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Level of Service and the Transit Neighbourhood - observations from Dublin City and Suburbs

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ABSTRACT

Few studies have looked at the impact Level-of-Service (LOS) might have on the distances people walk to public transport. The relationship, if any, has implications for transit-oriented-development and the viability of different transit modes serving suburban areas. This paper examines pedestrian catchment areas and LOS at across a light rail, a metro rail and two bus corridors in Dublin. Over 700 public transport users were surveyed at 17 stops and their trip origin identified. Catchment areas for bus services with high levels of service were found to be comparable and often greater than those for LRT or metro rail. 65% of all bus trip-origins are more than 500m from stops. A standard distance analysis suggests natural catchment limits of over 1400m for high quality bus, significantly greater than light rail and metro rail of similar service levels. The shape of transit catchment areas are also distinctive and appear to be most influenced by: network density, stopping patterns, urban gravity and quality of service. While further analysis is recommended, public transport users in the Greater Dublin Area appear more influenced by level-of-service than by modal type when deciding how far they are prepared to walk to public transport.

1. Introduction

This research queries the behaviour of 700+ public transport users in Dublin at a range of public transport stops around the city and analyses the factors which influence their propensity to travel to different modes of public transport. The research aims to measure actual pedestrian catchment areas around public transport hubs and the factors which influence their extent.

Relatively few studies, to date, have looked at the impact Level-of-Service (LOS) might have on the distances people are prepared to walk to public transport. The relationship, if any, has implications for transit-oriented-development insofar as the

natural pedestrian catchment area is affected. The viability of different transit modes serving suburban areas is also affected if, for example, customers have a natural bias towards a particular mode, irrespective of the quality of service provided.

Much received wisdom in planning implies a catchment limit of 400-500m for bus corridors and 800-1000m for rail (Ker & Ginn, 2003). As an example, Irish national planning guidance recommends that “increased densities should be promoted within 500m walking distance of a bus stop, or within 1km of a light rail stop or rail station” (DoEHLG, 2009). This would imply, if true, a natural inferiority of one transport mode over another, irrespective of levels of service or other potentially critical factors. This walking catchment guidance is generally utilised by planners in Ireland as a “Euclidian” circle, with a 1km radius, on a map centred on a rail station. There is very little documented research on the origins or relevance of this method and yet this seemingly unproven rule of thumb is the basis for many planning policies in Ireland and elsewhere (Daniels & Mulley, 2013; DoEHLG, 2009; Harrison et al, 2012).

2. Planning Context and Overview of Literature

Recently, a number of papers have examined the propensity to walk to public transport and the factors which contribute to catchment area size. This reflects a growing interest in the performance of surface passenger transport systems and their relationship with the urban fabric which they serve (Dittmar & Gething, 2008; Munoz & Paget-Seekins, 2015).

A study examining walkability to Bus Rapid Transit (BRT) stations in Jinan, China, analysed the extent of the pedestrian service area and environmental factors which influence its scope and size (Jiang, Christopher Zegras, & Mehndiratta, 2012). The authors assert that “knowing the size of a station catchment area is important to transit system planning and operations since the station area largely determines the number of final origins and destinations, thus potential demand, the system will serve” (Jiang et al., 2012). The paper specifically explores the relationship between walking catchment areas and built environment and urban design factors. An ordinary least squares regression demonstrates that people are likely to walk materially further distances under more amenable urban environmental conditions. While the study controlled for trip-maker and trip characteristics there was no specific examination of level-of-service. One interesting finding was that the station-type with the largest catchment was the terminus station and the authors acknowledged a potential relationship with service reliability, without building this in as a specific variable.

Mulley and Daniels (2013) also examine walking distances to public transport, based on a household travel survey in Sydney, Australia. They find that the mode of public transport is the most important determinant of walking distance and that people walk farther to the train than the bus. It is observed that there are clearly different supply levels for either mode. Sydney’s rail network has 307 stations but there are over 35,000 bus stops within the same area. Land use also appears

relevant as “train stations are more likely to be immediately surrounded by non-residential land uses in their close catchment compared to bus stops” (Daniels & Mulley, 2013).

Ker and Ginn (2003) show that a one size fits all catchment distance is irrelevant even within a single city as distances walked to stations vary across urban bands. A key finding is that people are found to walk further than generally held rules of thumb. El-Geneidy et al (2014), in a study of walking distance to transit in Montreal, Canada, also find that the commonly-used buffers are lacking in nuance and that service areas are a factor both of the type of service offered, the environmental characteristics and trip-maker characteristics.

The idea of the transit neighbourhood is probably as old as that of modern town planning itself. Movements such as the Victorian tramcar suburbs, the garden cities and metro towns were early exponents of the idea (Hall, 1988). The contemporary notion of the transit town or neighbourhood is explored extensively, by scholars such as Calthorpe, Dittmar and others (Calthorpe, 1993; Dittmar & Ohland, 2012).

The propensity for people to walk to public transport also has wider implications for health and walkability. A surge of renewed interest in this field, according to Talen & Koschinsky (2013), is due to the walkable neighbourhood being seen as “a key factor in the promotion of health, economic and communitarian goals”.

The effectiveness of public transport network design itself is considered by a more select number of key thinkers, including Mees, Nielsen, and Walker (Mees, 2010; Nielsen, 2005; Walker, 2012). Each of these attests particularly to the role and impact of service levels in delivering mode share and patronage. While an investigation into the extent of pedestrian catchment areas is missing from many of these studies, Nielsen and Lange (2008) suggest that simplified networks and higher quality services are essential to network success “even if this in many cases will result in longer walking distances for some customers”.

A variety of papers, therefore, exist exploring categories of factors, including: user-related issues; environmental factors; transit-related issues, etc. (Daniels & Mulley, 2013; El-Geneidy et al., 2014; Jiang et al., 2012). Across this growing number of studies into the transit service area, it appears that many are seeing mode as a critical choice factor, without questioning the relevance and variability of level-of-service within and between respective modes. For example, while bus in general terms can be classified as a modal type, this often fails to recognise different levels of bus system design (such as Bus Rapid Transit (BRT), Bus with High Level of Service (BHLS), other local bus service types, etc.) which often have distinctive level-of-service characteristics.

Crucially though, the extent of any spatial relationship between catchment areas and service levels remains poorly explored, nor does there appear to be much analysis as to how such a relationship could be quantified.

3. Dublin Policy Context

The Greater Dublin Area may provide a useful case study in being an urban transport market with median levels of public transport patronage¹, but which is predominantly dependant on bus for the bulk of ridership. Consequently, a range of service levels prevail, from very high (more than a bus per minute on key corridors) to very low, (two or less buses per hour) serving particular districts. This presents a good opportunity to analyse, in relative terms, the spatial relationship between level of service and propensity to utilise public transport.

The bus network in Dublin is also in a state of transition. A route review programme, “Network Direct”, was implemented between 2009 and 2013 and comprised a large-scale reorganisation of routes by the main (semi-state) operator, Dublin Bus. The number of buses in service reduced from 1300 to fewer than 800. The overall number of routes was reduced from over 200 to 110, while patronage was largely held at a steady state. 27 of these routes now carry an estimated 70% or all Dublin Bus trips (O'Connor, 2015). A further review is currently being developed by the passenger transport authority, and a launch of a consultation programme, entitled “BusConnects”, was announced in May 2017 (NTA, 2017; O'Connor, 2017). As such, an investigation into catchment areas may have local as well as more general relevance.

4. Collation of Existing Studies

The paper brings together three sets of existing studies which have looked at catchment areas around public transport stops in the Greater Dublin Area in varying contexts. The research builds on a number of papers previously submitted to the Proceedings of the Irish Transport Research Network (Harrison & O'Connor, 2012; O'Connor & Kavanagh, 2014a, 2014b), which detail the three studies. Within these studies are examined pedestrian catchment areas and level-of-service across two rail corridors (one light rail and one metro rail), as well as along two “quality bus corridors” in the Greater Dublin Area.

4.1 Study A: DART metro rail and LUAS LRT study

In 2012 a study examined a light rail transit (LRT) corridor and a metro rail corridor on the south-side of Dublin (Harrison & O'Connor, 2012). The study set out explicitly to investigate the applicability or otherwise of Euclidian distances to determine transit catchments. The study also posited that conventional catchment thresholds are routinely misleading. In addition to its core conclusions, the study included a set of trip origin distribution maps. These displayed actual walking catchment areas for four LRT and four metro rail public transport stops.

The focus of the study was an LRT corridor (the “LUAS Green” Line) and a metro rail corridor (the “DART” service) in Dublin. These networks were chosen as both

¹ <http://www.cso.ie/en/census/census2016reports/> According to the 2016 Census, morning peak hour traffic in Dublin City and suburbs comprised 23% public transport, of which 15% was by bus

are substantively parallel, fixed line rail networks that run through comparable socio-economic areas of south Dublin city, the DART rail line being less frequent but having a higher carrying capacity than the LUAS light rail line.

The study concluded that a one size fits all 1km walking catchment distance for all rail stations is an inadequate measure to determine a station's true catchment population. Even though the 1km distance appeared accurate in relation to certain stations it either underestimated or overestimated the distances rail users were prepared to walk at other stations. Furthermore, by mapping the real walking routes of pedestrians to a station's entrance using the ArcGIS Network tool, much more accurate information is seen to be produced on a station's catchment than when using the Euclidean method. This suggests that new, more specific, walkable catchment distances should be used based on the actual urban grain instead of the current generic 1km for all rail stations. The research is corroborated by other international studies with similar findings (Alshalalfah & Shalaby, 2007; Ker & Ginn, 2003; O'Sullivan & Morrall, 1996).

4.2 Study B: Stillorgan Quality Bus Corridor

The evidence from the initial 2012 study illustrated the validity of examining actual network catchment areas around public transport hubs. A gap was identified, insofar as only rail corridors had been examined. In 2014, an appraisal was carried out of the Stillorgan Quality Bus Corridor (QBC) (O'Connor & Kavanagh, 2014b). The Stillorgan QBC is a high frequency bus corridor with good running priority along most of its length. It also runs in between and parallel to the corridors in Study A.

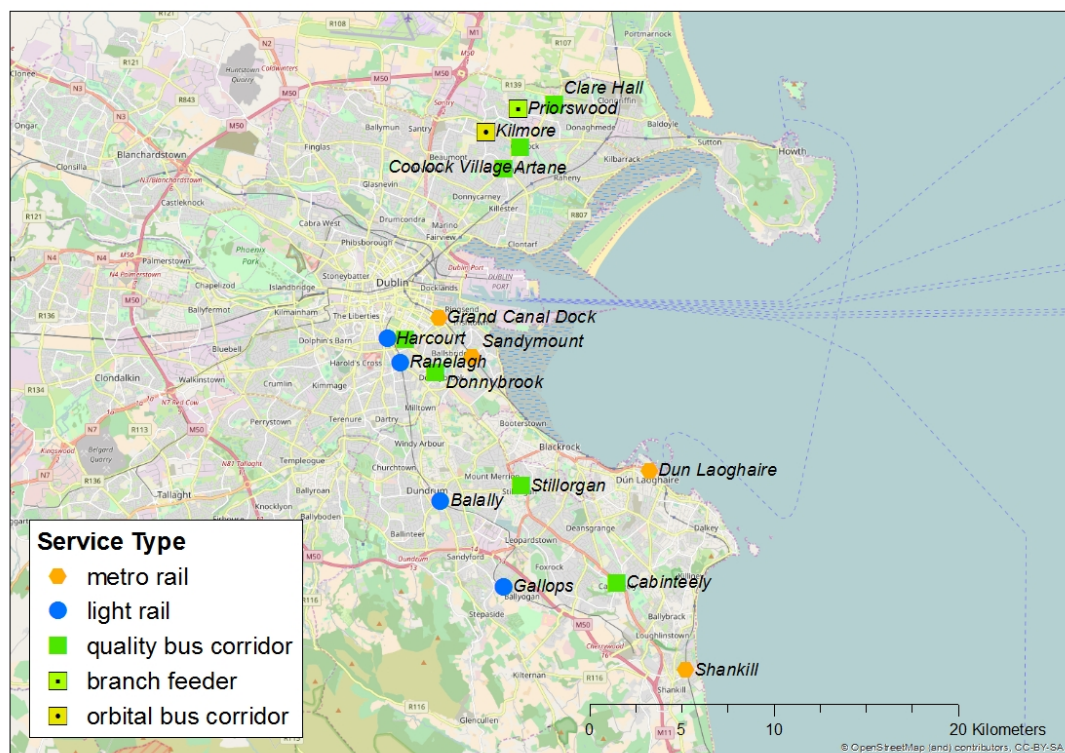


Figure 1: Surveyed Public Transport Stops by Service Type

For both Studies A and B, the city was split into four bands that were comparable in relation to distance from the city centre, urban grain, service provision and public transport availability. The established urban bands included: *urban; outer urban, inner suburban and outer suburban* (Harrison & O'Connor, 2012). One station per corridor was selected in each band.

4.3 Study C: Malahide Quality Bus Corridor

Also in 2014, a similar study was undertaken on the Malahide QBC, a bus corridor on the north side of Dublin city (O'Connor & Kavanagh, 2014a), which itself has been profiled in a report on "bus with high level of service" systems (ESF/COST, 2011). This study formed part of a wider, community-based research programme, the "Northside Partnership Healthy Communities" Project, being steered by Northside Partnership, a local partnership company with a social inclusion mission in a disadvantaged part of the north-east city (O'Connor, Borscheid, & Reid, 2013). The "Healthy Communities" study area is directly adjacent to the Malahide QBC which accesses the city centre. It is served by a number of branch (or local) feeder services. It also connects with an orbital service, the "17A" route, which links to other centres in north Dublin. This offered two particular opportunities. Firstly, to carry out an appraisal of public transport catchment areas in a part of the city which demonstrates levels of disadvantage, particularly in comparison to the areas examined in Studies A and B. Secondly, the study examined a number of services with a lower Level-of-Service profile, including branch feeder, local and orbital services.

5. Survey Methodology and Data Collection

Across the three studies 733 public transport users were surveyed at a total of 17 public transport stops. Each stop was chosen to represent a particular corridor- and service-type. A corridor can be, for example, the Malahide Quality Bus Corridor and its environs. A Service type can be either metro rail, LRT, QBC, orbital bus or feeder bus. The location of surveyed stops is shown in Figure 1 above. The stops, their service types and number of surveys collected at each are set out in Table 1 further below.

The primary form of data collection was field survey, through the use of in-person questionnaires, targeting individual users waiting at public transport stops. Bus surveys (Studies B and C) were kept short (less than 2 minutes) and people had discretionary time while waiting, which they were generally willing to share. Sample sizes of 35% of all users were recorded as part of the bus corridor surveys, where an accompanying boarding/alighting survey was conducted.

A target quota of 50 users was set for each stop, or a maximum survey time of 2 hours if the target quota could not be reached. Surveys were mostly carried out between 08.00 and 10.00 AM. The quota targets were easily met at the rail stops and most of the QBC stops. Quotas were too high on the orbital and local stops, relative to the number of passengers actually using these stops, but an adequate quantum was sampled.

In order to establish the catchment area, users were queried as to their absolute trip origin. The users were prompted, if necessary, for a specific street- or estate-name. Users were also queried as to their mode of arrival to the stop and their mode of onward travel (after using the service). Various other coding data was collected (ticket-type, gender, age-group, etc.). Finally users were asked about their perceptions of service levels on the service they were boarding.

A parallel operational survey, carried out by a second enumerator, accompanied the bus surveys. At each stop, the number of services during each time period was counted. This yields a headway or frequency. The number of people boarding and alighting at each stop was also counted.

The rail corridor surveys (Study A), which were carried out initially as part of an undergraduate thesis research project, collected additional data points around stated preference and perceived acceptable distances, details of which are available in the respective paper (Harrison & O'Connor, 2012).

6. Levels of Service Appraisal

Whereas one aspect of this research relates to the pedestrian catchment area of transit hubs, the other side of the research is the transit level of service. This study is interested in catchment areas across a diversity of service types (LRT, QBC, etc.). Therefore a common understanding of Level of Service (LOS) is desirable.

A widening range of LOS appraisal systems exist, particularly with the burgeoning success of BRT systems worldwide. Traditional and conventionally accepted systems exist, such as the Transit Capacity and Quality of Service Manual (TRB, 2003), the TRL Demand for Travel Report (Paulley et al., 2006) and the EU Quattro (European Standard EN13816) Project (CEN, 2002). These are now being supplemented with newer performance appraisal systems such as the ITDP BRT Standard (ITDP, 2016).

For the purposes of this study, the LOS on the Malahide Corridor has been previously assessed in the context of the Transportation Research Board's Transit Capacity and Quality of Service Manual (TCQSM) (Caulfield & O'Mahony, 2004). The TCQSM provides a multi-criteria toolkit for measuring the quality of a public transport service. Principle criteria include: Hours of Service; Relative Travel Time; Service Frequency, etc. Overall, in the 2003 assessment, the Malahide corridor scored highly in terms of all measures applied, yielding TCQSM scores of LOS A-C, and in most cases A-B. This current assessment similarly finds the QBC services scoring highly in terms of respective TCQSM LOS criteria.

As part of the bus corridor surveys the number of buses per hour serving each stop location was recorded. All QBC stops could be categorised as LOS A in the context of the TCQSM standard for frequency. There was, however, a difference in Level of Service between the QBCs and non-QBC routes. On the orbital route, at Kilmore, 4-

5 buses per hour were recorded (in both directions). At the Priorswood stop, a local branch route, 5 (inbound) buses per hour were recorded.

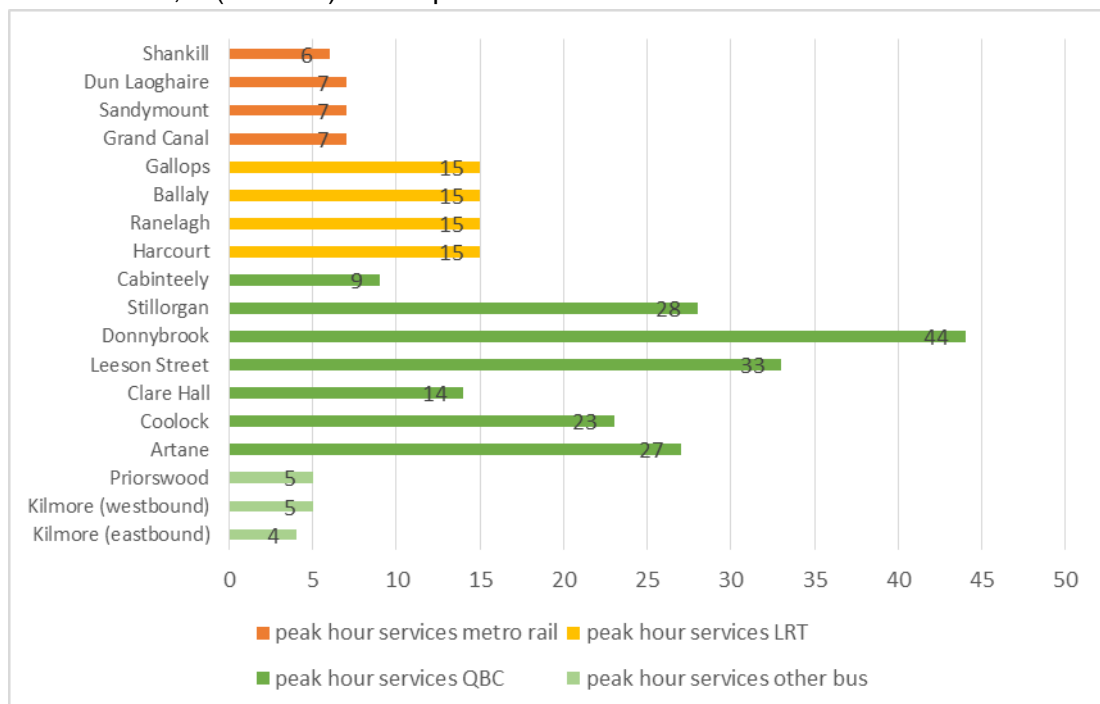


Figure 2: Service frequency by stop location

Level-of-Service was not recorded as part of the (Study A) rail corridors, however both the LRT service and the metro rail service would both attain a LOS A rating under the same criteria. Timetable records from the survey time period indicate a frequency of 15 trams per hour on the LRT service and 6-7 trains per hour on the metro rail service. Figure 2 shows the TCQSM Level of Service by stop location and service type.

7. Catchment Analysis

The surveys' main purpose was to establish the catchment area of public transport stops around Dublin. The surveyed stops and trip-origins of respective public transport users were coded into a geo-spatial database, using the ArcGIS 10.3.1 geographical information system (GIS). For convenience this was titled the "Dublin Networked Neighbourhood Database" (DNND) and it is envisaged this will provide the main spatial analytical framework for this and further related studies.

For each stop location within the DNND, a catchment distribution map was prepared showing the origin of each surveyed trip using the ArcGIS Network Analyst function. For the purposes of this study, non-walking trips to the stops were excluded in order to examine purely pedestrian catchments. 562 out of 733 surveyed trips are included in this pedestrian-only sample.

Stops were chosen to present a range of (a) service types and (b) levels-of-service. This allows a comparison of pedestrian catchment thresholds, firstly, across contrasting modes and, secondly, across contrasting levels-of-service. Table 1 provides a breakdown of the quantum of walking trips by corridor and stop.

Table 1 also shows three initial levels of analysis for each of the transit hubs surveyed: Mean Walked Distance; percentage of walking trips > 500m; and, 85th Percentile Distance.

Table 1: Surveyed stops by service type and distances

Service Type	Corridor	Stop	Urban Band	Level-of-Service (TCQSM)	Number of Users Surveyed	Number of Pedestrian Users Surveyed	Average Walked Distance (metres)	85th Percentile Distance (metres)	%age walking trips > 500m
Metro Rail	DART	Shankill	outer suburban	A	41	41	644	857	66%
	DART	Dun Laoghaire	inner suburban	A	31	31	637	904	61%
	DART	Sandymount	outer urban	A	48	48	486	881	37%
	DART	Grand Canal	inner urban	A	48	48	655	948	58%
					168	168	601	948	55%
LRT	LUAS	Gallops	outer suburban	A	35	35	470	1016	31%
	LUAS	Ballaly	inner suburban	A	30	30	587	867	67%
	LUAS	Ranelagh	outer urban	A	46	46	459	701	35%
	LUAS	Harcourt	inner urban	A	42	42	491	639	52%
					153	153	495	823	45%
QBC	Stillorgan	Cabinteely	outer suburban	A	25	21	888	1357	57%
	Stillorgan	Stillorgan	inner suburban	A	54	41	1156	1908	93%
	Stillorgan	Donnybrook	outer urban	A	45	41	506	618	29%
	Stillorgan	Leeson St	inner urban	A	21	18	919	1441	39%
	Malahide	Clare Hall	outer suburban	A	56	42	1058	1381	95%
	Malahide	Coolock Village	outer suburban	A	50	43	897	1233	72%
	Malahide	Artane	inner suburban	A	50	35	522	738	49%
					301	241	845	1417	65%
Branch feeder	Malahide	Priorswood	outer suburban	B	20	20	327	490	15%
					20	20			
Orbital service	17A	Kilmore	outer suburban	B	17	17	1022	1544	71%
					17	17			

Mean walked distance takes a simple mean average of all walking trips to the respective stop.

Percentage walking trips under 500m demonstrates what percentage of trips are less than 500m in length.

The 85th percentile is a widely used traffic statistical metric. Although most commonly used for speed-related issues, its purposes is to identify standard deviation at the upper end of a normal distribution. The 85th percentile value for travelling speeds is calculated starting with assuming a normal distribution. Half of the vehicles will have an operating speed below the average and 1 standard deviation of vehicles will travel at a higher, but still safe speed. The operating speed will approximately be equal to 84.1% (50% + 34.1). To ease the calculation, the value was conventionally rounded to 85%. For the purposes of this analysis, an approach also adopted by El-Geneidy et al (2014), this is regarded as an appropriate measure of the accessible or optimal service area for transit stops, an indicator, as it were, for the extent of the transit neighbourhood (or “networked neighbourhood” as it shall be posited later in this study).

7.1 Comparison across modes

In the first instance, it is interesting to make a comparison of catchment areas across modes, where there is a common or comparable level of service. 15 of the stops are classified as (TCQSM – frequency) LOS A. These include, on the southside of the city, four LRT stops, four QBC stops and four metro rail stops. On the north-side of the city three LOS A bus stops are included, on the “Malahide” QBC.

The south-side stops were located across each of the four urban zones identified (*inner urban, outer urban, inner suburban* and *outer suburban*). Two of the north-side stops are in the *outer suburban* zone and one in the *inner suburban* zone.

Across all of the LOS A stops the mean walked distance is greatest for bus (845m), followed by rail (601m) and then LRT (495m).

65% of bus trip-origins, 55% of metro rail trip-origins and 45% of LRT trip-origins are more than 500m from the transit stop.

An 85th percentile analysis indicates a catchment threshold range of 1400m for bus, 825m for LRT and 950m for metro rail, based on behaviour recorded across the three respective surveys in the Dublin area.

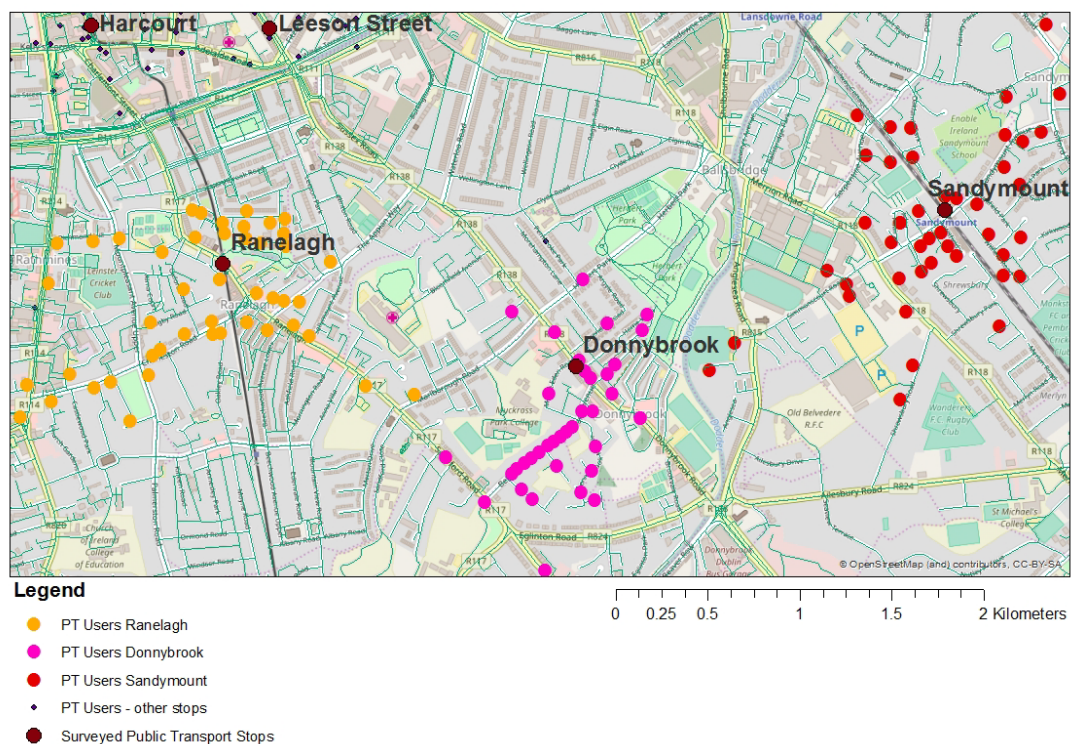


Figure 3: Ranelagh [LRT], Donnybrook [QBC] and Sandymount [metro rail] public transport user catchment areas

On aggregate, across all of the surveyed stops on these high level-of-service corridors, catchment areas for quality bus corridor appear greater than those for LRT or metro rail. This is most markedly in the *suburban* zones where bus catchments were comparatively far wider.

Figure 3 above shows the public transport user distributions for three stops in the *outer urban* zone. The Donnybrook bus stop, for example, has a comparable, though lower, catchment (618m) to its neighbouring LRT (701m) and metro rail (881m) stops within the same *outer urban* zone. The catchments are overlapping in places and a gradient, as the lands falls eastward to the sea, is at least visually relevant as a variable.

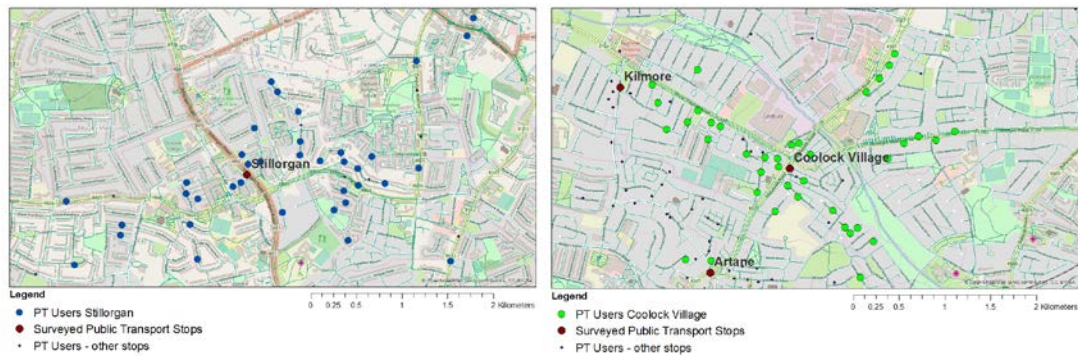


Figure 4: Stillorgnan [Stillorgnan QBC] and Coolock Village [Malahide QBC] catchment areas

Of interest is that, albeit within a relatively small sample of stops, there seems to be little if any influence of socio-economic well-being on catchment areas. The Stillorgnan QBC serves mostly socio-economically highly-stratified suburbs on the southside of the city. The Malahide QBC serves predominantly lower socio-economically stratified suburbs on the north side of the city. Figure 4 shows the public transport user distributions for a stop on the Stillorgnan QBC (Stillorgnan) and Malahide QBC (Coolock Village), both of which are broadly comparable in extent.

7.2 Comparison across Level-of-Service

Across the entire study sample only two transit stops were identified with (TCQSM – frequency) LOS B or lower. Both of these were within the Malahide QBC corridor catchment: one branch feeder service (Priorswood) and one orbital service (Kilmore). Figure 5 shows the public transport user distributions for Priorswood and Kilmore stops.

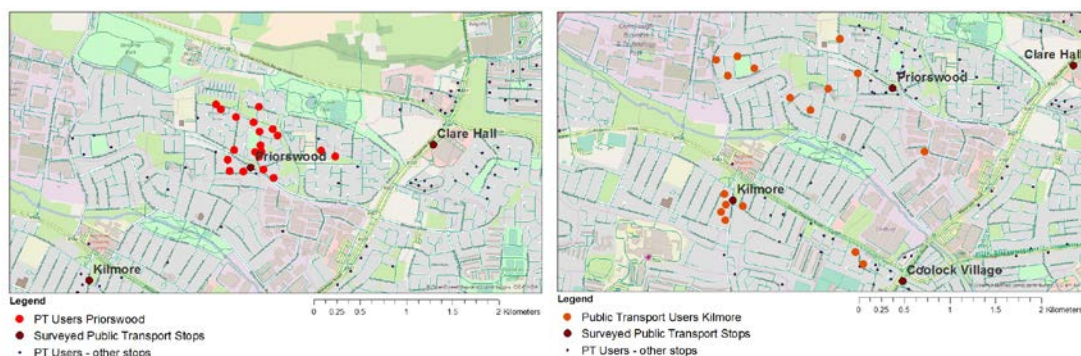


Figure 5: Priorswood [branch feeder] and Kilmore [orbital] catchment areas

At the Priorswood stop (served by the “27A” branch feeder service) the 85th percentile of trip origins is 490m. This stop at Priorswood, alone of all the transit stops surveyed, has a clearly defined walking catchment threshold of under 500m. While it is difficult to draw conclusions from such a small sample, it is noticeable that the stop with the lowest level of service has the smallest service area. It is the only transit stop that corresponds in any way to the conventionally held concept that bus service catchment areas are naturally under 4-500m.

At the Kilmore stop (served by the “17A” orbital service) by contrast, 71% of trip origins are 500m or greater. An 85th percentile analysis suggests a natural catchment threshold of 1,544m. The orbital service stop is also directionally biased, indicating possible catchment overlap with another stop. Beaumont Hospital, a short distance to the southwest, is a major trip attractor and may influence the catchment characteristics.

The orbital stop operates at a lower level-of-service than, for example, the QBCs, but it has a markedly wider catchment area. This may be as a result of a dearth of alternate orbital transport services, though examination of further such orbital-type services is warranted.

8. Patterns on a Map

The geo-spatial analysis also indicates that the shape of transit catchment areas are distinctive. In the majority of cases they are sharply dissimilar to the Euclidian catchment areas (which might be expected), but there are also dissimilarities with the network catchment areas.

8.1 The Euclidian and Network Catchment Area

The Euclidean method of measuring a transit station’s catchment, a circle on a map, is widely discredited in most literature; the failure of it to allow for natural and manmade obstacles means a more detailed method is generally recommended for accurate results (Ker & Ginn, 2003; Landex & Hansen, 2006). For these reasons it is not unexpected that the distribution of transit users for each stop is spatially dissimilar to the Euclidian buffer area. The ArcGIS Network Analyst function provides network-based spatial analysis tools for generating service areas. Many analysts of neighbourhood planning support the use of the Network Analyst approach to map the real routes travelled (Andersen & Landex, 2009; Barton, Grant, & Guise, 2003). The “network” service area can be described as the area bounded by the actual walkable distance from the transit stop utilising fully walkable pathways.

8.2 Examining the “Networked Neighbourhood”

Observations of actual walked catchment areas in Dublin (and potentially supported by evidence from other mapped studies of walking to transit (Jiang et al., 2012)) suggests that the actual walked catchment areas differs structurally from both the Euclidian and Network service areas. This implies the potential for a third type of catchment area definition: the “Networked Neighbourhood”. The “networked neighbourhood” might be described as the area surrounding a transit hub created by actual walking patterns of transit users, the *neighbourhood of people accessing the public transport network* as it were.

These “networked neighbourhoods” seem to be influenced by a variety of factors (other than simple distance from the stop), including: network density, stopping patterns, urban gravity, environmental factors and quality of service.

Figure 6 shows the Euclidian and network service areas (calculated using the ArcGIS Network Analyst function) for Harcourt, Stillorgan, Clare Hall and Shankill stops. These are shown with 1000m Euclidian distance buffers and with 500m, 1,000m and 1,500m network distance buffers indicated. The network service areas are based on actual distances from each transit stop utilising the fully walkable network (based on OpenStreetMap data). OpenStreetMap spatial data was utilised and validated to ensure that all pedestrian paths and routes accessing the transit hubs are coded into the open source spatial dataset.

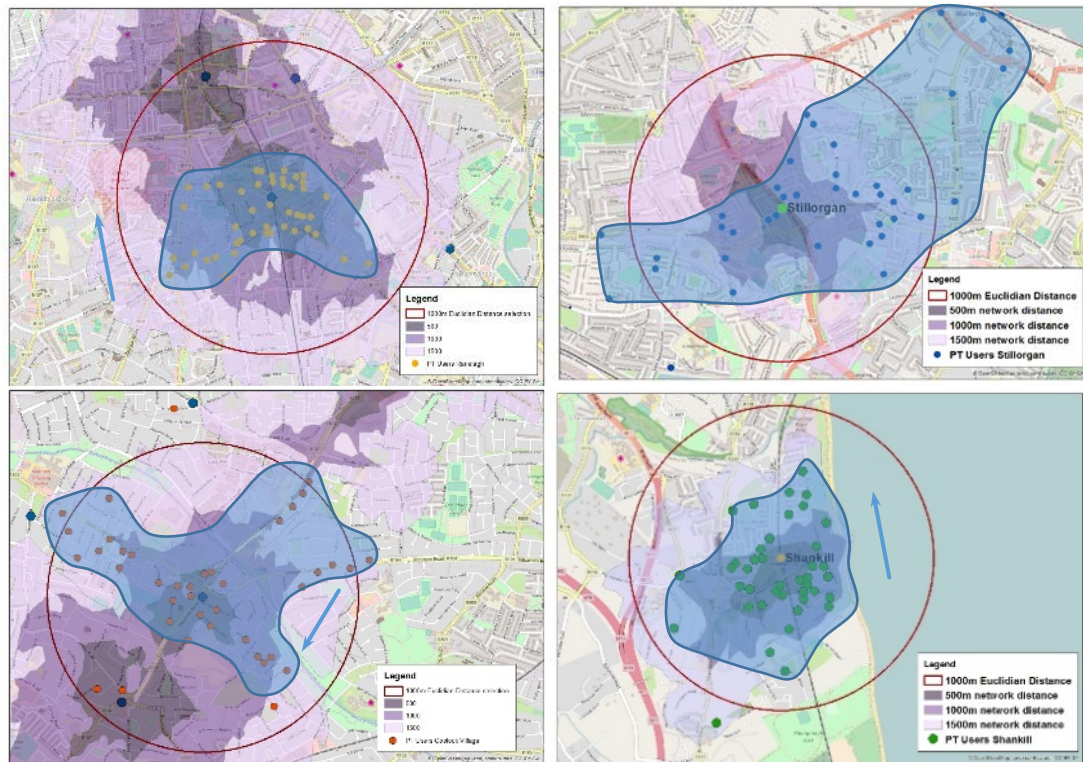


Figure 6: Euclidian, network and actual walked distances for (i) Harcourt [LRT] (ii) Stillorgan [QBC] (iii) Coolock Village [QBC] and (iv) Shankill [rail] stops

Inner urban hubs (e.g. Figure 6 (i)) appear most shaped by the density of the public transport network itself, i.e. where a choice of high-frequency corridors is offered, users appear to tend towards the closest line. In *outer urban* and *suburban* areas networks are less dense and their influence as a controlling factor becomes reduced. Many hubs, particularly on bus corridors, display *oval-shaped* catchment areas, with journeys which are transverse to the corridor being longer in most cases (e.g. Figure 6 (ii)). This suggests that the line stopping pattern is a significant controlling factor (and may be inefficient). In some cases a directional bias is evident – creating a *delta-wing* pattern – with the dominant direction of travel being discernible in people's walking choices (e.g. Figure 6 (iii)). In some cases (e.g. Figure 6 (iv)) the “networked neighbourhood” is reasonably aligned with the network service area, particularly suburban rail stops which may have sparser stopping patterns.

Level-of-service itself may be a relevant controlling factor. As indicated in Section 7.2 above, low level-of-service stops may potentially be associated with smaller catchment areas.

Finally, some patterns suggest that environmental factors, such as gradient, may be an influence in the shape of the networked neighbourhood, a factor also suggested by Jiang et al. (2012).

This idea of the networked neighbourhood being something distinct from the Euclidian or network service area may be important for a number of reasons. For transport planners the design of networks and stopping patterns may become clearer if more is known about how far and under what conditions people are prepared to walk to public transport. Land use planners may also seek to optimise the location of hubs within communities in order to optimise access and the efficient utilisation of transport networks themselves. Communities and business stakeholders might also benefit from a better understanding of actual travel behaviour and real catchment patterns. For these reasons, some investigation may be warranted. It would appear, to at least some degree, that while other factors are clearly evident, the shape and central tendency of the public transport catchment area, or “networked neighbourhood” as it might be known, is a function of the design of the service itself as much as anything else.

9. Further Research Stages and Exploring the Networked Neighbourhood

This paper is part of a wider doctoral research project, on the subject of “Public Transport Service Levels and the Networked Neighbourhood”. Part of this research entails the development of a geo-spatial database, referred to for convenience as the “Dublin Networked Neighbourhood Database” (DNND), whose purpose is to support research into public transport catchment areas and the extent to which these are influenced by levels of service and other factors. Initial survey data has been collected and processed through the DNND, as set out in this paper. It is planned ultimately to sample at least 1000 public transport users overall. This will facilitate increased sampling of lower level-of-service stops, to balance the high amount of high-frequency corridors gathered to date. On completion of the DNND it is hoped to quantify, as far as possible, the relationship between the extent of transit catchment areas and level-of-service, as well as other geo-spatial attributes. Relevant attributes are likely to be grouped into three areas: user-related factors, environmental factors and socio-economic factors. An extended review of literature is also merited given the wider state-of-the-art in this emerging field of analysis.

9.1 Other Issues and study limitations

Some inconsistencies in data collection methodology exist across the various surveys, which themselves were conducted over different periods. For example the metro rail and LRT surveys collected data from walkers only, and included certain stated preference-related inquiries. A potential course of action, adopted within this study, may be to exclude non-walkers across the sample range and to focus

exclusively on pedestrian catchment. A separate sub-analysis might then be included, focussing on range-extendors, such as cycling, kiss-and-ride, etc.

The level of precision in coding of trip-origins varies according to the information from respondents. Interviewees are asked for their street or residential estate of origin. Frequently, travellers provided the names of estates or districts, rather than street names. In either case the trip was geo-referenced approximately around the street or estate centroid and plotted accordingly. In the context of this analysis the margins of error are acceptable but in further studies more effort might be made to increase precision of trip-origin identification. Some studies have had recourse to household travel survey data (Daniels & Mulley, 2013; El-Geneidy, Grimsrud, Wasfi, Tétreault, & Surprenant-Legault, 2014). Where absolute trip origins are captured within large-scale urban surveys of this nature it would be a significant advantage. A clear benefit of the field survey approach, though, is the ability to map the data and associate the trip origin with certainty to the public transport node. The field surveys also permit focus on revealed preference and actual observed behaviour.

A final issue remains around how to quantify and measure Level-of-Service (LOS). Several competing frameworks for transit levels-of-service prevail and, within them, varying but relevant units-of-measure. In respect of walkable neighbourhoods, for example, how much more pertinent might frequency be over reliability? It may be necessary to identify a number of relevant units-of-measure and include them as study variables. LOS appraisal also has to consider consistency (or lack thereof) across modes. Rail systems might have lower frequencies, for example, but these might be compensated by higher relative travel speeds and carrying capacity.

9.2 Main Study Findings

The study demonstrates that across three surveys of public transport users in Dublin, high level-of-service bus stops typically have catchment thresholds significantly greater than either LRT or metro rail. 85th percentile analysis suggests natural catchment thresholds of up to 1400m for bus, 825m for LRT and 950m for metro rail, aggregated across several urban zones. It is noted in this study that rail services access comparatively more compact settlements, reflective of the land use and transport planning principles underlying their planning. Bus travel times, along well-planned quality bus corridors, may have comparatively more favourable frequencies, directness and travel times. Nevertheless, the study suggests that bus corridors with sufficiently high levels of service can have comparable or even greater walking catchment areas than LRT and metro rail corridors. Public transport users appear to be more influenced by LOS than by modal type.

Although further studies are warranted, these results do point towards a number of potentially relevant and new understandings about public transport user behaviour within the Greater Dublin Area and possibly beyond: -

- that a high level of service bus corridor can have as large or larger a catchment area than light or metro rail equivalents;
- that users may be more influenced by *quality of service* than by transport mode;

- that the neighbourhood of people accessing the public transport network may have controlling factors other than distance;
- that the shape and extent of the public transport catchment area might be distinctive and, likely, a function of the design of the service itself;

The available data and relevance of the findings suggest that further more detailed assessment is warranted, especially into the factors that determine the shape and extent of these “networked neighbourhoods” as they might be termed. A larger study sample may add robustness to the analysis. Overall this may assist towards a better understanding of what influences the distances people will walk to public transport and to what extent it is a function of the service attributes of the transit system itself.

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