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 32), 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.
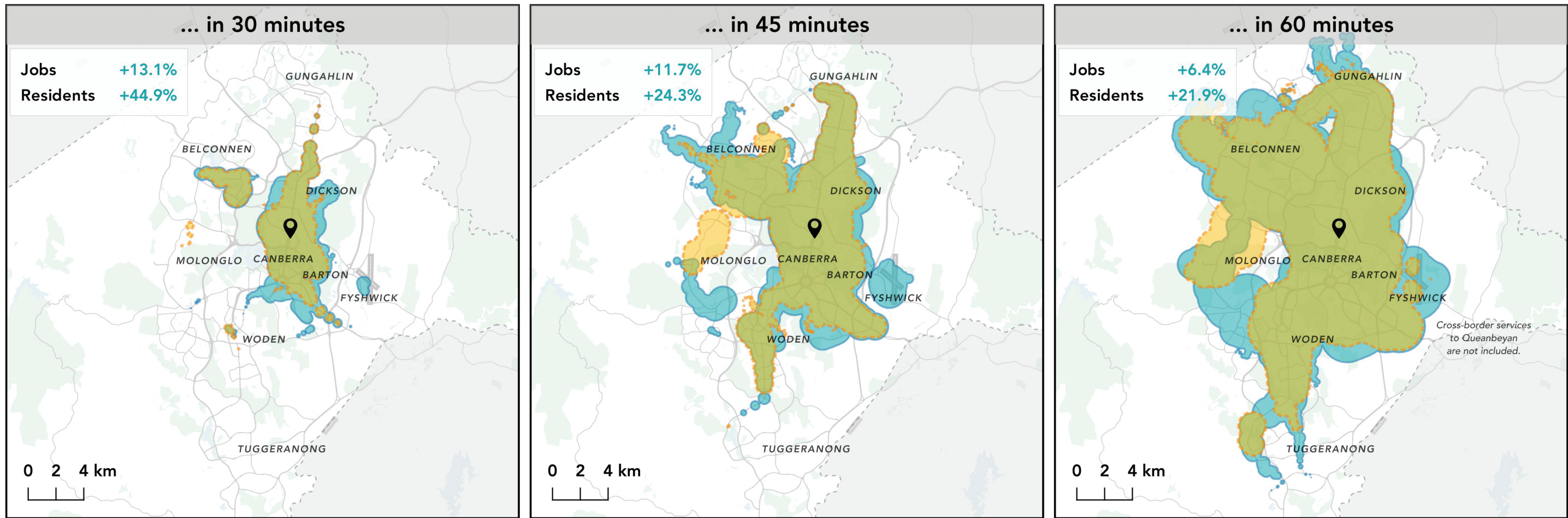
The potential to expand this freedom and opportunity is the foundation for the increases in patronage that a network design can achieve. This does not strictly predict patronage, because patronage also varies with external factors including prosperity, the costs of car ownership, petrol prices, and the 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* **favourable patterns in the built environment***.*

Figure 32: The isochrones below compare how far one can travel using Canberra, Australia's existing network (yellow) versus the proposed network (blue) in the indicated amount of time.

... in 30 minutes

| Jobs | +13.1% |
| Residents | +44.9% |

... in 45 minutes

| Jobs | +11.7% |
| Residents | +24.3% |

... in 60 minutes

| Jobs | +6.4% |
| Residents | +21.9% |

Cross-border services to Queanbeyan are not included.

Why Frequency Comes First

Patronage is a function of many service features, including speed and reliability, but the dominant factor is frequency. Frequency is the elapsed time between consecutive buses (or trains, or ferries) on a route, 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 favourite 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 routes to become a network. A public transport route without good connections is useful for travelling only along that route. A network of frequent routes can make it easy to travel all over the city. This massively expands the usefulness of each route.

- **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 33 shows a dot for each Dublin Bus route, with the x-axis indicating frequency and the y-axis indicating productivity, which is patronage divided by the quantity of service. 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 34 shows a similar graphic for hundreds of routes 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 routes 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 routes 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.**

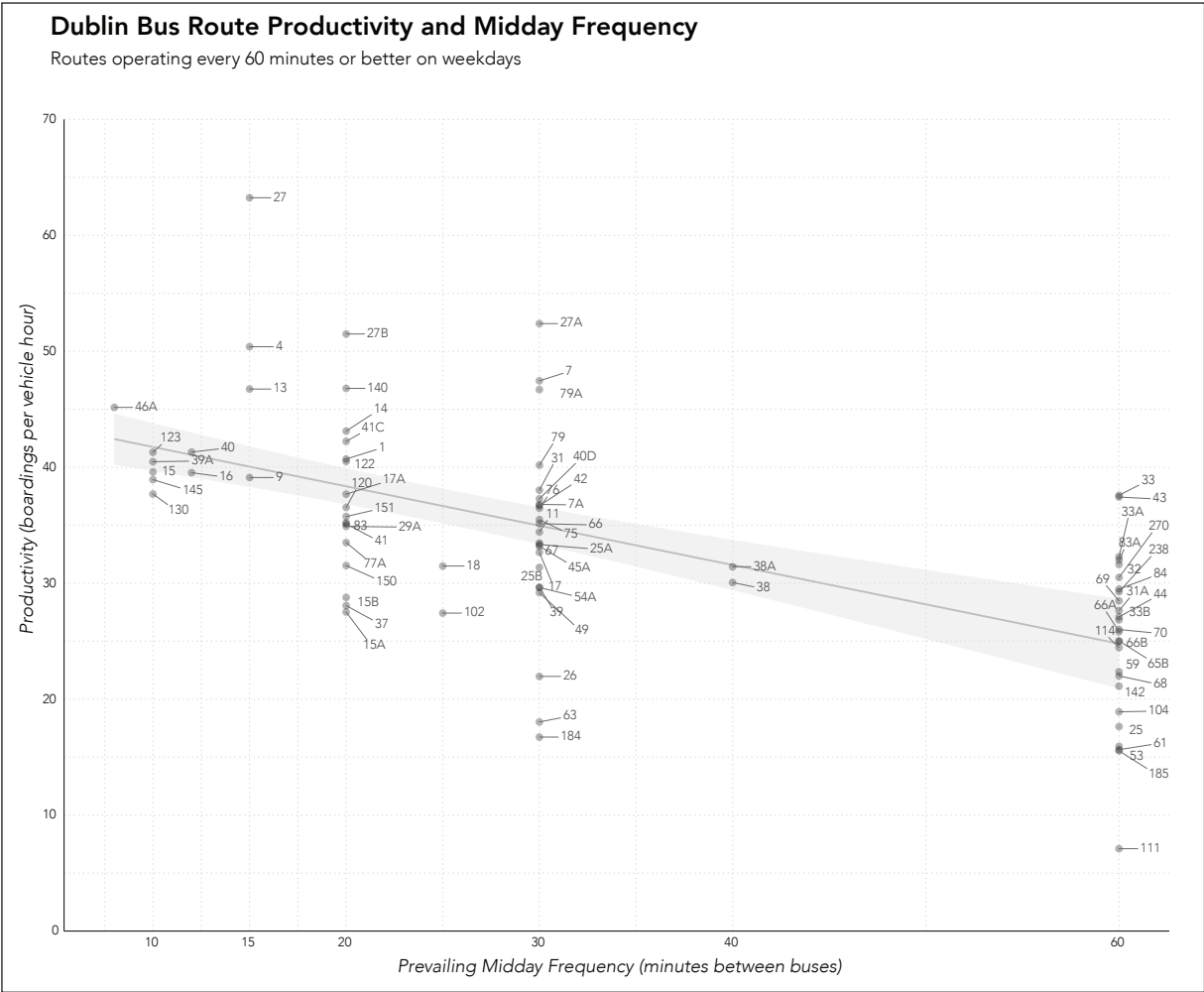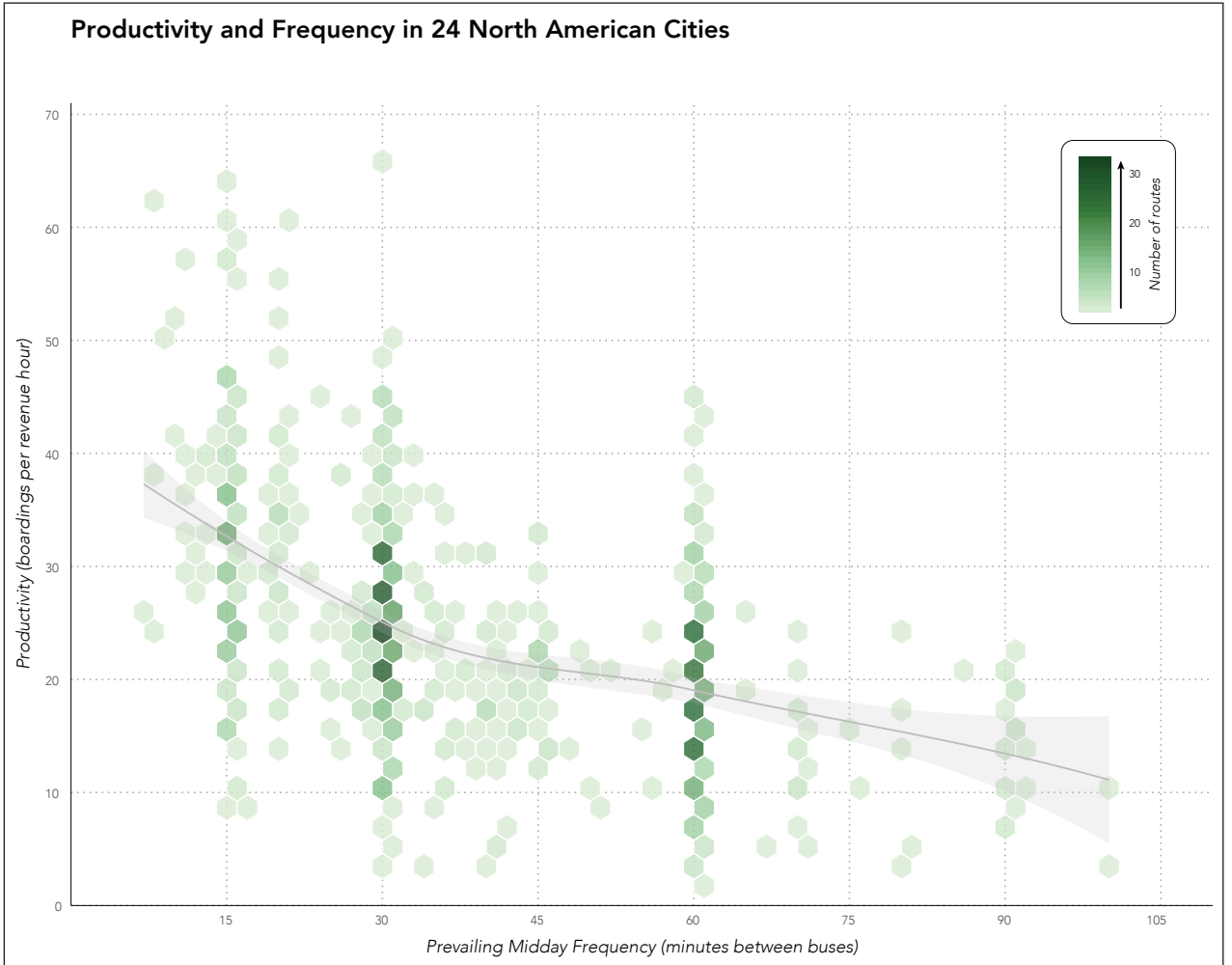## Figure 33: Frequency vs. productivity (boardings per hour) on bus routes in Dublin

Dublin Bus Route Productivity and Midday Frequency
Routes operating every 60 minutes or better on weekdays

Figure 34: Productivity vs. frequency in 24 North American cities

Productivity and Frequency in 24 North American Cities

Note: darker shades of green indicate more routes, i.e. most routes at 30 minute frequencies in this sample of 24 cities have a productivity between 20 and 35 boardings per revenue hour. The grey line shows the midpoint at different frequencies.

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.

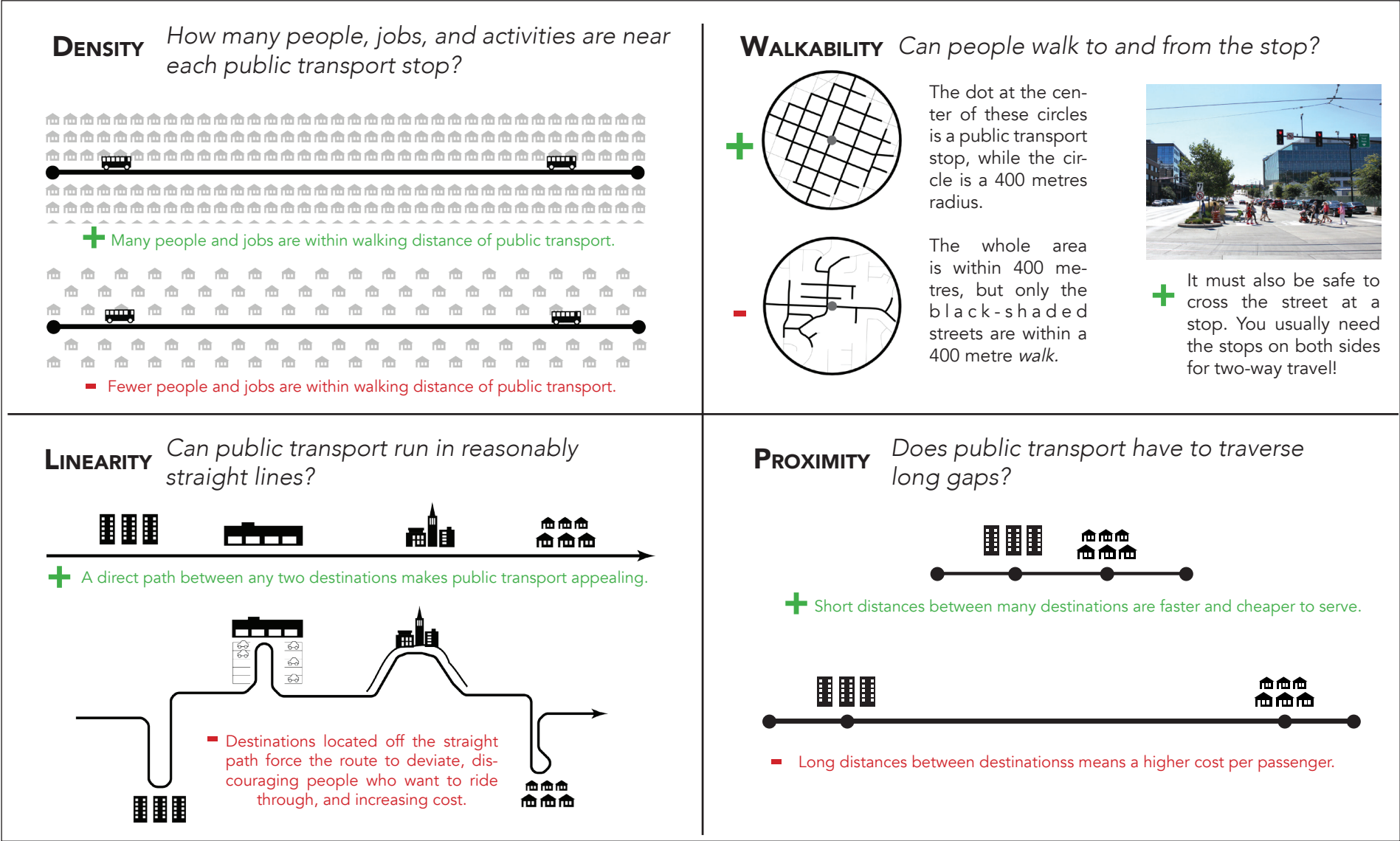The following factors are critical:

- **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 35: Aspects of the built environment contribute to public transport patronage.

DENSITY *How many people, jobs, and activities are near each public transport stop?*

+ Many people and jobs are within walking distance of public transport.

− Fewer people and jobs are within walking distance of public transport.

WALKABILITY *Can people walk to and from the stop?*

The dot at the center of these circles is a public transport stop, while the circle is a 400 metres radius.

The whole area is within 400 metres, but only the black-shaded streets are within a 400 metre *walk*.

+ It must also be safe to cross the street at a stop. You usually need the stops on both sides for two-way travel!

LINEARITY *Can public transport run in reasonably straight lines?*

+ A direct path between any two destinations makes public transport appealing.

− Destinations located off the straight path force the route to deviate, discouraging people who want to ride through, and increasing cost.

PROXIMITY *Does public transport have to traverse long gaps?*

+ Short distances between many destinations are faster and cheaper to serve.

− Long distances between destinationss means a higher cost per passenger.

> *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 neighbouring estates, people must take 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 36). 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 37). 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.*

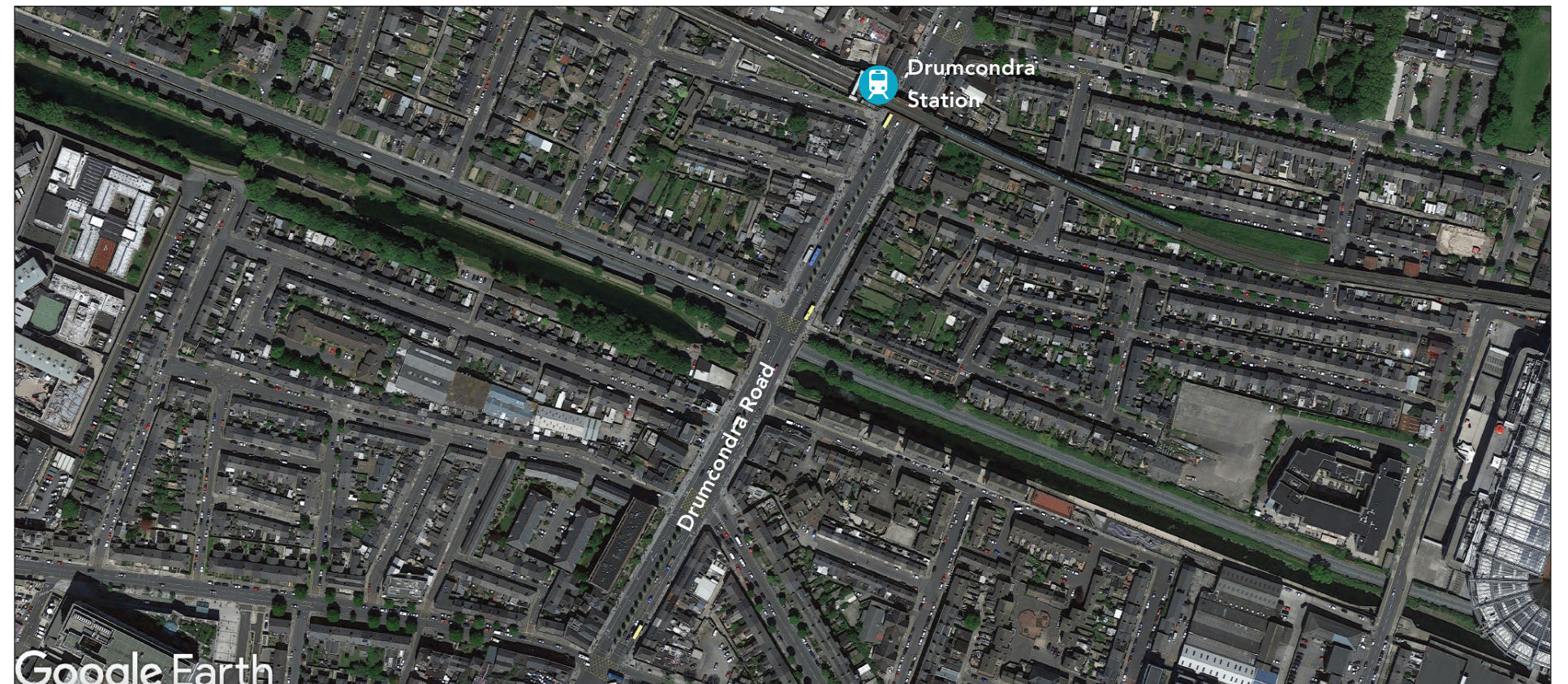**Figure 36: The area around Drumcondra Station features both high density and high walkabililty.**

Figure 37: 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 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 routes in this area (and the Luas Green Line as well) have some of the highest levels of patronage 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 route that focuses primarily on serving the bypass will be fast, but less accessible, like Route 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 neighbourhoods requires reaching off of the bypass to the local network of secondary roads.

  » This means any route that tries to solve the bypass problem by entering the neighbourhoods is confined to a slower and far more circuitous path, as Route 40 is today.

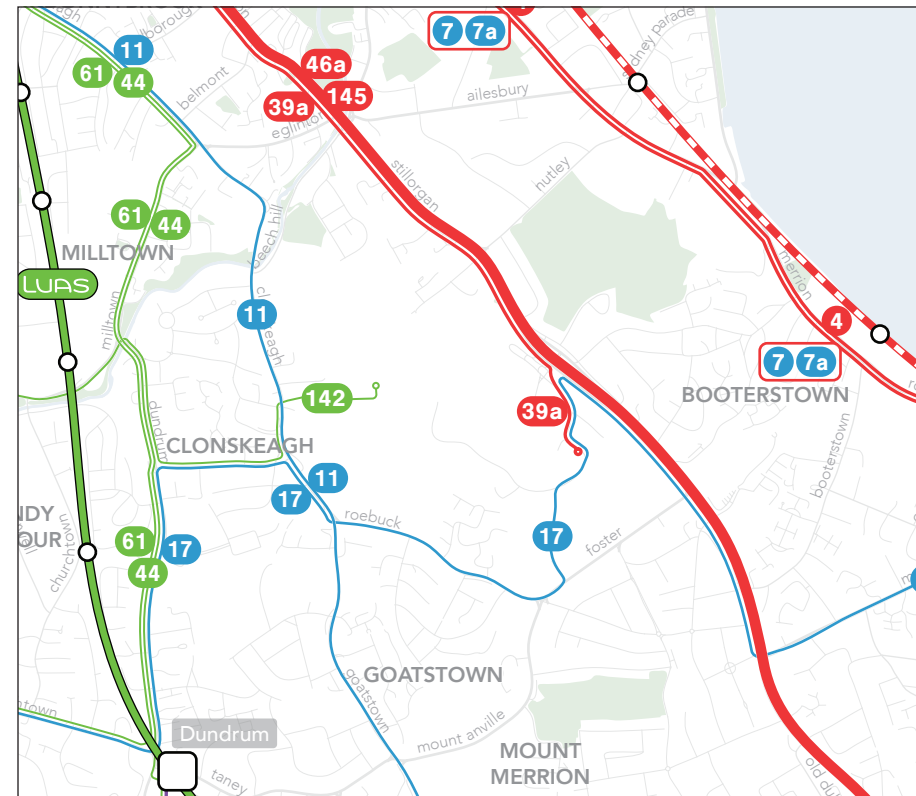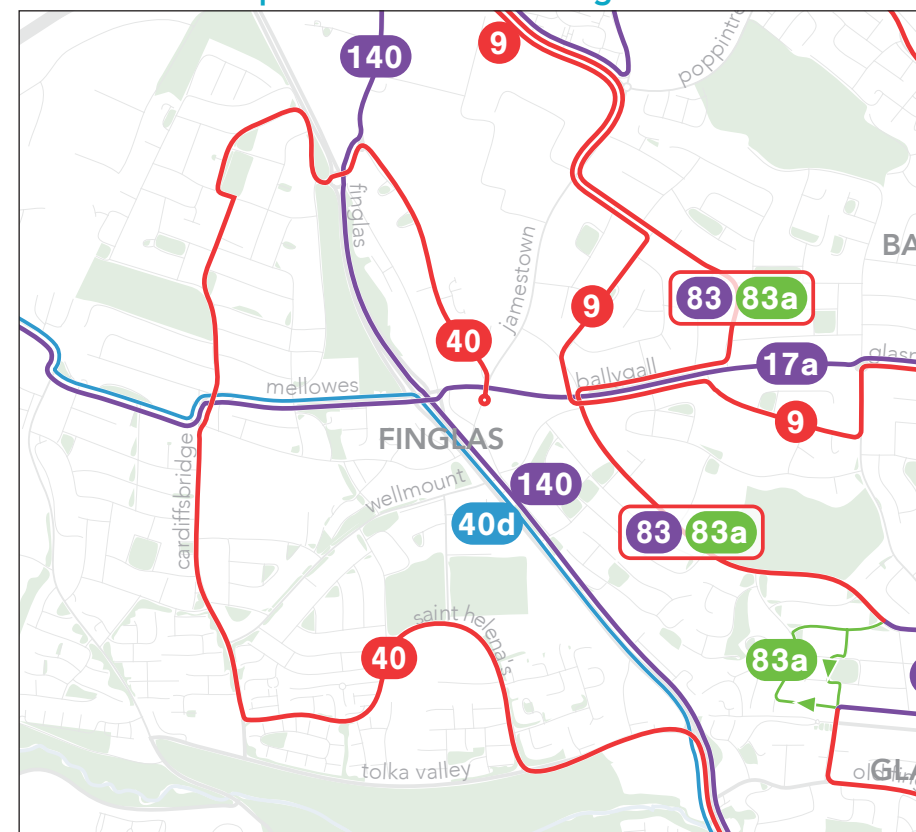**Figure 38: In southeast Dublin, straight roads allows bus routes to be linear while serving all neighbourhoods.**

Figure 39: In Finglas, the road network forces bus routes off the most direct path to serve each neighbourhood.

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

In Finglas, however, the most direct path to the city centre is taken by the pedestrian-unfriendly Finglas Bypass. This means Finglas' main radial bus routes are constrained to operate on circuitous paths through neighbourhoods.

*As a result, **achieving an equivalent level of service will always require more resources in Finglas than in southeast 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 routes traverse long stretches with weak demand in between.

Figure 40: The blue dots indicate continuous demand along Malahide Road, based on a count of bus boardings.
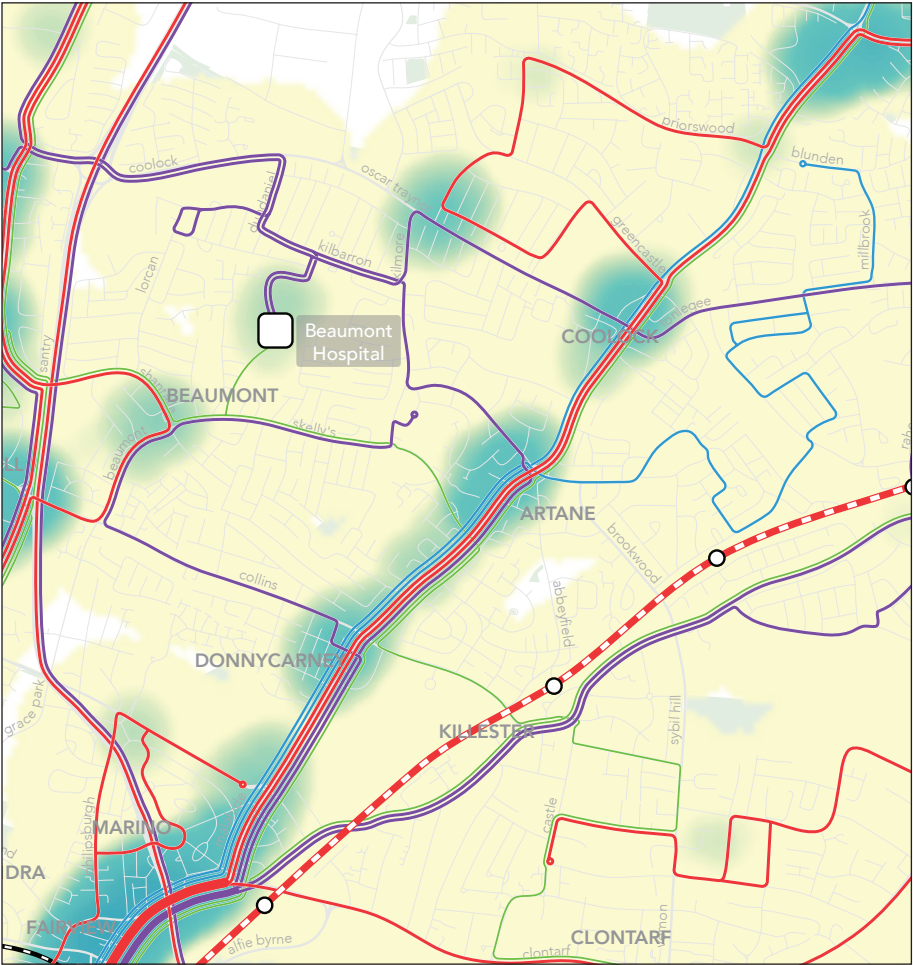
Because of the continuous development and steady demand throughout the corridor, any bus route on Malahide Road will serve a higher number of boardings per kilometre than a comparable service on Navan Road, which connects high-demand centres through a long area of low demand.

Figure 41: The same measure shows long gaps in demand along Navan Road, largely reflecting corresponding gaps in development.
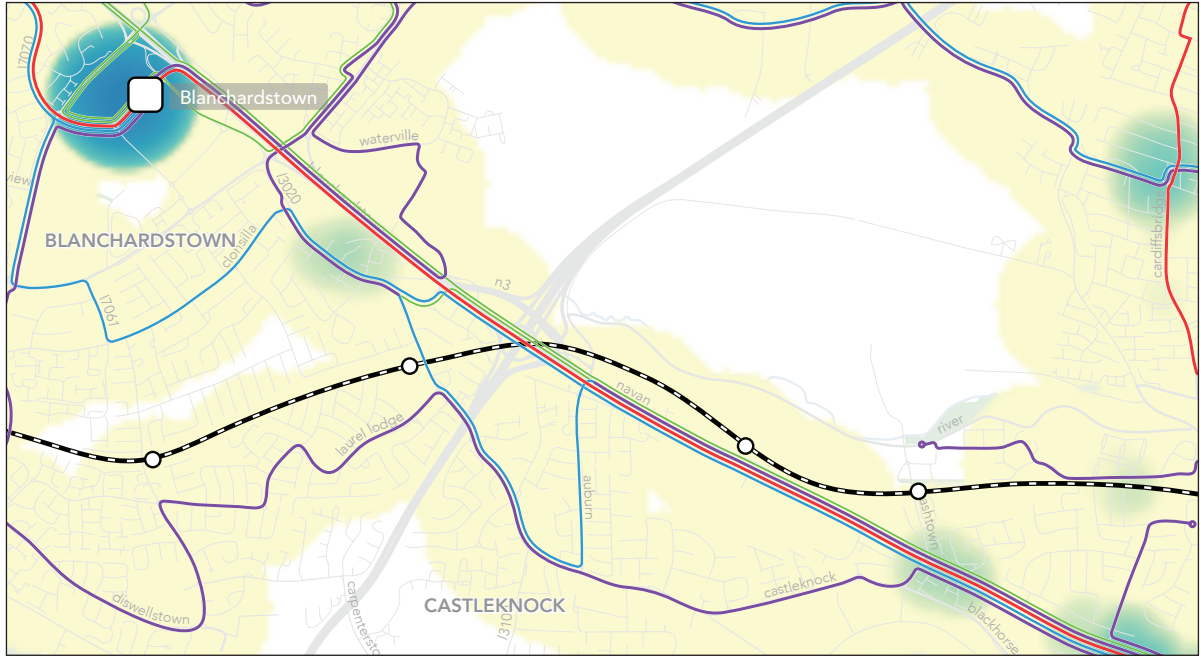
Summary

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, walkability, 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.