will ensure that adequate service is provided to meet capacity needs.
- *Adequate shelters and information are found at every interchange stop.*
- *Any walk required for the interchange is safe, efficient, and short*.
- *Reliability continues to improve*, through added bus lanes and other tools that reduce disruption and delay.