The design and development of a client-server based tool to compute accessibility to sporting facilities in Wales

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Summary

This paper draws on a new database of gymnastics facilities, the use of Two-Step Floating Catchment Area (E2SFCA) techniques, to measure potential accessibility for both private and public transport networks using a web-based tool to collect the network distances for the transport. Plans to incorporate both the public and private networks into a multi-modal approach are outlined, along with open-source web-based solutions to visualise the dataset and results, highlighting the role multi-modal accessibility GIS-based approaches can have an influence on creating future investments and decision making within planning processes of sport facilities.

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

1. Introduction

Ensuring adequate and equitable geographical access to facilities and opportunities is a concern for most bodies charged with any form of public service provision. Sport Wales is a national organisation responsible for developing and promoting sports and physical activity in Wales at both elite and grassroots levels. Driven by the Welsh Government's *Creating an Active Wales* policy, a key aim is to encourage people of all ages to choose to be more physically active, and to support children and young people to live active lives. This should improve the health and wellbeing of the population and reduce future health expenditure associated with inactivity and poor lifestyles.

This paper describes the planning, design and construction of a browser-based tool to enable the calculation and visualisation of sophisticated geographical accessibility measurements. Specifically, enhanced two-step floating catchment area (E2SFCA) metrics, as described by Lou & Qi (2009) that calculate localised supply-demand ratios. In this study, gymnastics facilities are used as the service supply and populated weighted centroids with age-group population totals at OA or LSOA level as the demand. E2SFCA scores can assist in the management and development of future sporting infrastructure and service provision, leading to improved opportunities and greater public participation in sporting activities across Wales.

2. Background

Previous research led to the development of a plugin tool for E2SFCA analysis using the proprietary ArcGIS software (Langford, et al., 2016). Similar capabilities have since been developed with free-and-open source software (FOSS), as a standalone C# application linking to a PostGIS spatial database, using QGIS to visualise outputs.

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This paper describes progress in an on-going PhD concerned with identifying and overcoming the computer science challenges associated with replicating such capabilities in a distributed client-server architecture. This involves careful integration of a number of key computing technologies including:

a. HTML/CSS for browser interface development.
b. JavaScript for client-side data processing, manipulation and analysis.
c. PHP for server-side data processing, manipulation and analysis.
d. PostgreSQL/PostGIS for spatial data management and analysis.
e. OpenTripPlanner (an open source multi-modal trip planner) for network journey tracking using both public and private transport.
f. REST, JSON, and other web services for communication and data flow between servers and clients used within the infrastructure.
g. Leaflet/OpenLayers for data visualisation and presentation of outputs.

This work implements the advantages of free web-based open source software throughout, enabling access via a web-browser from any connected location, on any convenient platform (Desktop PC, laptop, tablet), thus providing access anywhere it may be required. It also relieves the burden of downloading and storing data in current road networks and the need to construct/maintain a topological network in the likes of pgRouting or ArcGIS Network Analyst. The setting up and maintaining of central server infrastructure and all key datasets can be done by IT specialists, so need not concern the spatial analyst or system user.

3. System Design

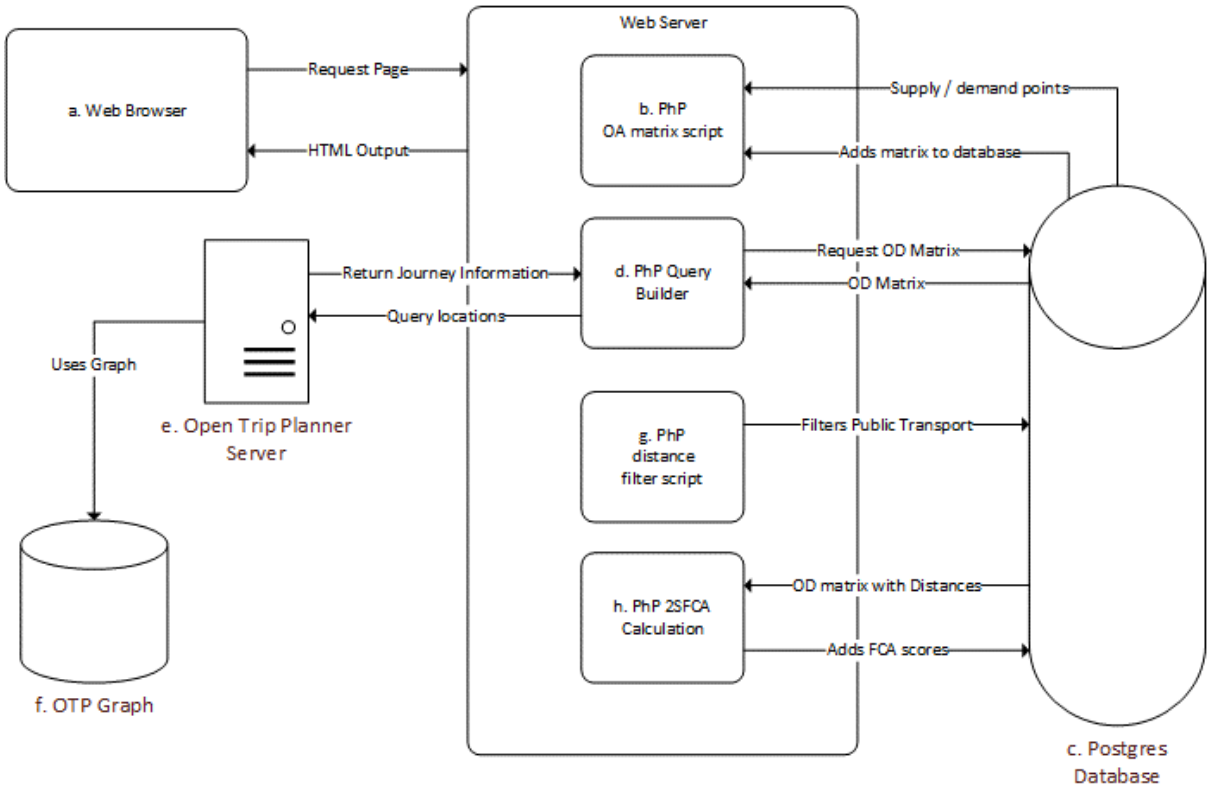

Figure 1 Implementation of the software used to calculate private and public transport distances, and generate FCA scores.

Within the design are four major components. A PostgresSQL Server and spatial database to hold details of population demand points (currently LSOA centroids with selected UK Census statistics), and service delivery points (currently Welsh Gymnastics sites and service quality/volume indicators). The database also stores/manages Origin-Destination (OD) matrices used in E2SFCA calculations, and retains the outputs of accessibility scores generated by analyses. The second being an OpenTripPlanner Server and corresponding OTP Graph database containing a road network and public transport timetable. The third, a web server containing server-side data processing and analysis scripts. Finally, a web browser for front-end modelling functionality and the display of results.

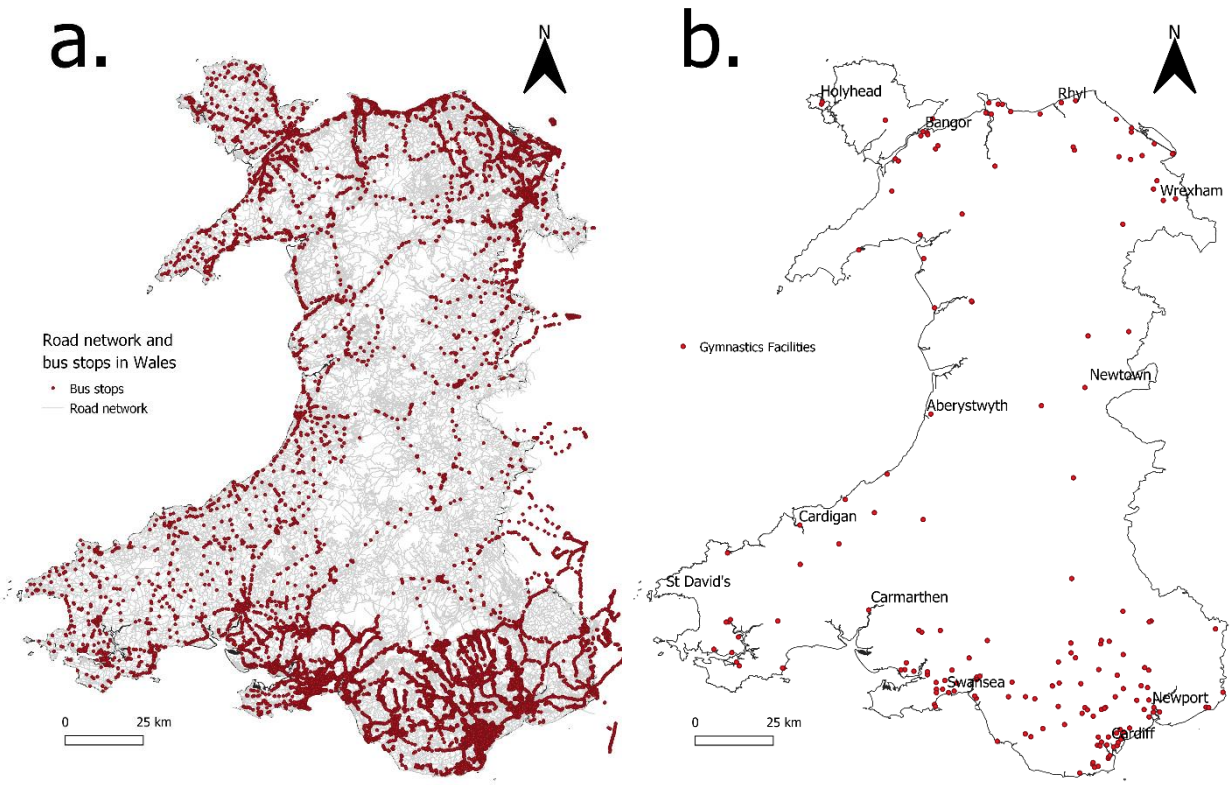

Figure 2 Road network, bus stops, routes and gymnastics facilities. (a) Road network based on OpenStreetMap at Geofabrik (Geofabrik, 2019) with bus stops and routes provided by TravelineData (TravelineData, 2019) (b) Gymnastics facilities locations

Following Figure 1, a typical workflow model is thus:

1. Browser (a) is used to interact with the web server holding core PHP scripts. The user is able to select desired data inputs and modelling parameters before initiating the analysis. For example, the choice of service and capacity measure, the threshold travel distance used in the FCA calculation, and the choice of distance-decay model.
2. Supply points (gymnastics facilities) and demand points (LSOA Centroids) tables are pulled from the PostGIS database to begin the process of generating FCA accessibility scores. The tables consist of a Primary Key ID, stored geometry (locations represented in Latitude/Longitude coordinates) and respective service volume and demand metrics.
3. The PHP script instructs the Postgres server to construct a ‘skeletal’ OD matrix relating to the selected supply and demand points. The PHP script represented as (b) first instructs

PostGIS to identify all demand and supply points falling within a stated straight-line distance of each other. This is achieved quickly with little computational effort in PostGIS by using R-Tree indexing, and since network distances are always longer than straight-line distances the matrix entries are now limited to include only those supply-demand pairs that might be needed in the FCA calculation rather than an exhaustive cross-product evaluation.

Table 1 Example of typical data required in the OD matrix to allow further processing within the model.

Supply ID	Supply Volume	Demand ID	Demand Volume	Supply Lat	Supply Lon	Demand Lat	Demand Lon
116	1	1676	350	51.39379226	-3.26954090	51.41963891	-3.26930221
154	1	1676	350	51.39379226	-3.26954090	51.41963891	-3.26930221

4. A PHP query builder script (d) retrieves the skeletal OD matrix from the Postgres Database and loops through each listed combination of origin and destination point.
5. Each pair contains coordinates that are attached to a URL string and passed as a query to the Open Trip Planner webservice (e). Essentially, the string is used to query OTP's RESTful API.
6. OTP responds by constructing a set number of journeys between the stated origin and destination point. The query also includes control parameters such as the desired mode of transport (e.g. bus, bicycle, pedestrian), the time and date, and maximum accumulative walking distance allowed when not in transit.
7. OTP uses its stored graph to generate possible journeys. The graph (f) consists of a road network sourced from OpenStreetMap (Geofabrik, 2019) and a general transit feed specification (GTFS) of all current bus stops and bus routes in Wales from the online Traveline Data resource (Traveline Data, 2019). OTP uses the graph to calculate available journeys and returns them to the controlling script in JSON format.
8. The query script (d) retrieves the JSON and extracts pertinent information such as the network travel distance, total travel time, waiting time, total walking distance and number of mode transfers. Data for all OTP generated journeys are stored in a new table on the Postgres server.
9. The OTP server typically returns several public transport journeys for each request, based on the numerous start times and bus routes that may be available between origin and destination. A further PHP script (g) analyses and identifies the option that represents the shortest distance or time solution. Private transport queries issued to OTP return a single shortest distance/time in the JSON response so need no further filtering
10. After filtering the network travel distance/time for both public and private transport modes are used to complete the OD matrix.
11. With the OD matrix completed for both public and private transport modes, E2SFCA calculations are then performed (h). A series of SQL queries are issued to PostGIS, ignoring any computed network distances that exceed the specified FCA catchment size, to compute the estimated demand on each service point (Step 1 of the algorithm). These are written back to the table holding supply points. A second series of SQL queries tally these availability scores within the catchments of each demand point (Step 2 of the algorithm) to yield the final E2SFCA score, which is appended to the demand points table.

12. With analysis complete, accessibility scores can be read directly by QGIS to provide cartographic representation, such as the maps in Figure 4. In the future, additional HTML/CSS/JavaScript coding will present maps directly in the browser by using the Leaflet mapping API, or a GeoServer installation running on the same Web Server.

4. Results and discussion

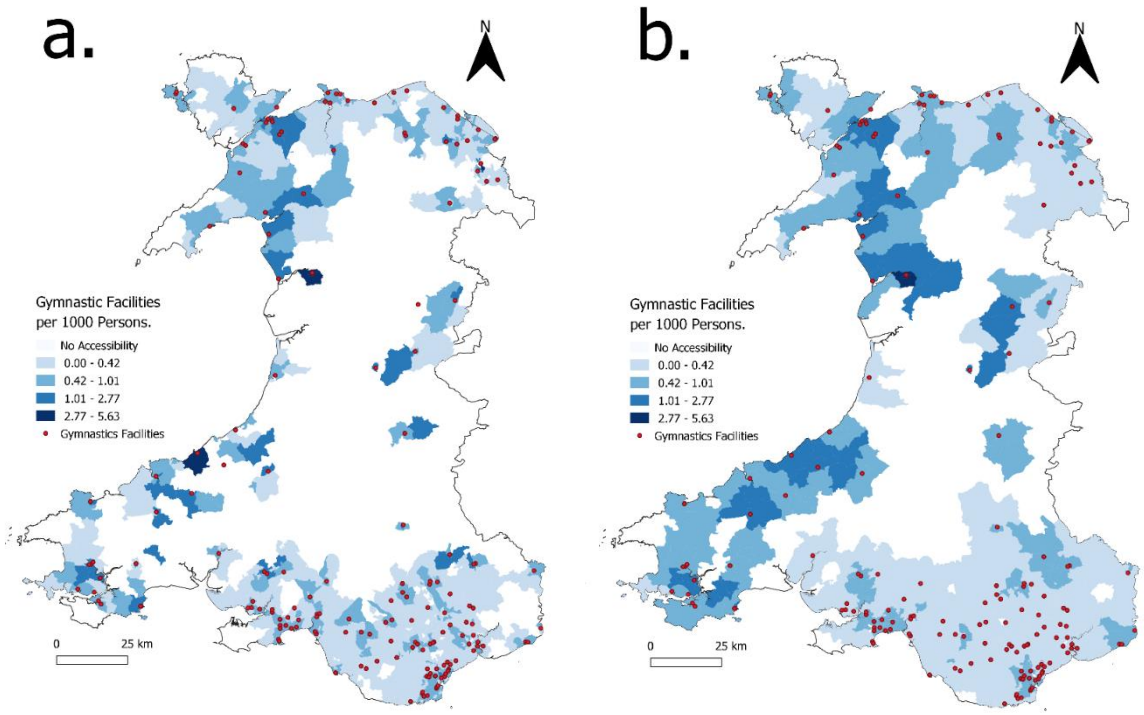

Figure 3 FCA scores for access to Welsh Gymnastics facilities. (a) Public transport with 45 minute catchment and maximum 1km Walking distance to bus stops. (b) Private transport with 45 minute catchment.

Currently all servers and web services required by the model have been configured. Core datasets have been assembled and mechanisms to maintain current timetables and road networks established by uploading from Traveline, OpenStreepMap, Census UK etc. Data for the initial test case was assembled with help from Welsh Gymnastics who provided supply side locations and facilities along with demographics of users. These data will help us to explore the potential of the information generated and to calibrate E2SFCA models before extending to other sports activities.

Future objectives are to develop the browser-based display of outputs using Leaflet API and GeoServer. We also expect to implement full multi-modal E2SFCA models, as described by Langford et al. (2016). This will create separate scores based on the number of people likely to use private and public transport. Cycling and walking can also be taken into consideration in future multi-modal modelling.

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6. 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.

Mitchel Langford is a Reader at the Faculty of Computing, Engineering and Science, University of South Wales. His current research interests include dasymetric mapping, population modelling and geospatial analysis within the fields of healthcare, social equality and environmental justice.

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.

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