Using circuity analysis to explore pedestrian access to healthcare services in York

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1 Introduction

Carlos Moreno first proposed the 15-minute city concept in 2016. The focus of the concept is that access to essential services and amenities, such as healthcare and greenspace should be within a 15-minute walk or cycle from a persons home (Moreno et al., 2021). The COVID-19 pandemic then highlighted the importance of local access to essential services, because lockdowns and other restrictions on movement limited the ability to travel beyond ones immediate neighbourhood. The 15-minute city concept has gained traction more recently within the disciplines of urban planning and sustainable development. It also provided a new perspective on “chrono-urbanism”, in which there is an inversely proportional relationship between peoples quality of life and the time people invest in transportation and is especially true in the use of motor vehicles (Logan et al., 2022).

Active travel modes such as walking and cycling improve health outcomes for people. They enable better potential fitness levels and reduce inactivity. In addition, benefits to the economy through increased active travel can be measured through a healthier society, which results in fewer people needing to use the NHS, therefore saving it money. The environment benefits from active travel because these modes of are emission-free, which reduce airborne particulate matter, increasing air quality in towns and cities (DfT, 2023).

However, time and its availability is an important factor when it comes to peoples decisions around mode choice. The study by Ralph et al. (2020) highlights this very well, and is pertinent to the study in this report because it shows that people were more likely to overestimate the length of the route, and therefore the time it would take to walk/cycle, along routes where there were barriers to overcome and many turns to take. This decreased the chance of people using an active mode of transport over motorised vehicles. Other reasons for choosing against walking in their study were fears of crime, getting lost, and carrying something heavy. They also found that people were more likely to lower their estimations of the time and distance of a route with experience and familiarity of a route.

Through urban design and service planning, it should be possible to increase active travel, and reduce (private) motorised vehicle use. In order to achieve these goals, understanding the current situation in terms of accessibility is important. This study looks to contribute to this understanding, using the City of York Local Authority District (York LAD), which includes the City of York and the surrounding villages and by analysing peoples access to essential services (healthcare provision in this case), though circuity of walking route measurements.

2 Scope

The primary aim of this study is to analyse ease of pedestrian access to basic essential (health) services. This will highlight the areas in which access is more or less likely to occur by active travel modes and could help towards future policy in urban design that has a focus on economic and environmental sustainability as well as population health.

Access will be measured through defining a reasonable travel time from each service, based on 20 minutes average walking distance. Twenty minutes was chosen, because the average distance walked in this amount of time is equivalent to one mile (Foundation, n.d.).

In this report, I will firstly describe the methods that will be used, and justify some of the decisions made in regards to the preparation, cleaning and processing of the data, including communicating and visualising the results. I will then comment on how these results may contribute to planning the urban environment in respect of the tenets of the 15-minute city. Finally, I will highlight some of the problems and limitations of the study, and propose any changes that could be made to similar studies in the future.

3 Area of study

The York LAD was chosen because of the physical makeup of the area. It sits in the county of North Yorkshire, and has a population of around 200,000, of which there is a large student population of around 48,000 (York Council, 2024), many of which could potentially benefit from cheap and healthy transport options around the city, especially as the main campus of the University of York sits some way outside the centre. Buildings in York are tightly packed within the walled old center, which is immediately surrounded by decreasingly dense suburban neighbourhoods, and at the periphery by smaller more isolated and rural towns and villages, such as Haxby and Bishopthorpe. This study area should provide a variety of different urban/suburban settings in which analysis can be carried out and compared.

3.1 Spatial Scale

The spatial scale for analysis was based upon the smallest or lowest level of geographical area. This is the Output Area (OA), and typically represents between 40-250 households and is made up of around 100-625 people (National Statistics, n.d.). They were chosen because they provide the one of the smallest scales of aggregation that is available for the UK, and therefore provide a good level of detail/granularity for analysis.

4 Datasets

- The data was extracted, processed and analysed using RStudio 2023.12.1+402 "Ocean Storm".
- The study area boundariies were extracted from the Open Geography Portal (National Statistics, 2023).
- Point data for the healthcare services was extracted from OpenStreetMap (OSM) using the `osmdata`, and the services chosen were `"clinic", "dentist", "doctors", "hospital", "pharmacy"`.
- A graph of the study area was locally built using the `opentripplanner` package which is a multimodal route planner, using imported OSM networks and allowed for both the isochrones around the services, and routes to them to be calculated.

5 Pre-Processing, Understanding & Preparation

Once the data was extracted, and in order to be able to process them correctly, it was important to understand their structures and content. The OSM data returned points and polygons. So that we were able to calculate isochrones properly from point data, it was necessary to convert polygons consisting of larger buildings such as hospitals, to points representing the centroid of these polygons. This was done using the `st_intersects` and `st_centroid` functions. It was then possible to combine the point data and the new centroid points ready for processing. In addition to these conversion processes, any unwanted data was removed from the datasets to make navigation and further processing easier and more efficient.

6 Exploratory data analysis

The cleaned data was then plotted so that we could make sure that both the numerical counts of the different amenities looked feasible, and also the spatial distribution of them was correctly within the study area. This can be seen in Figure 1.

Figure 1: Healthcare services in York

7 Methodology

7.1 Isochrone calculation

Once the data had been prepared, 20-minute walking time isochrones were calculated around each of the health-care points. This was carried out using the `opentripplanner::otp_isochrone` function. Isochrones were used because we did not want routes to be calculated for origins that were further away than this walking distance. If isochrones were not used, routes would have been calculated to destinations that would not need to be accessed because they were further away than the closest service, which would have skewed the results of the circuity calculations, and provided no benefit to analysing access.

7.2 Make the hex grid

It was decided that points of origin would be created from a hex-grid, so they could act as a proxy for exact origin locations. One of the alternatives would have been to use Output Area (OA) population weighted centroids. This would however have meant that it would have resulted in a single origin location for each OA. Postcodes could have also been used, but this would have resulted in more processing power being required (something that is limited at this time), so the most effective solution was to calculate a hexagonal grid using `st_make_grid` from the `sf` package, with a `cellsize` of 250 (units). The grid was then transformed from polygons to points/centroids (so 7 in total for each hexagon). Duplicate points for those neighbouring polygons were then removed and the final point data was then ready for calculating routes from.

7.3 Calculating routes & circuity

Once the point data was clipped to the isochrones, routes were calculated from each point within each isochrone to the relevant amenity destination. This was done using the `opentripplanner::otp_plan` function using `walk` as the only valid method of transit.

Circuity was then calculated for each route using the following formula: -

$$k_{ij} = \frac{(l_{ij} - d_{ij})}{l_{ij}}$$

Where k_{ij} is the circuity, l is the route distance between node i to node j, and d is the geometric distance between node i and node j. The resulting measurement will be between 0 and 1, with the least circuitous (straightest) routes being closer to 0 and the most circuitous routes being closer to 1.

7.4 Output Areas

Output areas were then loaded and the origins that intersect with each were calculated. The mean circuity for each OA to provide the final results for the study area. These were then plotted and can be seen in Figure 2.

8 Results

Figure 2 shows the spatial distribution of the mean circuity for each OA in York. We can see a number of places with relatively high circuity; one area in the south and one in the north-east and the OAs with the lowest circuity seems to be mainly in the east, with a small area around Haxby in the north displaying particularly a low mean circuity. This however does not show the numeric distribution of the mean values, so a histogram was produced to visualise this.

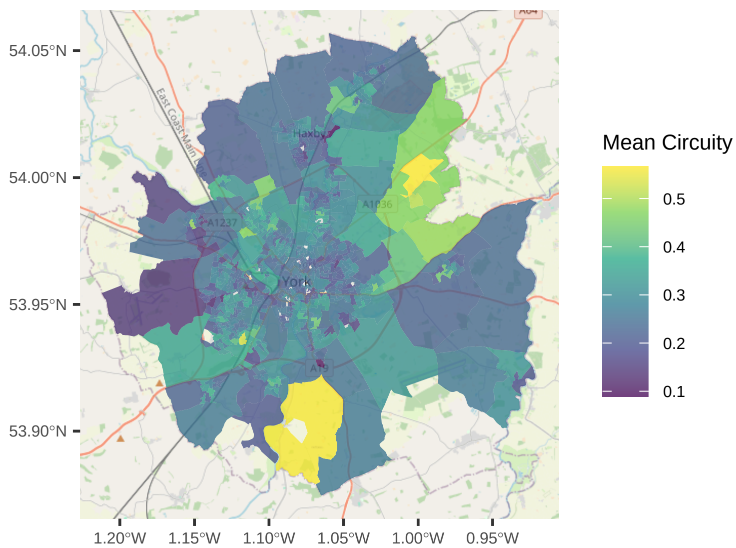

Figure 2: Mean circuity of routes to healthcare services in York

As we can see in Figure 3 the histogram shows that distribution displays a small right-skew. The box-plot and the Table 1 allows us to see this distribution more clearly, with the interquartile range (IQR) between around 0.23 and 3.0, and the median around 0.25. The upper and lower limits are around 0.42 and 0.12 respectively, and outliers at either end. This is a good sign in terms of access to healthcare services as it shows that the majority of the circuity values are relatively low, equating to a fairly low circuity overall in York. I will be concentrating on the outliers mentioned above in order to understand possible reasons for the variation at either end of the spectrum of circuity.

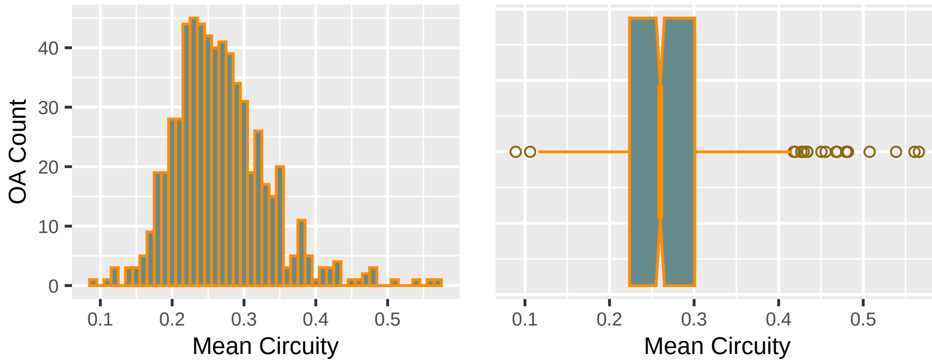

Figure 3: Distribution of mean circuity for York OA’s

Table 1: Mean circuity statistics for routes to healthcare services in York

	Min.	1st Qu.	3rd Qu.	Max.
value	0.09	0.47	0.3	0.57

To better understand two most polar outlier OAs, and their route circuity calculations, plots were created to visualise them. Figure 4 shows that the OA with the lowest circuity is in the village of Haxby to the north of the study area. The circuity for this area ranges from 0.06 to 0.14 and can be seen on plot a) to consist of relatively direct routes from the origins (blue) to the services (red). By contrast, the OA with the highest circuity can be found in the north-east of the study area. The circuity for this area ranges from 0.42 to 0.52 and can be seen on plot b) to consist of more circuitous routes from the origins (blue) to the services (red).

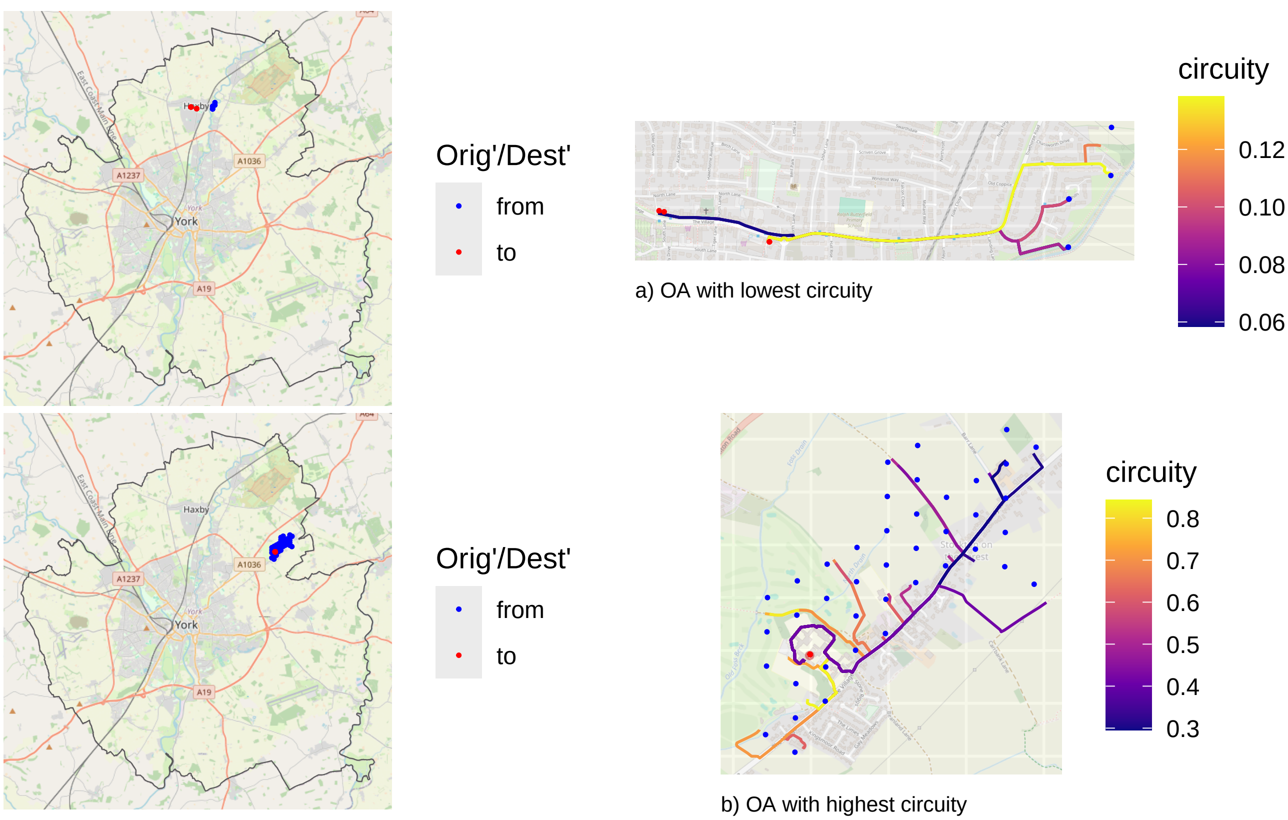

Figure 4: OAs with the lowest and highest mean circuity routes

Table 2 shows that the lowest circuity averaged around 1208 meters walking, and the highest around 1275 meters. This shows that the walking distances for each route averages to somewhat similar values.

Table 2: Mean walk distance comparison

Lowest	Highest
1208.7	1275.6

9 Discussion

Having investigated the locations of the two examples above, services in Haxby seem to be located on the main high street of the town. This street consists of a single relatively straight road through the town. By contrast, the OA with the highest circuity was to the north-west of York and is overall more rural, and less densely built up. The location of the services is important to the calculations here, because it sits away from the main street through the village of Stockton on the Forest. This means that the route to the service is longer and more circuitous than it would be if the service was located on the main street. This is a good example of how the location of services can affect the circuity of routes to them. The circuity of routes to services in rural areas is likely to be higher than in urban areas because rural areas are less densely built up, meaning housing is more spread out, meaning that walking to a service takes longer via fewer roads, if indeed the service exists at all.

Transport and travel in rural locations is often defined through a lack of availability as opposed to what options exist. This could be termed as forced car ownership through what can be described as transport poverty (Milne et al., 2024). This fact hints at the importance of both the availability of, and the access to services such as healthcare in more rural areas. If people are more likely to own a car, and they do not have sufficient access to services, they are more likely to have to drive to the required service. This inevitably impacts on the persons health, through decreasing the frequency that shorter trips are taken by walking, and increases vehicle use, which negatively impacts the environment by increasing air pollution.

10 Policy Implications

With regards to policy, the results of this study could be used to inform the location of services in the future. By understanding the circuity of routes to services, it is possible to understand how easy it is for people to access them. It could also be used to inform the potential in relocating existing services to improve access. This could be particularly important in rural areas, where the circuity of routes to services is likely to be higher than in urban areas. The study of travel mode choice and in particular the routes that people take is vital when trying to promote more sustainable travel options (Costa et al., 2021).

Access to healthcare, particularly in rapidly ageing populations is vital, and this study could start to help in deciding where to focus interventions. Similar studies such as Poudyal et al. (2023) highlight the importance of networks in this area and show how this type of work can influence the design of infrastructure to facilitate more direct access routes to healthcare. As Nicoletti et al. (2023) points out, disadvantaged communities such as lower income neighbourhoods in more rural locations have lower access to urban infrastructure such as healthcare services. This study could be expanded to include measures of deprivation, which is another factor leading to poorer health outcomes, which could help to further focus policy makers looking to make changes to improve equitable access to healthcare, and improve health transit through communities.

11 Limitations

This study would have benefited from a number of additions or changes to the method, however, some were omitted due to the lack of laptop processing power available. With hindsight, it would have useful to incorporate pedestrian crossings nodes into the graph and may have had an impact on route circuity. Another example would have been to include extracts from the OpenStreetMap data of other types of services and amenities, such as essential shops like grocery stores and schools. If it was possible to calculate routes for all of this additional data, a more comprehensive approach would have been taken, and the results more representative of the real world. It would also have allowed for a comparative piece of work to look at peoples access to different types of service/amenity, and could have shed light on how to build them into the neighbourhood.

Another possible change would have been to use Output Area Population Weighted Centroids as the origin points. This would have meant that routes were calculated from places where people were located rather than, as with the method chosen, random but equally distributed points across the study area, and within the isochrones defined. It may have allowed for all routes to have been calculated and subsequently delimited by the isochrone, and would have allowed for a measure of whether populations had access to amenities/services in the first instance, and in addition, how easily they could be accessed through circuity measurements. This may have produced very different and more useful results than those found in the method used.

12 Conclusion

To conclude, this study has successfully highlighted the differences in access to healthcare services between rural and ore urban environments. By using York as a study area, pedestrian route circuity measurements from origin to healthcare service destination points and calculating circuity, shows that more rural locations display routes that have higher circuity than more urban areas. Although the example of Haxby shown in the study is a somewhat large village/small town, it demonstrates how low circuity can be designed in relation to access to services. Contrast this with the second example, where the services were situated away from the main thoroughfare, circuity increased. As discussed, this is important when looking at trying to provide easily accessible services, but also services that do not require motorised transport to obtain access to them. Although the study was very limited by various factors, it shows how even a simple study can highlight issues around access to services and sustainability goals linked to this access. Policy that links access to services, route choice and sustainability, as we continue to aim for a healthier more equitable society over the coming years will be vital.

13 References

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14 Appendix

Access to the full code and data can be found on Github here.

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