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Mapping active travel variations in access to key services in Wales

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Links to accompanying website:

https://ces-web2.southwales.ac.uk/staff/aprice5/ats_in_wales.html

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1. Introduction

Events surrounding the COVID-19 pandemic drew attention to the importance of local neighbourhoods as people were encouraged wherever possible to work from home, the physical and mental health benefits of active means of travel were promoted, and communities became more reliant on services in their local areas. At the same time governments around the world have been promoting the benefits of active travel in policies geared towards encouraging modal shift. Active means of travel continue to be promoted in the recently published Welsh Government Transport Strategy (*Y Llwybr Newydd*) which sets a target of 45% of journeys to be made by public transport, walking and cycling by 2040 (Welsh Government, 2021a). The increased investment in active travel infrastructure by the Welsh Government (to £75m in 2022/23) to support policy goals geared towards reducing the impact on the environment, support local economies and promote wider health benefits for residents has also raised the public profile of such research. At the same time, the need to enable sustainable access to key services within reasonable travel times using active modes of transport is a strategic goal of the national spatial development plan, *Future Wales* (Welsh Government, 2021b). The pandemic brought many of these issues to the fore for planners concerned with wider implications of neighbourhood design encompassing the provision of open spaces and accessible services via active and public transport means (Bolleter et al., 2022). Hence, the role of active travel (walking, and cycling) in enabling access to facilities and services for shorter journeys within local jurisdictions has gained even greater prominence.

Chen et al. (2011; p. 58) define accessibility as "the ease (or difficulty) with which activity opportunities may be reached from a given location by one or more modes of transportation." There is an extensive literature on the merits and limitations of different approaches to measuring accessibility (Higgs, 2004). With respect to policy measures concerned with neighbourhood planning activities and the availability of services within reasonable travel times, Geographical Information Systems (GIS) have been widely used to create catchment areas from fixed points of demand that encompass service destinations (Geurs and van Wee, 2004). The primary focus of the current paper is on the types of *cumulative opportunity measures* that are widely used to measure accessibility within neighbourhood studies. This involves aggregating the opportunity types or total numbers of services within defined travel times via alternative means of transport from defined points of demand (summarised in this instance by postcode headcounts). This presents an intuitive measure of accessibility that permits a sensitivity analysis that enables the impact of varying travel time thresholds, or different means of transport, on the number of facilities 'reachable' to be easily modelled.

Political recognition of the desire to gauge local levels of provision comes in the form of governmental policy documents such as the Scottish Governments' *Programme for Government 2020* which includes ambitions for 20-minute neighbourhoods with claims that this is a realistic goal in Scotland in a range of geographic settings (O' Gorman and Dillon-Robinson, 2021). Using networking tools, isochrone analysis has been used to calculate the numbers of facilities or job opportunities and to estimate populations within specified catchment areas at different cut-off times. Most recently, this has been facilitated by the increased availability of open-source data sets that can be used to calculate a wide variety of accessibility measures via different modes of transportation. One of the main aims of the current study involves the inclusion of active means of travel that enable postcode level cumulative opportunity measures to be calculated for access to key services in Wales. By

examining spatial patterns in access to some of the key services included in the accessibility domain of the Welsh Index of Multiple Deprivation (2019) index, this analysis has the potential to support studies concerned with promoting active means of travel to access facilities at national, local authority and political constituency levels.

Local authorities in Wales are required to prepare and promote active travel network maps (ATNMs) to meet the statutory requirements of the Active Travel (Wales) Act (2013) (National Assembly for Wales (2013). Despite some local progress however, national levels of active travel in Wales remain low and are largely confined to those engaging in exercise and leisure activities rather than users accessing services. The maps included here present a benchmark with which to monitor changes in access by such means over time, but also illustrate how such approaches can be used to target areas of lower availability should access-standard approaches to monitor trends in public service provision be implemented by the Welsh Government.

2. Mapping Neighbourhood Variations in Access to Services

2.1 The 'nth' minute neighbourhood

Whilst some argue that the implementation of accessibility models is lagging (Boisjoly and El-Geneidy, 2017), there appears to be an increased politically driven interest in defining neighbourhoods based on round trips within time bands from demand origins (for example 5, 10, 15, 20-minute etc). More recently, with the advances in crowd-sourced geo-information, there has been an increase in research concerned with developing empirically derived measures based on active travel opportunities using walking (or cycling) times. Others have been concerned with examining the implications of using different cut-off times in isochrone calculations. Xi et al. (2018) for example used isochrone cut-off times at 5-minute increments by three travel modes (care, public transit, and walking) to examine the impacts on accessibility measurements using cumulative population and job estimates in the Greater Toronto area. While there is an on-going debate concerning objectively agreed cut-off times for implementing isochrone analysis, our research builds on previous studies that have highlighted the need to consider sensitivity analysis by varying approaches to estimating catchment size. This includes investigating the implications of exploring alternative catchment distances/times by transport mode to, for example, measure access to services or employment opportunities or by varying population demand within such models (Owen and Levison, 2015).

Multi-modal approaches are increasingly being developed to incorporate different modes of transport to a wider range of destination/opportunities (McNeil, 2011). In our own research we address recent calls that "researchers should keep moving on, improving the existing measures and providing easy-to-use and open-access tools to enable the wide adoption of accessibility for planning for various modes of transport" (El-Geneidy and Levinson, 2022; p. 131). This should acknowledge that accessibility to services needs to consider a wider range of issues than pure distance especially in relation to active modes of travel (such as safety, network characteristics and a wider range of factors that influence propensity to walk or cycle).

The Scottish Government (2020) define the 20-minute neighbourhood as "a place designed so that residents can meet the vast majority of their day-to-day needs within a 20-minute walk (approximately 800 metres) of their home." In their definition, 800m is used to reflect a 10-minute walk to a destination and the return journey. Whilst there some consistency in the use

of this metric across international studies, such studies have also acknowledged the arbitrary nature of 800m as a cut-off distance that often ignores population characteristics and needs, the service type under consideration and the types of streets/pathways needed to access such facilities (O' Gorman and Dillon-Robinson, 2021). There is also a lack of agreement on which 'bundle' of services constitute those necessary to meet the needs of population groups in different places and studies have tended to use a variety of service types that encompass retail, recreation, health and educational opportunities in different national and international contexts. More recently, the importance of green spaces has been recognised during the COVID-19 pandemic as people sought local recreation opportunities during periods of lockdown. The role of active travel and public transport to access such opportunities has been to the fore in such studies. This in turn has led to several studies concerned with measuring and analysing spatial patterns of access using GIS approaches that incorporate the types of open-source databases that have come on stream in the last decade or so.

Calafiore et al (2022) describes ways in which 20-minute neighbourhoods can be defined and compared to socio-economic patterns in an urban context of the Liverpool City Region. Their study drew attention to the historical background and conceptual basis behind the use of 15- or 20-minute neighbourhood with the latter involving a 10-minute walk from residence to service location. They draw attention to the types of services that are typically included within these targeted times, to encompass health, retail and educational facilities, but also suggest a lack of clear guidance and rationale for the types of services used within previous empirical studies. There may for example be a strong case for including recreational opportunities either through formal means of provision or via open (green/blue) spaces within these neighbourhoods. Others have suggested that six urban functions could be captured by such an approach, namely those associated with living, working, commercial, healthcare, educational and cultural aspects (Moreno et al., 2021). Grodach et al. (2019) similarly confined their infrastructure analysis to facilities in an 800m (10-minute walking distance on average) catchment that included access to green spaces, education and religious institutions, sport facilities, shops, post office and health centres.

Calafiore et al (2022) developed an accessibility measure based on a 10-minute walk to identify clusters of areas that meet the 20-minute criteria and compared this with socio-economic and environmental data to examine potential inequalities. Using the location of twelve service types from the Ordnance Survey (OS) Points of Interest (PoI) database and the OS Open Greenspace dataset, and using postcodes as the origin points, the walking times to the five nearest destinations from postcode locations were calculated for selected categories of services. These were based on straight-line (Euclidean) distance, and the shortest travel time of each category was used to obtain an average at the Output Area level. A binary value is then assigned to each Output Area depending on whether that service is accessible in 10 minutes – so the maximum number possible equates to the maximum number of chosen services. In reality, the choice and nature of services is subjective, often lacks any information on quality of provision and will be dependent on the transport mode and assumptions regarding the origin of travel (e.g. location of households, postcodes, census centroid). In this instance, their choice of services included food shops, public transport stops, sports facilities, green space schools, GP surgeries pharmacies, places of worship and entertainment venues. This enabled the proportion of Output Areas in which the population can access each (or all) services via a 10-minute walk to be calculated to provide an idea of 20-minute neighbourhoods in the city region.

2.2.Cumulative Opportunity (or Coverage) Measures

There is a long-standing literature base concerned with deriving methods of accessibility including those that adopt *coverage* or so-called *cumulative opportunity* measures to investigate access to a wide range of service types (Handy and Neimeier, 1997; Talen, 2003; Wachs and Kumagai, 1973). Despite the adoption of gravity-based approaches, they still have a wide user-base, are relatively easy to understand and interpret and continue to be used to examine multi-modal access to many of the facility types included in this study. Essentially cumulative opportunity measures involve a count of the number of potential opportunities that are reachable by a particular mode of transport in a predetermined time or distance. To capture service types and total numbers of facilities within a catchment area, cumulative opportunity approaches have relied on isochrones either based on straight-line buffers or more recently network-based measures that utilise road characteristics and public transport availability (Sleszynski et al., 2022). O' Gorman and Dillon-Robinson (2021) for example report on an attempt to gauge those areas in Scotland that could qualify as 20-minute neighbourhoods based on counts of services within an 800m zone.

Such measures often ignore the size of the facility or any supply-side indicators of 'attractiveness' or the impedance of reaching those within the defined isochrones. However, they are increasingly being used to monitor access by different transport modes. For example, previous studies have used walking distances and public transport times to a wide variety of supply-side/destination types (Klumpenhouwer and Huang, 2021; Mavoa et al., 2012). Klumpenhouwer and Huang (2021) describe an approach to 'bundling' destination types together to examine patterns of accessibility to a wide range of services by public transit using open data sources for Calgary, Canada. By applying category weights for different service types within these bundles and using General Transit Feed Specification (GTFS) network data, alongside OpenStreetMap data, 30-minute isochrones were generated using OpenTripPlanner. Variations in access to these services were then examined to examine potential gaps in provision that could help in planning transit services in the city.

More recently, open data sources such as transport timetables and modelled road speeds have led to increasingly sophisticated approaches to deriving dynamic cumulative opportunity measures that provide potentially more robust measures than straightforward Euclidean buffers. Chen et al. (2011) have extended static approaches to examine variations in the availability of opportunities during the day using secondary data on the temporal availability of opportunities and changes in the transportation network impacting on travel times. However, in the absence of data on sidewalks and cycle paths, they did not consider non-motorized means of travel when generating such maps. There is a long history of applying cumulative opportunity maps – many in relation to the types of services included here. For example, Guy (1983) and Handy and Niemeier (1997) have used cumulative opportunity measures to examine access to food shopping opportunities. Paez et al. (2012) applied these types of measures to examine variations in access to day care facilities in a Canadian city. Cheng, et al. (2021), as part of a wider study of social inequities in provision, have compared counts of the average number of libraries within a specified walking distance for several cities in the US with other accessibility metrics such as shortest distances to the nearest library. Others have explored the numbers of physical activity facilities available via car and bus networks for a range of travel times to explore potential socio-spatial inequalities in provision of recreational facilities (Ferguson et al., 2013). The potential association between a mix of destination types such as

schools, transit stations and shopping malls on walking and physical activity levels within specified catchments of household locations was examined by McCormack et al. (2008). Finally, Sonea and Westerholt (2021) used isochrone analysis to calculate the number of people with access to post offices in Wales in relation to the Governments access criteria guidelines.

3. Methods

3.1 Data

Services included in this initial analysis are the same as those used in the construction of the *Access to Services* domain of the November 2019 version of the Welsh Index of Multiple Deprivation, WIMD (Welsh Government, 2019). These are services that are considered to be "necessary for day-to-day living" and have also been used to measure deprivation in previous versions of the WIMD, albeit with some variations in methodology including the services included in the access calculations (Page et al., 2019). The access domain has a weighting of 10% in WIMD 2019, calculating travel times to services by public and private transport for each Lower Super Output Area (LSOA). Each service is weighted using factor analysis. The services were: pharmacies, food shops, general practitioners, post offices, unavailability of broadband at 30Mb/s, primary schools, public libraries, sports facilities, secondary schools, and petrol stations (this for private transport only). In the following analysis, we do not consider access to broadband or petrol stations because our focus is on those facilities/services that are accessed via active and public transport modes.

Point locations for the eight remaining service types were obtained through Digimap using PointX data. Table 1 shows the classifications and descriptions of the points of interest used.

PointX classification code	Group description	Category description	Class description
05280364	Education and health	Health practitioners and establishments	Chemists and pharmacies
06340458	Public infrastructure	Infrastructure and facilities	Libraries
05280369	Education and health	Health practitioners and establishments	Doctors surgeries
09480763	Retail	Household, office, leisure and garden	Post offices
04240293	Sport and entertainment	Sport complex	Gymnasiums, sports halls and leisure centres
09470819	Retail	Food, drink and multi item retail	Supermarket chains
05310375	Education and health	Primary, secondary and tertiary education	First, primary and infant schools
05310379	Education and health	Primary, secondary and tertiary education	Broad age range and secondary state schools

Table 1: PointX classifications used to calculate accessibility to key services.

3.2 *Computation of cumulative opportunity maps*

Akin to the approach taken in estimating public transport access in the WIMD Access to Services Domain, we use computed isochrones (including those for walking and cycling) to examine spatial variations in access amongst postcodes to each facility type.

Cumulative opportunity records the number of facilities in reach of a demand location by using isochrones, which are a geographic area (polygon/catchment) that indicates how far people can travel from a point of origin within a given timeframe. The calculation of isochrones was undertaken using OpenTripPlanner, an open-source routing engine (OpenTripPlanner, 2022). OTP was fed the 85,000+ active residential postcodes in Wales with catchments computed for four modes of transport (walking, cycling, private car, and public transport). Walking, cycling, and private transport isochrones are all generated from shortest path distances computed using a road/path network based on OpenStreetMap data (OpenStreetMap, 2022). Public transport isochrones are based on published public transport timetables. In addition, they also incorporate the walking elements needed to get to and from bus stops or train stations to the specific point of origin and destination. OpenTripPlanner makes use of public timetables supplied in General Transit Feed Specification (GTFS); our information on buses in Wales was sourced from Traveline (Travelinedata, 2022) while that for rail was obtained from the Rail Delivery Group (Rail Delivery Group, 2022). Sets of isochrones were generated using multiple travel times ranging from 5 minutes to 30 minutes, in 5-minute intervals. This generates a total of approximately 2 million isochrones, constructed automatically by a bespoke python script.

Once all isochrones are computed, the number of facilities reachable from each postcode is computed using SQL queries executed within the PostgreSQL/PostGIS spatial database, where the PointX data, the isochrones, postcodes, and all other necessary data resources are held.

This process results in database tables holding cumulative opportunity scores at postcode level ready for visualisation and delivery via the web site (see Figure 1, and Figure 2). Static images were then generated automatically by another Python Script, making use of several spatial packages to calculate and clip the areas of interest (GeoPandas, Contextilty). Additional open-source packages are exploited to plot the maps and related statistical charts (Matplotlib, Seaborn). A Python script iterates through an enumeration of areal units consisting of both local authorities and Westminster parliamentary constituencies, extracting information for those postcodes that fall within the area of interest. These are then plotted on a Matplotlib canvas and saved as an image. By this process it was possible to create cumulative opportunity graphs for each area or interest, each service type, and each travel time threshold, an example of which is illustrated in Figure 1.

Once cumulative opportunity scores for postcodes had been computed, further analysis identified the number of unique services available at every postcode, again repeated over the four transport modes and for multiple time thresholds. This results in a score from 0 to 8, which is the total number of services considered. Calculated scores were again stored in PostgreSQL, then accessed via a Python script to generate the maps and charts illustrated in Figures 5 and 6. In the cumulative opportunity measures the maximum score was unknown until computed, whilst this information has a fixed maximum of 8. Chart styles used to represent each set of information are thus modified to accommodate this difference.

The outcome of this computational process is the construction of a comprehensive atlas of cumulative opportunity scores at postcode level to eight key services. In total, some 14,200 maps and associated graphs are produced, all of which are then made easily accessible through the website. Scripts have also been developed to save this information into GeoJSON formatted files to facilitate its import into GIS software such as QGIS (QGIS, 2022).

4. Introduction to the Website and Active Travel Access Maps

Figures 1 and 2 show examples of cumulative opportunities measurements to different services and locations in Wales. Figure 1 shows opportunities to pharmacies where the selected mode of transport is cycling, the catchment size is 10 minutes, and the locality is Pontypridd. Figure 2 also shows opportunities to pharmacies, but with the transport mode now set to private vehicle. Accompanying plotted maps are charts relating to the selected localities. Figures 3 and 3 show the chart outputs associated with the maps shown in Figures 1 and 2. These show the percentages of postcodes with a stated cumulative opportunity value. This aids in understanding the quantities of the values, in comparison to the maps which spatially highlight areas of low or high accessibility. The maps are also compared with national values to provide contextual understanding on how the locality compares to national level scores.

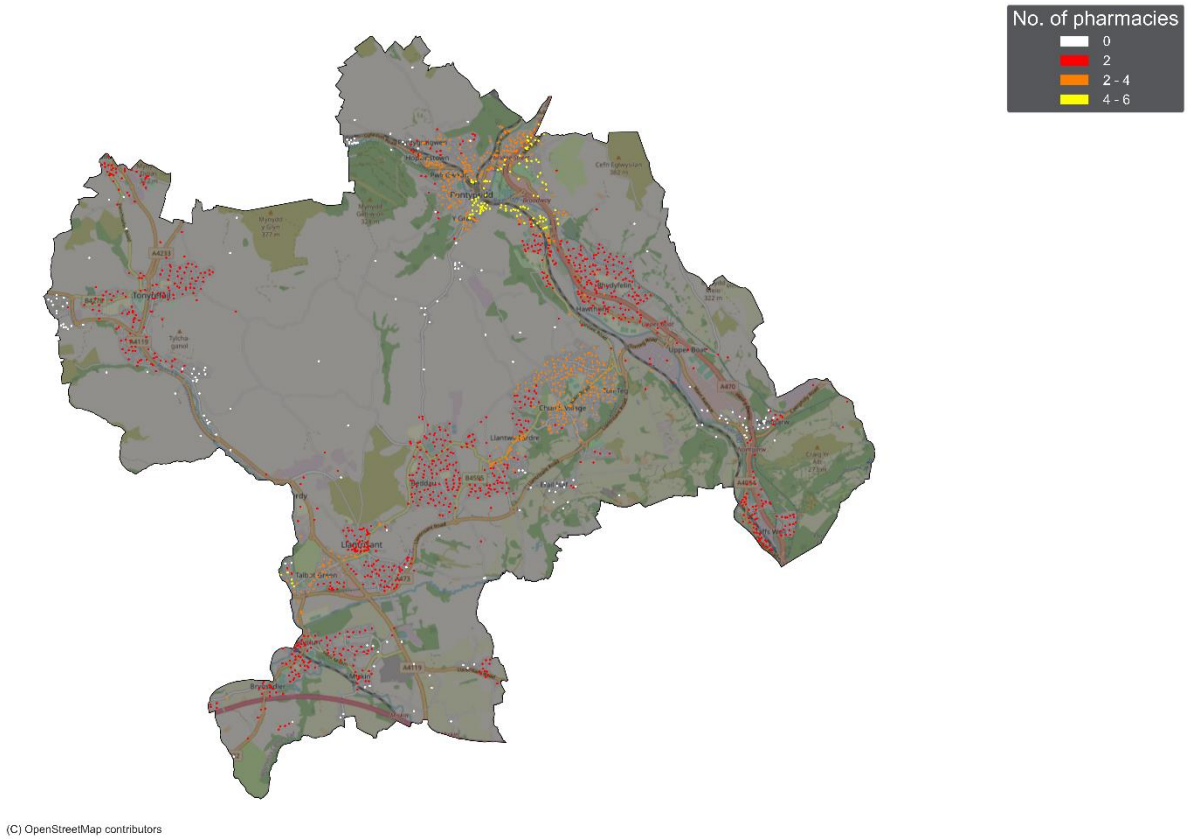

Figure 1: Opportunities to pharmacies, when cycling with a catchment of 10 minutes in Pontypridd.

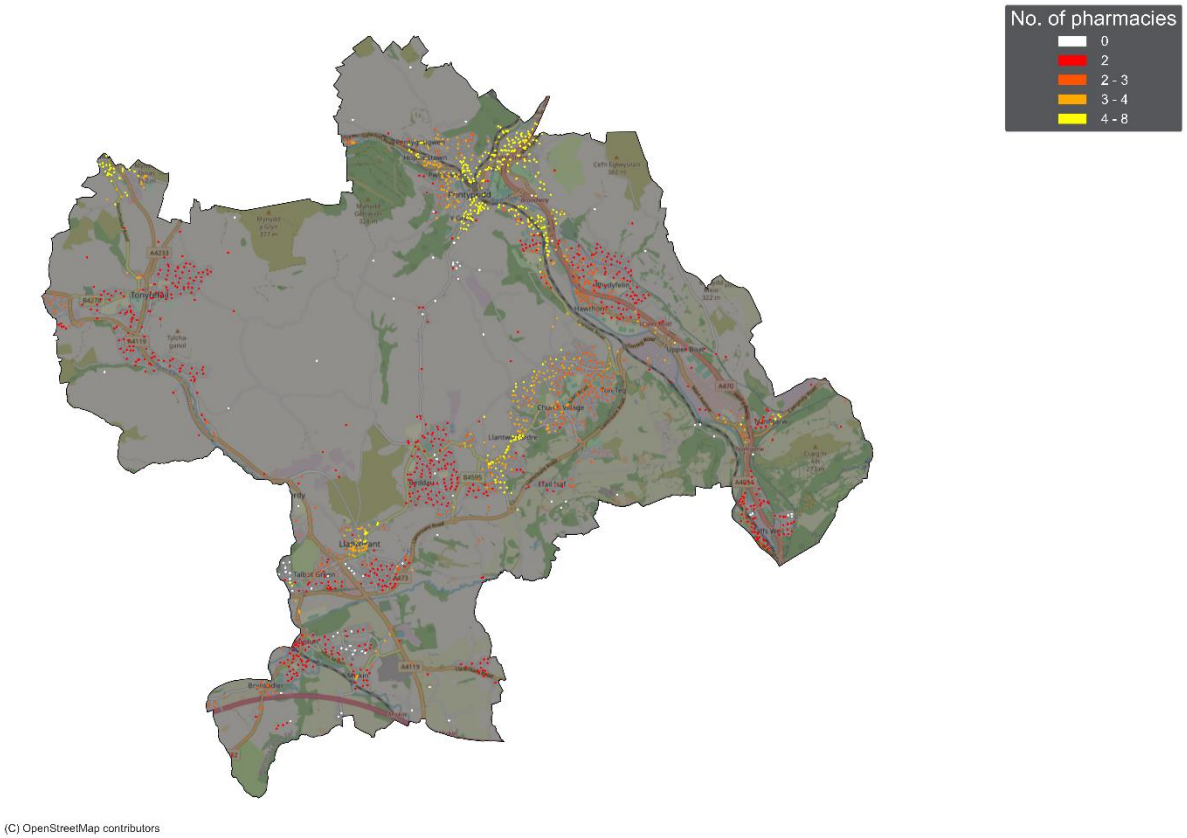

Figure 2: Opportunities to pharmacies, when driving with a catchment of 10 minutes in Pontypridd.

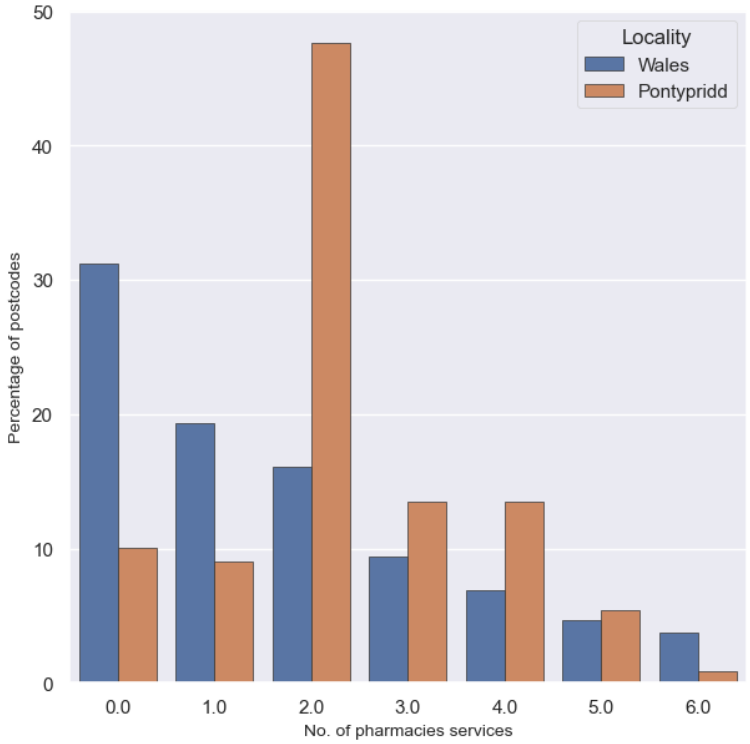

Figure 3: Graph related to Figure 1, based on cycling within 10 minutes to pharmacies.

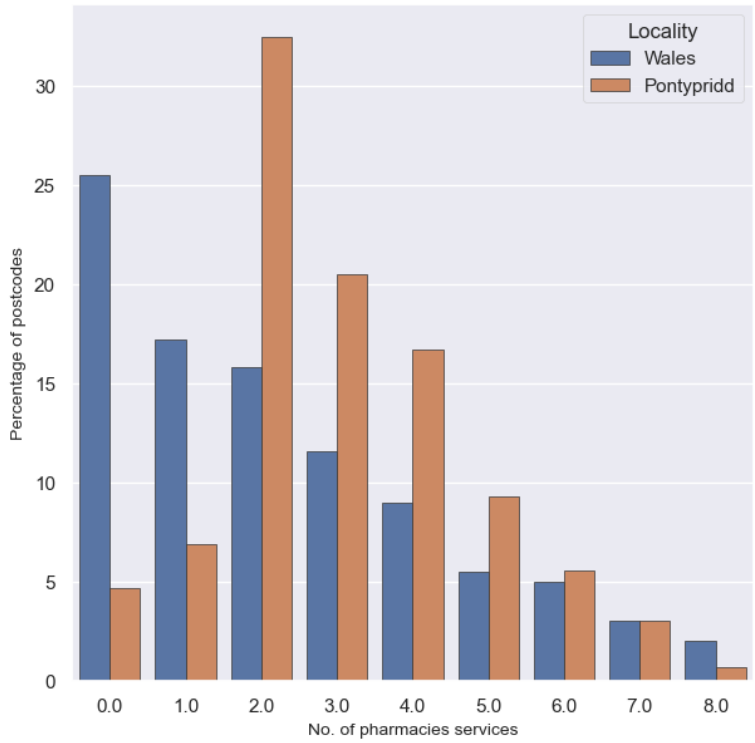

Figure 4. Graph related to Figure 2, based on driving within 10 minutes to pharmacies.

The map in Figures 5 shows the number of unique services reachable within a 10-minute cycling time from all postcodes present in Pontypridd. Figure 6 is its related graph, with the frequency plot of postcodes scoring between 0 to 8 services.

Figure 5: Map representing number of unique services accessibly via cycling for a maximum of 10 minutes.

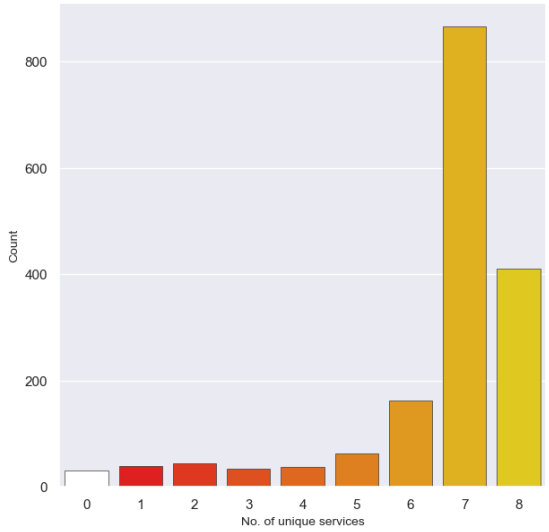

Figure 6: Chart associated with Figure 5, providing sums of each category.

All images and associated graphs can be viewed via the website shown in Figure 7. This interface allows users to browse through any combination of transport mode, service, travel time and locality.

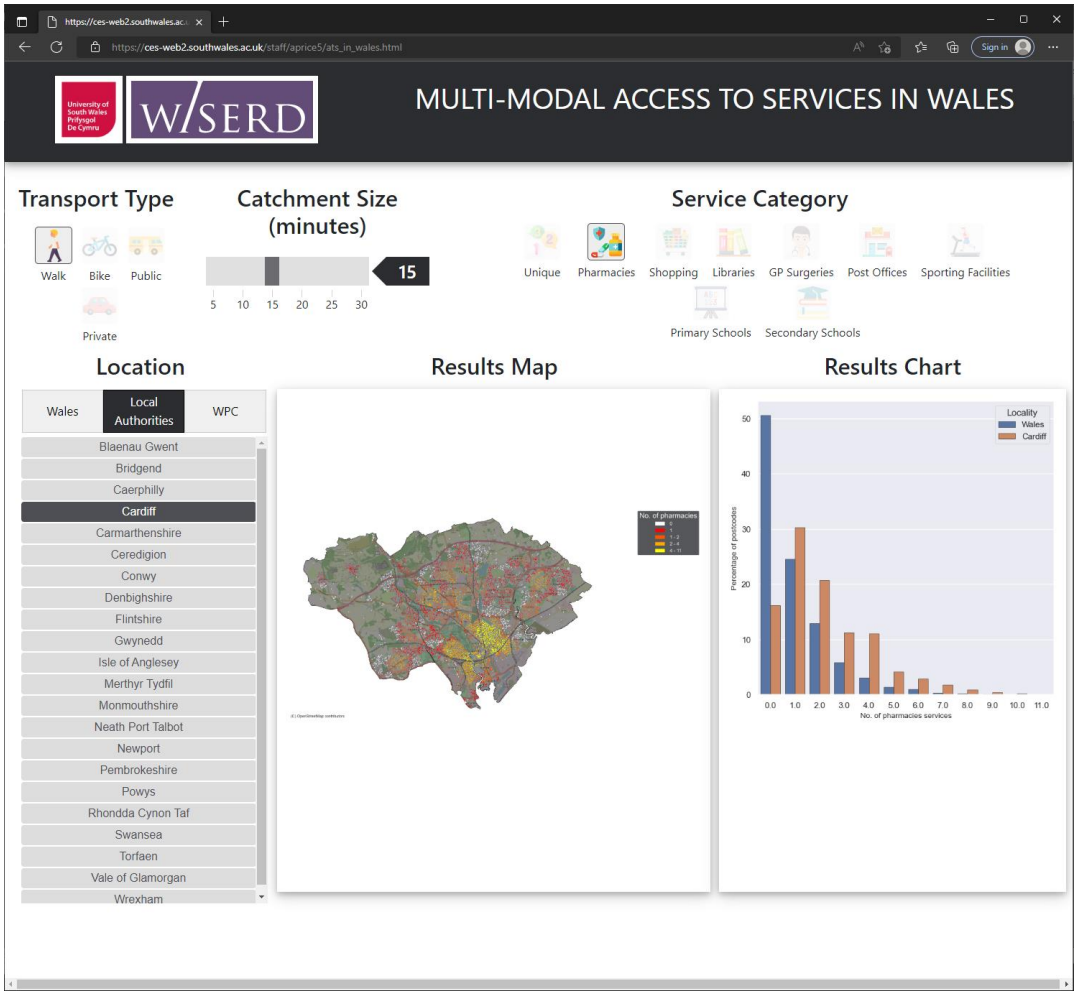

Figure 7: Website to access the multi-modal access to service in Wales atlas.

5. Discussion

5.1 Summary of Findings

A key strength of these maps is their ability to visually present accessibility scores at postcode level to eight key service types, for various transport modes including active travel. They can be used to conduct sensitivity analysis of the impact of different isochrone times on overall scores. They can be used is explore a specific facility type (e.g., pharmacies) or to report on the total number of the eight services analysed. Maps at local authority level include measures that encompass those facilities in adjoining authorities and provide a useful tool with which to conduct further spatial analysis (e.g. cluster analysis) on overall patterns of provision. They may also be used to examine the impact of mapping active travel routes across neighbouring authorities in order to monitor changes in access to key services.

These maps can be viewed alongside those showing variations in car ownership. It is estimated that 80% of bus users, and 23% of the total Welsh population have no access to a car (Senedd Proceedings, 2022). This implies that maps of access to key services via active and public transport can be useful in gauging those areas that may be experiencing some of the highest levels of transport related social exclusion.

5.2 Potential enhancements to the website

A potential limitation of the prototype site is the omission of any measure of 'attractiveness' of potential destinations. We have not attempted to include any measures of quality or capacity of service provision points and have only used a subset of opportunities/services considered to be essential for education, health and leisure activities. We assume equal weighting for each facility site within each category. Also, in counting the number of facility types reachable in the time allocated, no attempt is made to include a distance decay parameter. This type of impedance measure within the catchment is often adopted in gravity models but here we simply assume that all in-reach destinations are equally accessible. The cumulative opportunity measure adopted uses a standard methodology, but we are aware that others have suggested advancements to include elements of competition between services (Kelobonye et al., 2020).

Maps are presented for facility types included in the Access domain of the WIMD, but there remains scope for adding further categories. For instance, exposure to parks/greenspaces have been identified as being important to mental and physical wellbeing and have been subject to recent research in relation to neighbourhood availability (Olsen et al. 2022).

Demand is assumed to originate from postcode locations rather than individual households and we have not modelled the impact of population demand, or the likely differences in socio-economic needs or the role of, for example, gender, ethnicity or age, on the usage patterns of such facilities. Further research is needed to compare these patterns with those of alternative place- and people-based measures of accessibility (Neutens et al., 2010; Talen and Anselin, 1998). Follow-up research could also explore associations between accessibility and deprivation, or between urban and rural environments (Pearce et al., 2008). These scores are potential measures which are not based on actual utilisation behaviour which may more strongly reflect the perceived quality of provision. The measures assume uniform demand for services when in reality there is likely to be higher demand for some services (e.g. GP surgeries, schools) based on specific population needs and demographic profiles within some communities.

There is an assumption that the network database we used can adequately represent a true impression of active travel routes mapped by local authorities – nevertheless, the process we have followed at least shows what is possible should a more definitive version of actual routes be available in digital form. Furthermore, we recognised that distances individuals may be prepared to walk or cycle in order to access these facilities may in reality be dependent on a whole host of factors related to user characteristics, trip purpose, or suitability of the route. The aim here has been to demonstrate the principle of how travel times based on modelled or actual experiences could be included within these models.

Finally, a profitable area of further research could be to adopt the approach described by Chen et al. (2011) which considers the use of time buffers that incorporate the opening hours of facilities in relation to travel opportunities, leading to more dynamic cumulative opportunity measures. Their research shows how such buffers change in response to those services that are 'reachable' at different times of the day.

6. Conclusions

Outputs from this exercise may contribute to addressing aspects of transport poverty in Wales as highlighted for example in a recent sustrans (2022) report '*Making the Connection*'. The aim has been to identify those areas that currently lack access by mapping postcode-level accessibility scores to key services via multiple transport modes and travel time limits. This highlights those areas where active travel journeys can enable health, education, shopping, library and leisure facilities to be currently accessed. Furthermore, by identifying postcodes where a degree of choice is available for a particular facility, these maps paint a picture of overall provision that might help to address the goals of Planning Policy Wales (PPW) to plan developments that are fully accessible by walking and cycling (Welsh Government, 2021c).

Findings from this preliminary analysis point the way to further research that could examine socio-economic variations in access to a wider range of facility types, public transport hubs or employment opportunities. As such, these maps represent a benchmark whereby policies geared towards improving the walking and cycling infrastructure to services can be monitored by local authorities to assist in planning and locating new developments such as educational and health facilities. They may also help to target those communities with no or little access to services via public transport to address patterns of transport exclusion.

The sustrans report highlighted the need to connect people to jobs and services, especially in economically disadvantaged communities. The analysis considers the use of travel times that address concepts surrounding the 10-minute (or 15, 20, etc.) neighbourhood which appears to have received renewed policy impetus in recent years. One impact of COVID-19 was to focus attention on those services that are reachable within realistically timed round trips. These types of maps can be used to judge the impacts of the chosen time catchment threshold as well as the means of transport used to access services. Finally, the analysis included in this research has focused further attention on the need to consider wider aspects of transport availability when planning the provision of health, educational and shopping opportunities in local communities that helps address some of the key goals advocated in the Welsh Government's *'Llwybr Newydd*' Transport Strategy (Welsh Government, 2021a).

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