Computing geographical access to services: the design of an open-source multimodal client-server solution

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Summary

This study describes the design and implementation of a web-based solution for computing geographic accessibility, using open-source elements. The computation of accessibility scores incorporates the use of multiple modes of transportation and can be adapted to any form of service provision that can be represented as geographic points. The solution provided aims to extend previous attempts at measuring multi-modal accessibility by integrating a new approach of generating required variables to perform these calculations in a fully open source, open data environment. The infrastructure of this solution is described, demonstrating how the transport distances are generated and applied within the FCA calculation.

KEYWORDS: Multi-modal, Potential Accessibility, Two-Step Floating Catchment Area (2SFCA), Wales, GIS

1. Introduction

Sporting organisations and national governing bodies have an aim of ensuring the sufficient and equitable access to both their facilities and opportunities. In order to achieve this objective, such organisations are required to develop systems and tools that enable the calculation of accessibility and monitoring of service provision.

This paper describes the planning, development and implementation of a web-based solution that enables the computation and visualisation of geographic accessibility measures. The purpose of the solution is to keep it as cost effective as possible using open source and open data, while working in a web-based environment to allow access from any location with permission to collaborate in planning and decision making of service locations. The measurement of accessibility specifically used in this study is a modification of the Enhanced Two-Step Floating catchment area method (E2SFCA) that is described by Luo and Qi (2009) to calculate localised supply-demand ratios. This modification focuses on the implementation of multiple modes of transportation into the existing model, to incorporate the population who access these services via different forms of transport and give a more accurate result on the current levels of accessibility.

2. Background

Geographic accessibility is defined as the ease in which a population or set number of people from a location can reach a point of interest or service. Measuring sufficient and equitable geographical access has been a key topic within geographic literature for years. This discussion on accessibility has been covered over a great variety of areas that includes subjects such as healthcare, sporting facilities, school provision, disaster aid and employment opportunities (Billaudeu et al. 2011, Fransen et al. 2015, Langford et al. 2012, Narboneta and Teknomo 2013, Barbieri and Jorm 2019, Wang 2007, Bao and Deng 2011).

Previous research on accessibility within sport facilities led to the development of a plug-in within proprietary ArcGIS software that enabled an E2SFCA analysis of access to sporting facilities (Langford, et al., 2016). This research extends that research by implementing an open-source solution, as a standalone C# application that incorporates the use of PostGIS and QGIS applications to process and

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visualise the data. This work continues the open-source elements, while implementing the advantages of a web-based environment and multi-modal capabilities for a more accurate representation of current accessibility.

3. Data and Methods

Although the solution can calculate multiple accessibility models, the model used within this study is a variation of the E2SFCA model that implements a method of including additional modes of transport proposed by Langford et al. (2016). This model allows for any number of transport types to be accommodated into the calculation by incorporating times and distances for different modes of transport generated by a route planner.

There are several route planners available, some through paid services and subscriptions which maintain and supply their own data for bus networks and times such as Google Maps API (2021) and Baidu Maps (2021). Alternatives include OpenTripPlanner (2021), Open-Source Routing Machine (OSRM, 2021) or pgRouting (2021). The route planner used within this study is OpenTripPlanner (OTP) which has been previously been shown to prove useful when measuring distances for different modes of transport (Tsalamanis 2018, Owen & Levinson 2015, El-Geneidy et al. 2016). OTP is built on a graph that is generated using GTFS data that consists of bus times and routes, along with an open street map road network (Geofabrik 2021). The GTFS data in this study has been generated from Traveline Data (2021).

Finally, during the duration of this project, the supply points and services for testing were supplied by a national sporting organisation in Wales (Welsh Gymnastics). Although these were used during testing, any form of service provision with geographic points of access may be used in place of these service locations. The population demand points are based on census estimated population data. These can be at any level, including output area (OA), lower super output area (LSOA) and middle super output area geographic areas (MSOA).

4. System Design

The systems infrastructure, and the processes involved are outlined in figure 1. The structure mainly comprises of four primary components. The first of these components is the web-based interface that uses HTML/CSS for interface development. JavaScript is used for the client-side data processing during the interaction. The second component is a server that contains PHP coding that enables server-side data processing. The server is responsible for communicating between the web-browser interface and the remaining two components that allow for the data processing. The third component, is the route planner OpenTripPlanner for generating the distances, using its REST API, to produce JSON data to be extracted. The final component in the system is a PostgreSQL spatial database, that is used to house all the geographic data along with using its PostGIS extension for its geospatial analysis functionality.

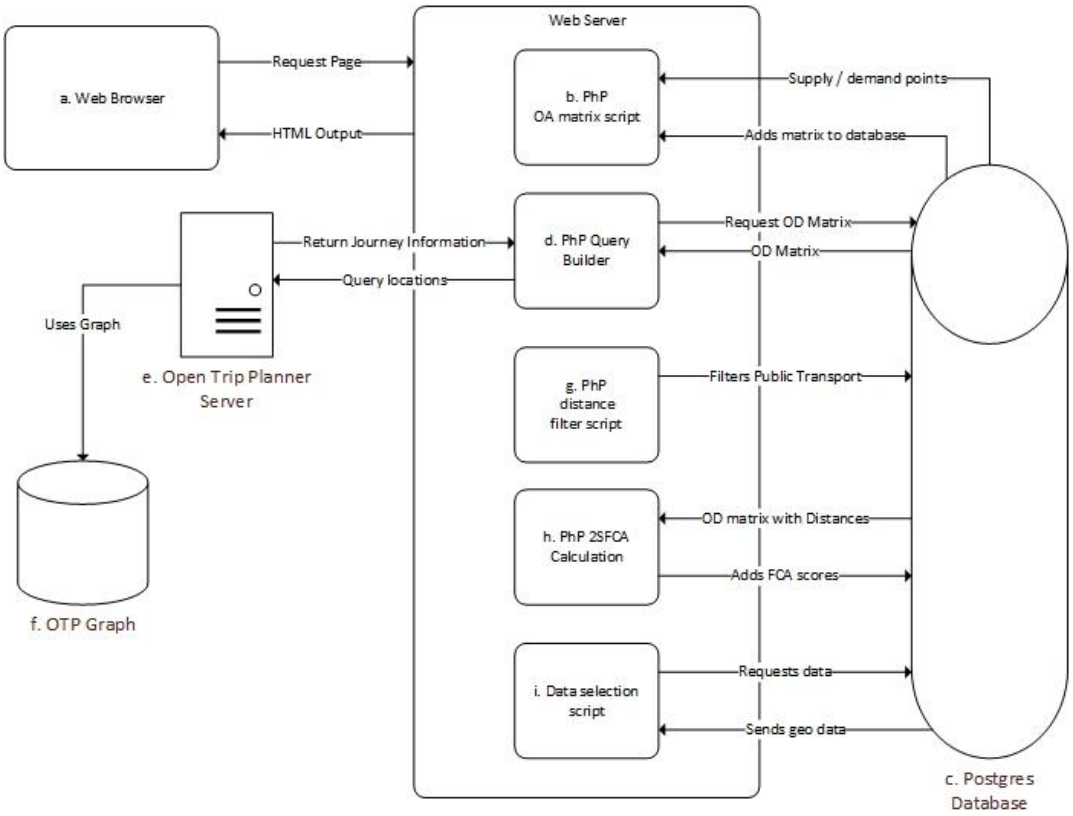

Figure 1: The infrastructure of the open-source web-based solution.

Following Figure 1, the workflow of the model involves:

a. A system user interacts with the web-browser interface (a) to input the desired values and modelling parameters of the initial calculation in the initial setup. The browser interacts with the web server holding each of the PHP Scripts. The initial setup is used to set a limit on the calculation to prevent unnecessary calculation of facilities and demand points.
b. The supply points (in this study the gymnastics facilities) and demand points (population-weighted centroids) within the Postgres Database (c) are extracted by the web server script (b) that generates an origin to destination (OD) matrix of each point within the desired parameters using PostGIS to calculate those points falling within a straight-line distance catchment. Figure 2 shows the interface used to set these parameters.
c. The PHP script (d) then loops through the OD matrix creating a URL string to query OTPs REST API (e) build on the graph that contains the GTFS and road network data (f). The URL string contains coordinates of the supply and demand locations to do this. OPT responds with JSON data of each journey for each of the modes of transport selected. The script (d) then extracts these journey distances and times and places them into a new table in the PostgreSQL database.
d. As the public transport returns several journeys that range in different bus companies and routes, a filtering script (g) is required to select the shortest distance (or based on other parameters the user may wish such as most cost effective etc). With the public transport distances filtered, all modes of transport journey times and distances are added to the OD matrix.
e. The user is now able to perform the calculation using the OD matrix with the journeys and times. Script (h) builds a SQL string using the parameters entered in Figure 3. The SQL string is then applied to the PostgreSQL database to generate the scores of each demand location.
f. Using the script (i) the user is able to select the data to display on the leaflet web-map (j) and interact with the data as shown in figure 4.

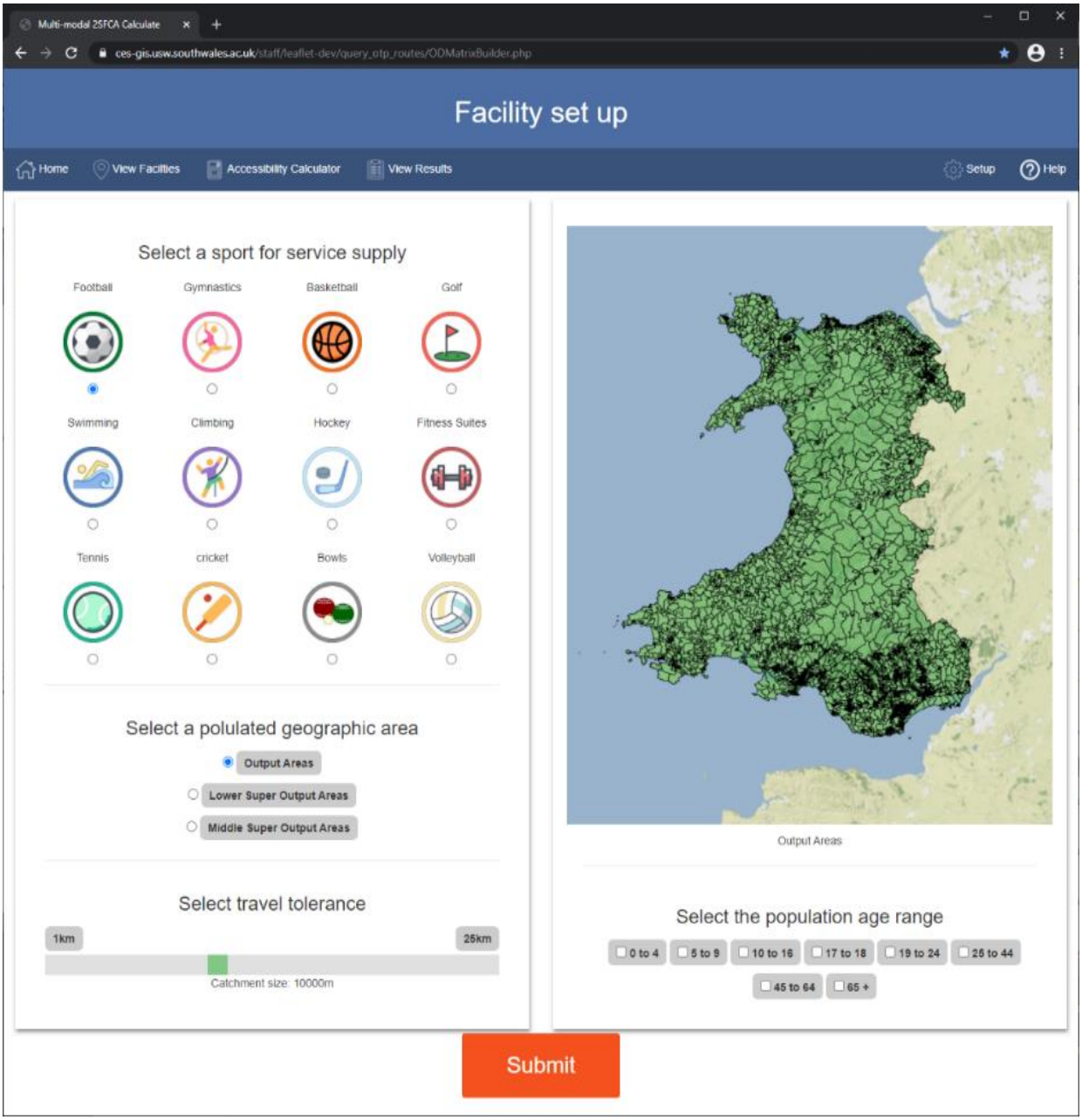

Figure 2: The origin to destination matrix builder user interface

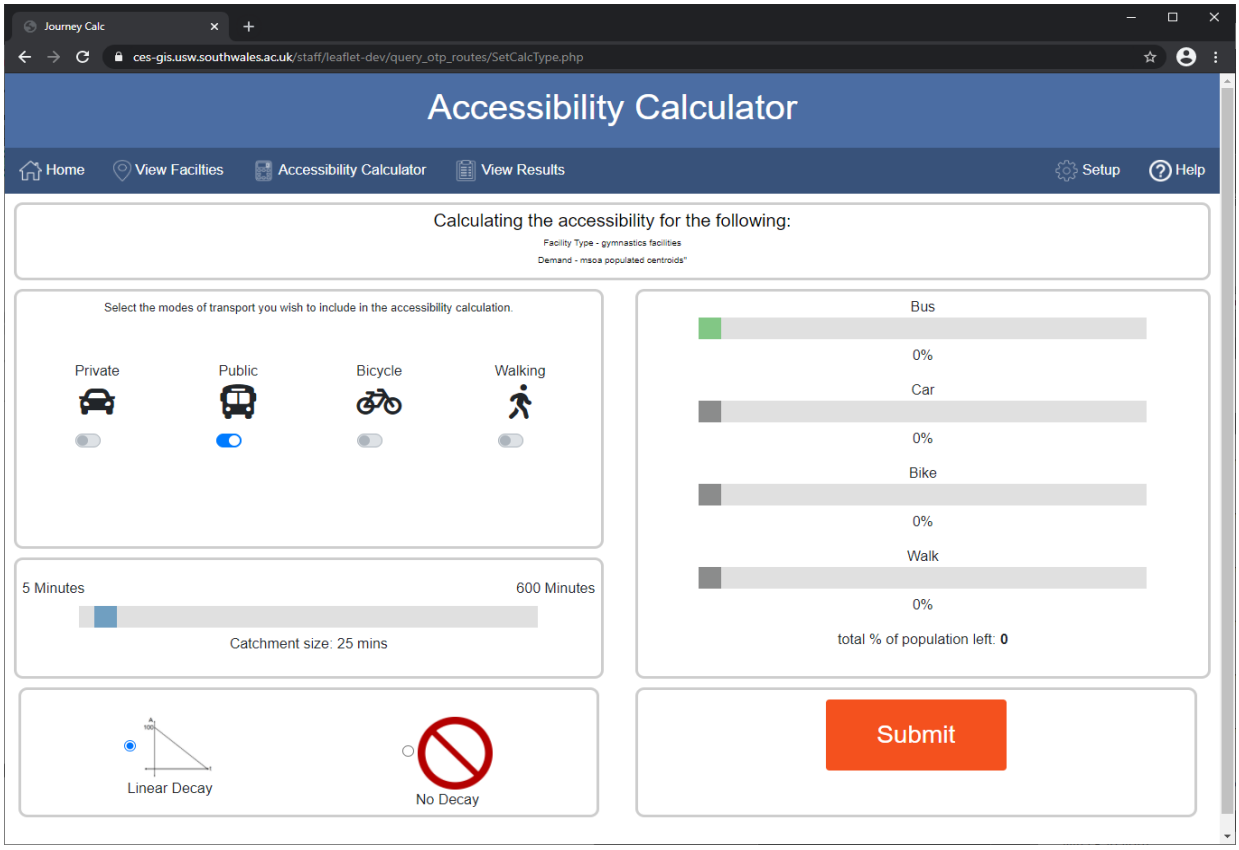

Figure 3 The accessibility calculation interface.

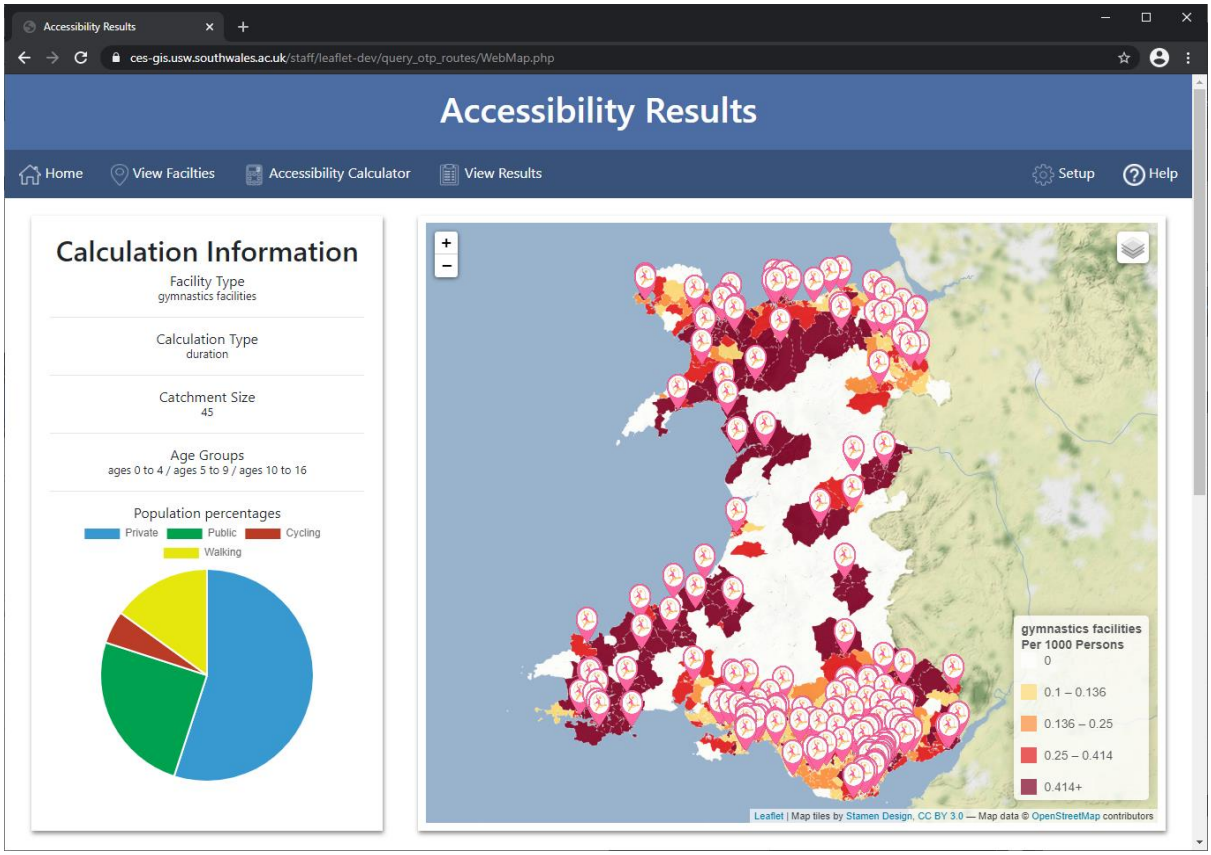

Figure 4 The interactive web map interface generated using the data calculated from the accessibility calculator.

5. Results and Discussion

The methods that have been applied within this study have extended previous approaches of measuring accessibility based around single modes of transport often within distance-based or cumulative opportunity-based techniques. Each mode of transport also uses the same road network, removing the need of maintaining multiple datasets for each mode of transport. Furthermore, the accessibility model used allows for any number of transport modes to be included as long as the route planner is capable of adding that form of transport.

With the help of potential users in Sport Wales, interfaces are designed for policy makers not necessarily familiar with GIS tools by hiding the complexity of the interaction and by providing appropriate guidance and help in implementing the models. The components used, including the web mapping API are open source which, together with the use of open data, lowers the cost of maintaining the service this solution offers in contrast to the use of tools such as Google Maps or Baidu Maps. The design of the system has gone through several iterations with full evaluation of possible solutions at each design stage. This will be discussed in further detail in the presentation.

Future work involves implementing additional functionality that aids in planning of service provision. An example being a "what if" scenario where a user simply clicks on a location to add a new facility or modify a current facility and the accessibility is recalculated with the new or modified facility to view the impact in access for that geographic location.

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Biographies

Andrew Price is a PhD Student based in the Faculty of Computing, Engineering and Science, at the University of South Wales. His PhD is based on improving our understanding to access of sporting facilities in Wales, using GIS.

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Gary Higgs is a Professor of Geographical Information Science in the Faculty of Computing, Engineering and Science, University of South Wales and co-Director of the Wales Institute of Social and Economic Research, Data and Methods (WISERD). Over-arching research interests are in the application of GIS in social and environmental studies, most recently in the areas of health geography and emergency planning.

Jonathan Radcliffe is a Senior Data and GIS Analyst at Sport Wales, after completing his PhD in the School of Geography and Planning, Cardiff University.