BUS CONNECTS

TRANSFORMING CITY BUS SERVICES

NTA

Údarás Náisiúnta Iompair
National Transport Authority

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 a map of where one could get to, from a particular point, on public transport plus walking. This type of map, called an isochrone (see below), is a simple example.

From a given starting point, the map shows a shape that includes all the places someone could be in 30, 45, or 60 minutes, by walking, waiting and using public transport.

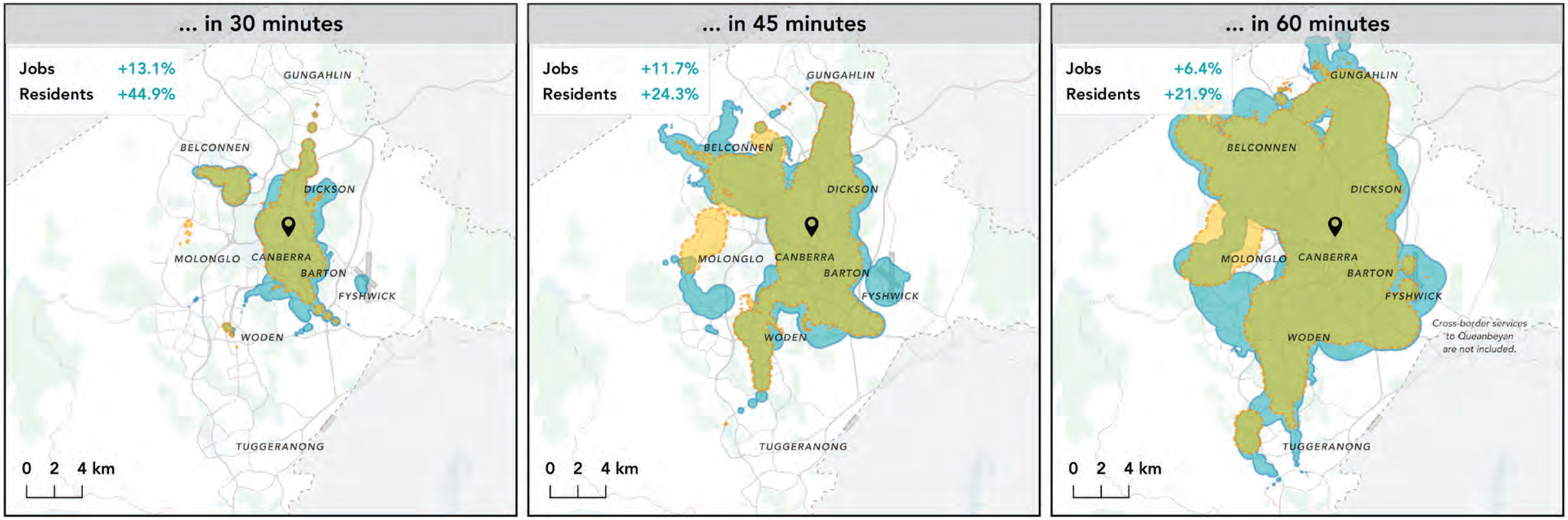
A bigger shape means on the map means it's possible to reach more places in a reasonable amount of time, which means people are more likely to find public transport useful for more purposes. We can roughly measure the level of usefulness of the service not just by the size of the shape but by looking at how many useful destinations – jobs, shopping, etc. – are inside each shape, and how that number grows or shrinks depending on the network design.

Beyond usefulness, these diagrams show the level of personal freedom afforded by the public transport network. The potential to expand personal 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 many external factors including economic conditions, the costs of car ownership, petrol prices, and others.

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 provides the foundation for why patronage might increase. And the result is true regardless of our assumptions about culture, behaviour or economics, whose effects are not reliably predictable.

> *To **maximise freedom and opportunity** for the greatest possible number of people, a public transport network must:*
>
> - *deploy **frequent service,***
> - *with optimal **speed** and **reliability**,*
> - *following **favourable patterns in the built environment**.*

Figure 31: The maps below are examples of isochrones. They compare how far one can travel using an existing network (yellow) versus a proposed network (blue) in the indicated amount of time (30, 45 or 60 minutes). In this case the proposed network would increase the number of destinations reachable. As such, it's likely the proposed network will be more useful and attract higher patronage.



Why Frequency Comes First

Patronage is influenced by many service features, including speed and reliability, but the dominant factor is frequency. Frequency is the number of minutes between buses (or trains) on a route, which determines waiting time.

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 it does not reduce the amount of time you are not on the move.
- **Frequency makes connections easy**, which makes it possible for a cluster of public transport routes to become a network. A route without good connections is useful only fro travel along that route. A network of frequent routes can make it easy to travel all over the city.
- **Frequency is a backup for some problems of reliability.** If a vehicle breaks down or is late, frequency means another will be along soon.

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

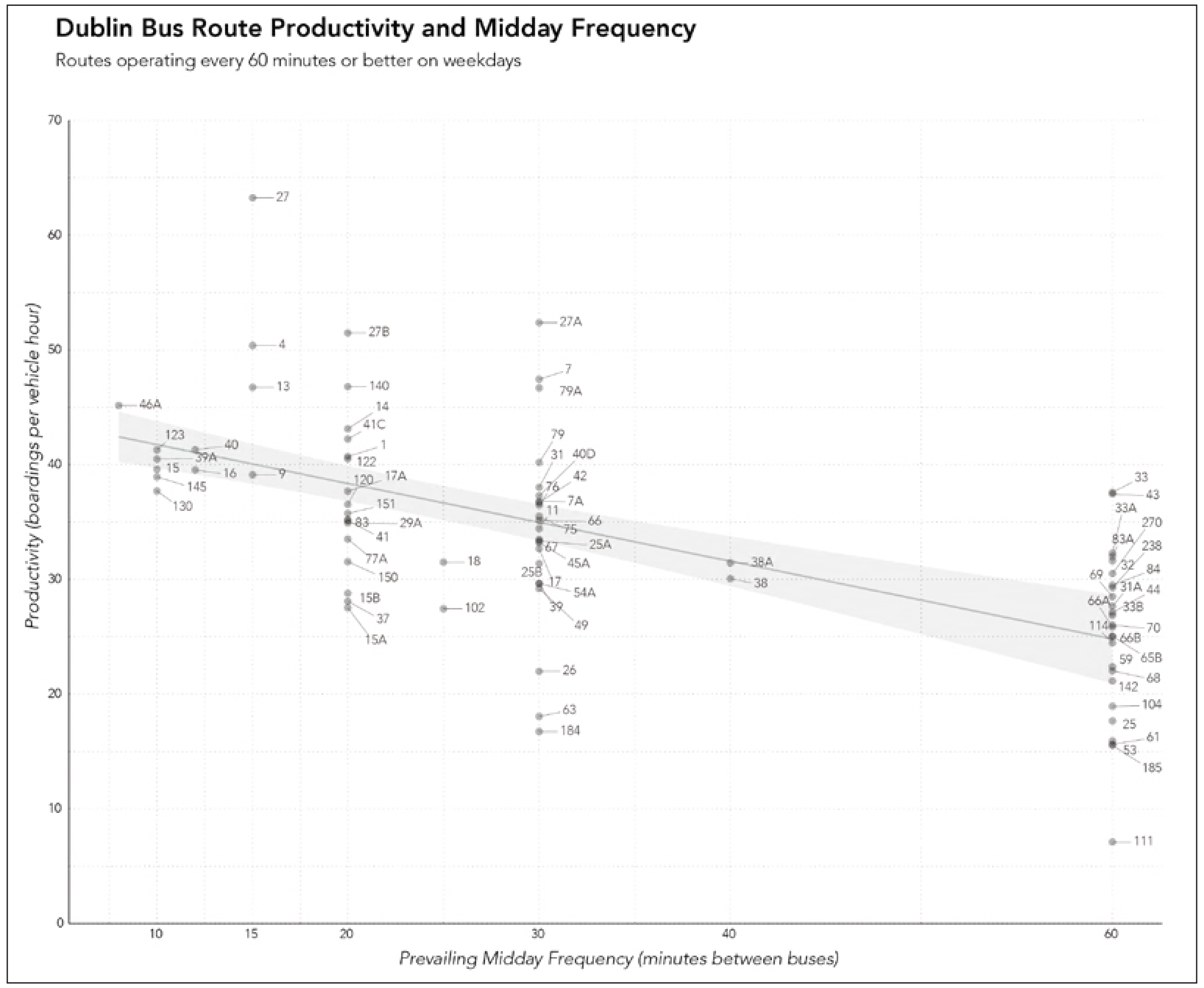
The graph below to the left shows a dot for each Dublin Bus route, with the x-axis indicating frequency and the y-axis indicating productivity (i.e. the number of bus boardings divided by the number of bus hours on the road). High frequency means a low elapsed time between consecutive trips, so it is shown to the left. The graph below to the right sows the same relationship for routes in 24 North American cities.

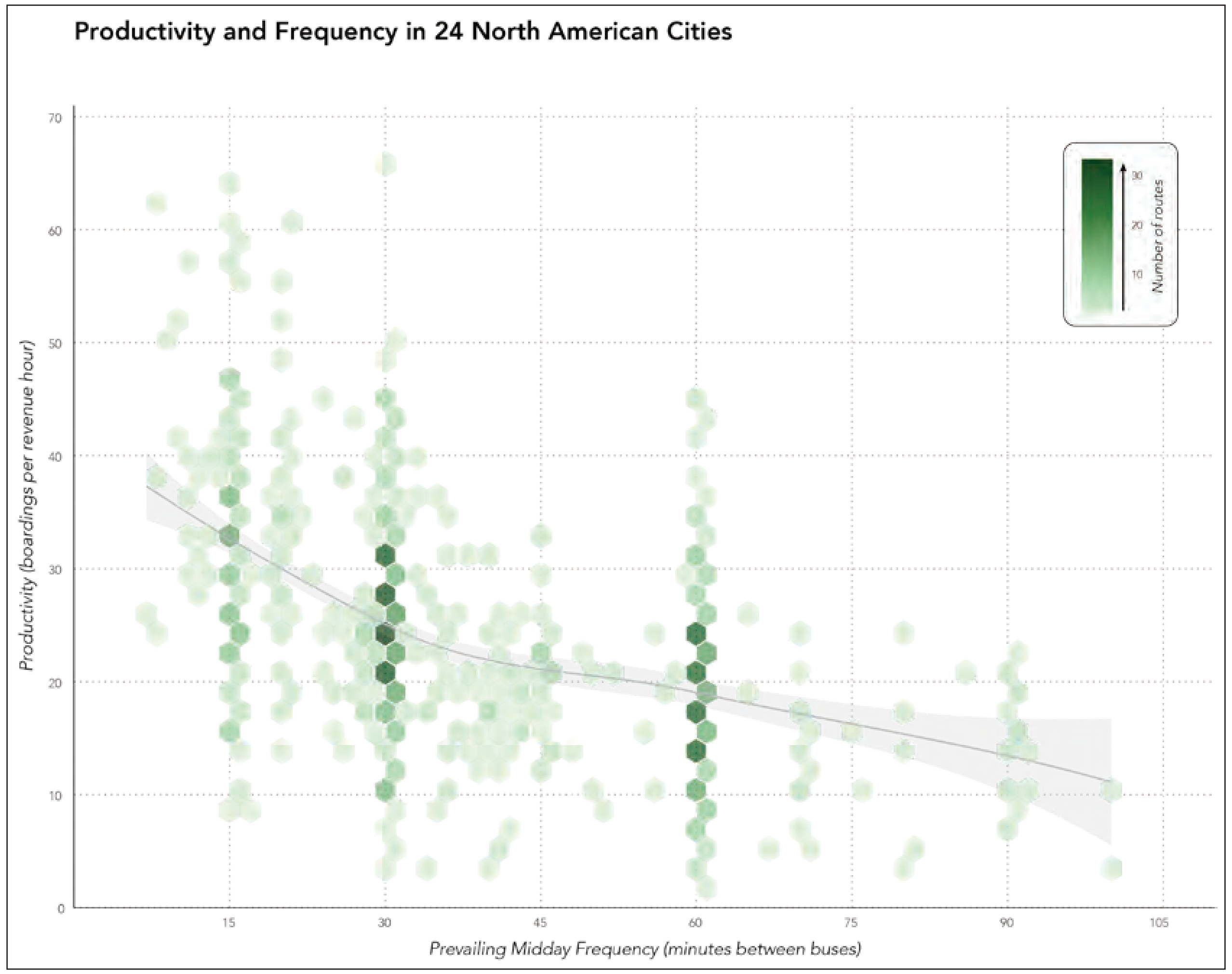
In both cases, **higher frequency is generally associated with higher productivity**. In other words, this is not a feature that is specific to Dublin or any particular place, but it is observable in a wide variety of cities.

The effect is slightly less obvious in the Dublin data. This is likely because many infrequent routes begin in more isolated areas and then join a main road to City Centre where service is overall very frequent. On the main road, people often take whichever bus comes first. As a result, there is less difference between frequent and infrequent routes than one might otherwise notice.

These graphs are more remarkable than they first look, because higher frequency means a higher quantity of service. So one might expect the curve to be flat or even descending as frequency increases. **This shows that higher frequency tends to deliver more patronage than would be expected just by the increase in service hours.**

Figure 32: The graphs below compare the frequency of bus routes to their productivity (number of people getting on the bus in the average hour of service). The graph on the left shows this relationship in Dublin, and the graph on the right shows the relationship in 24 other cities. In both cases, services that are more frequent are more productive, meaning they experience much higher patronage.





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 while making efficient use of public resources, a public transport service must also focus on places that are geometrically favourable to its success.

The following factors are critical:

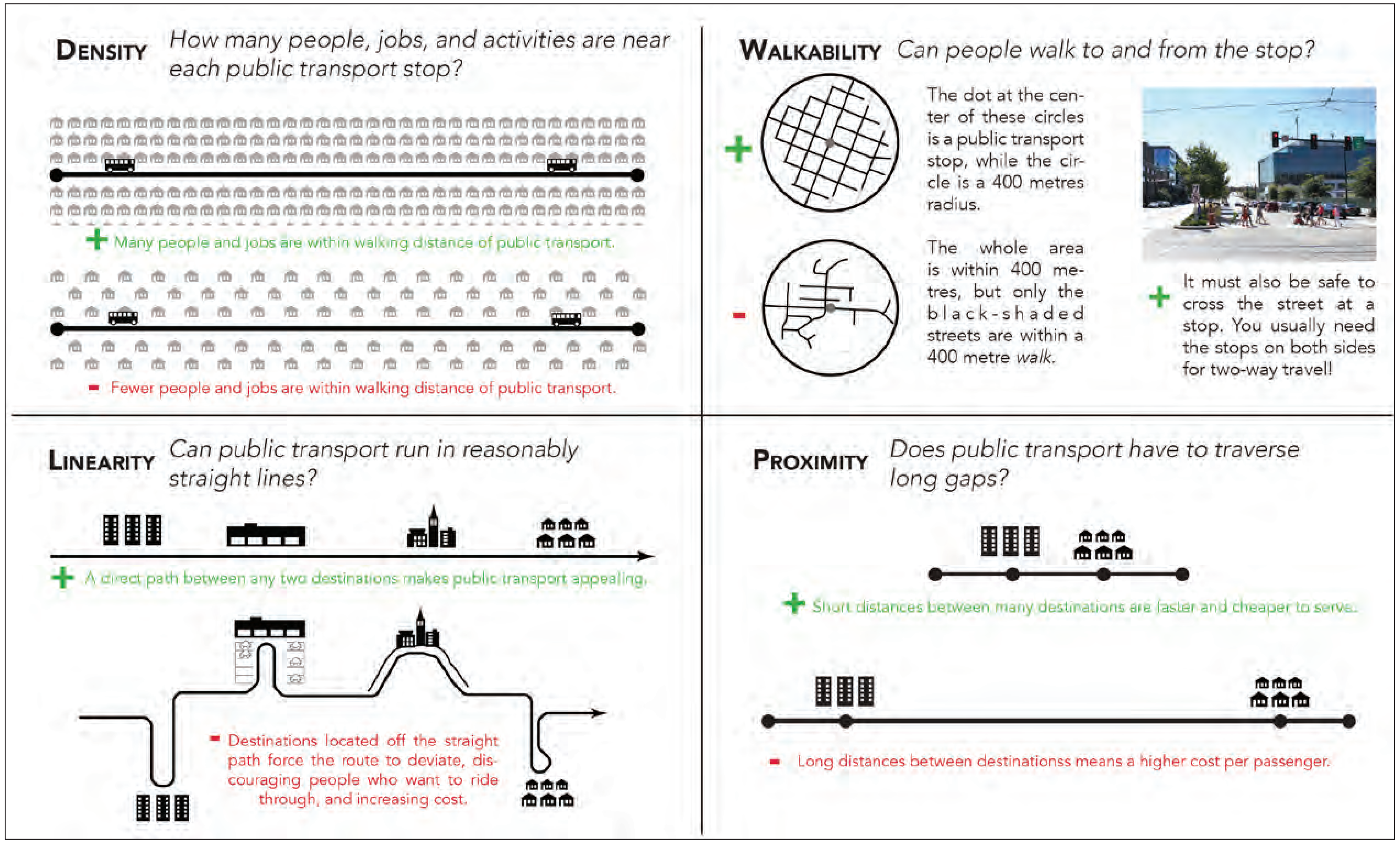
- **Density.** Density determines the number of people and destinations near any public transport stop, which is the primary determinant of how many people might possible use the service.
- **Walkability.** If more people can safely and comfortably walk to a bus stop (and cross the street to access both directions of service), the service becomes useful to more people. This depends primarily on both the shape of the pedestrian network (are many connections available, making it easy to walk from place to place?). It also depends on the condition of the pedestrian network, including but not limited to the availability and quality of footpaths, lighting, and cross-walks.
- **Linearity.** Where a bus can reach major destinations by running in straight lines (rather than weaving into and out of various estates, shopping malls and other major destinations located off of main roads), bus service is faster and more efficient. It's also less frustrating for through-riders, whose journeys are otherwise delayed by each deviation.
- **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 to provide less service where the geometry is unfavourable.

However, in this study, we stipulate that all areas now covered will continue to be, though not necessarily on the same exact street or at the same exact stop. We have focused on maximising patronage within that constraint.

Figure 33: The diagrams below show how the built environment contributes to public transport patronage.



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

- **Lack of pedestrian 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 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 with very different density and walkability characteristics.

- **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. 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 between Terenure and Rathfarnham village is dominated by semi-detached and detached houses, with almost no commercial uses present. 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 between Terenure and Rathfarnham, even if those two services operate at the same frequency, for the same hours, and serve all of the same other places.*

Figure 34: The aerial photo below shows the area around Drumcondra Station, which is dense and highly walkable.

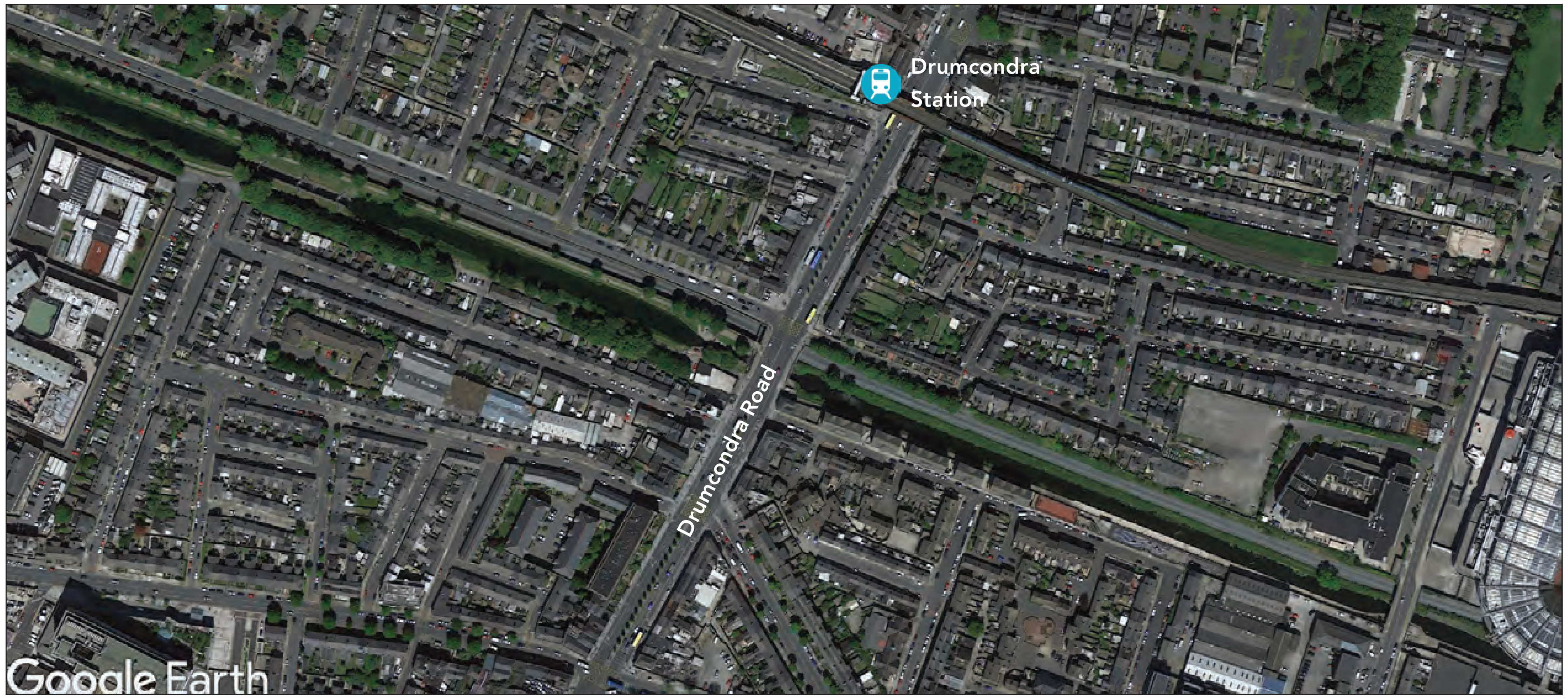


Figure 35: The aerial photo below shows the area between Terenure and Rathfarnham village, with relatively low density and limited walkability.

Examples from Dublin: Linearity

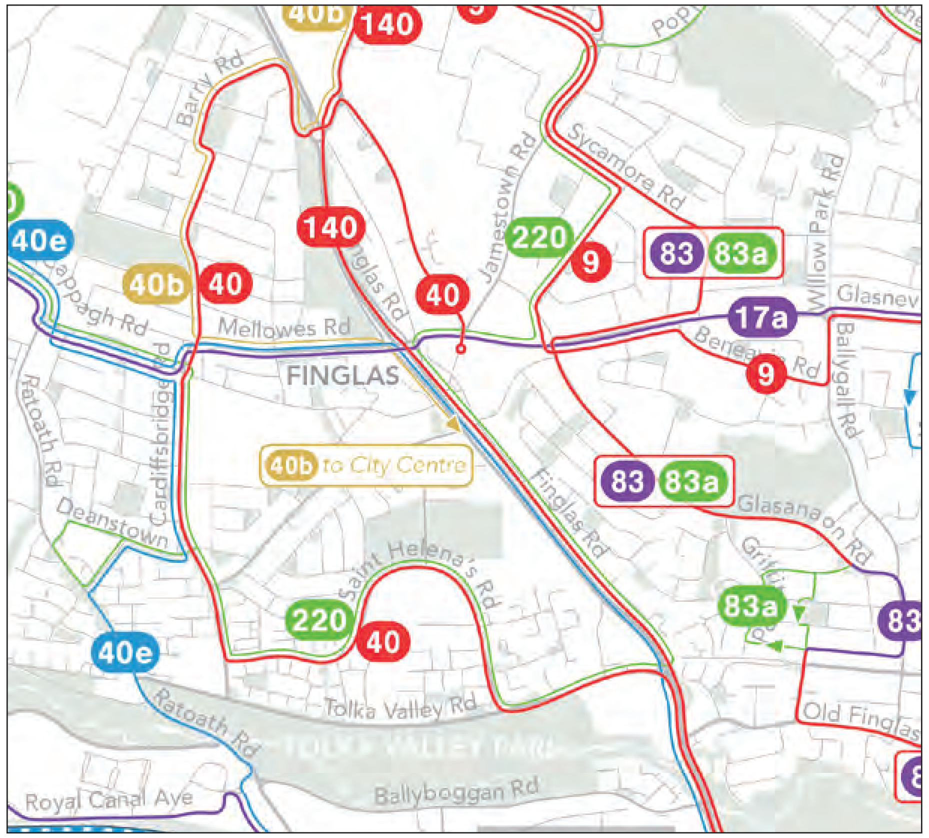
Because of differences in historic land use and road network decisions, some parts of Dublin are served by much more linear radial bus services than others. The following examples illustrate this:

- **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.
  - » 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 36: In southeast Dublin, straight roads allows main bus routes to be linear while serving all neighbourhoods.

Figure 37: 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, or to skip many important places to go fast on the bypass..

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 demand. The following examples illustrate this:

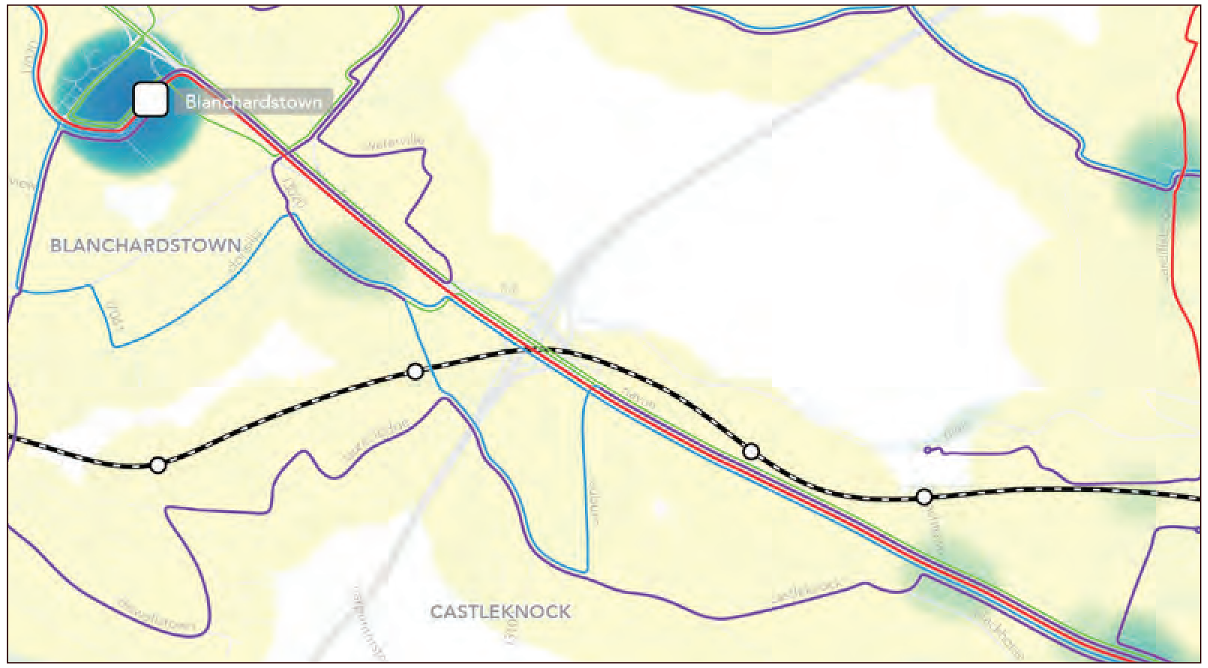
- **More Continuity:** Based on the measured number of weekday bus boardings, the Malahide Road exhibits a steady level of demand from Fairview to Clare Hall Road. Few of the areas in this corridor have extremely high demand, but there is consistent and significant demand throughout.

Figure 38: 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 the 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.

- **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 between those two (low-density residential neighbourhoods that don't extend far from the main road, and far more empty land) means that bus routes traverse long stretches with weak demand in between.

Figure 39: 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 – which 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.