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AequilibraE and Tradesman: Current state of affairs of modelling with open-source software

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1. Introduction

The infrastructure sector, particularly transportation, has seen data availability skyrocket in the last decade. While Crowd-sourced data such as Open-Street Maps have reached maturity, other data sources such as Location-Based Services (i.e. cell phone app data), satellite imagery and vehicle GPS data have flooded the market at a dizzying speed.

Yet, the distance between available data and actionable insight has not decreased at the same speed in this period, as the creation of digital transportation infrastructure models have remained a largely manual exercise, and the many commercial alternatives for "automatic" analytic model creation have continued to focus on capabilities required by agencies in developed countries, becoming far too onerous for the purpose of obtaining general insights on the state of the infrastructure.

On the same note, traditional transportation planning/modelling packages, which are ideal platforms to extract insights about a country's transportation network and how well it likely serves its population, have evolved to continue focusing on the creation and maintenance of complex models geared towards demand forecasting on more advanced transportation system, namely those of urban regions in developed countries and some major urban centres in middle income countries. Added to the lack of focus on countrywide models and exceedingly high license prices, commercial packages continue to be desktop-only software, requiring cumbersome software engineering for deployment in cloud environments and integration as part of an analytics pipeline.

If commercial software has evolved to continue tackling the same issues, the same way, and in the same regions, Open-Source solutions have, until very recently, evolved as convoluted research tools without many practical applications, especially in data-poor regions and for resource-constrained modelling efforts.

In this scenario, AequilibraE has been created to be able to perform as a general Python package that can be included in any analytics pipeline and bringing, for the first time, transportation modelling techniques to a data analysis environment. The software ability to automatically ingest large amounts of data from Open-Street Maps into an analytics-focused digital model is perhaps its greatest triumph over commercial packages when it comes to working with Open-Data, particularly for the deployment of cloud-based analytics solutions.

While AequilibraE focuses on the transportation infrastructure side and on the analytics algorithms required in transportation modelling and planning, Tradesman is a Python package dedicated to the creation of comprehensive digital models with all data sources freely available online.

2. Open-data opportunities

As mentioned before, Open-Street Maps (OSM) has reached maturity in the last decade, and there are now countless tools to utilise OSM networks directly and to parse them into computational models dedicated to transportation planning/modelling.

Other datasets, however, have not met the same level of use among transportation professionals, despite being widely and freely available, particularly population distribution across all inhabited regions of the planet as gridded population maps at the resolution of $100m^2$ (Darin et al. 2022).

The use of this type of population data to support development of Traffic Analysis zones is very recent (Camargo 2021), and the algorithms available in Tradesman are a more robust and slightly faster version than those presented in (Camargo 2021).

The use of Point-of-Interest data as the basis of demand models rather than as just a secondary dataset is also a new practice (Klinkhardt et al. 2021; Zhan et al. 2013), although data completeness continues to be a point of contention, particularly in developing countries.

As Tradesman is under active development and yet to reach maturity as a software package, this is an area where we would appreciate contributions and recommendations on the availability and use of other widely available open-data, particularly those available across a large number of countries.

3. Modelling capabilities

Having a wide acceptance among transportation professionals requires both availability of all (or most) tools usually required in the development and use of models. Two of the most complex activities to perform without a dedicated package, however, are network maintenance/editing and traffic assignment.

3.1. Network editing/maintenance

Editing transportation networks involves editing its geometry and tabular data, while keeping these two aspects mutually consistent and also keeping multiple different elements, such as links and nodes, also consistent.

In AequilibraE, data consistency is achieved through the explicit treatment of changes to each component of each one the objects considered (i.e. nodes and links) and the expected consequence to other elements/tables. As it is important to keep this consistency as the editing occurs, these consistency rules were implemented in the form of spatial and data triggers, based on the SQLite and SpatiaLite backends used to store the AequilibraE data in disk (Camargo 2020).

3.2. Traffic assignment

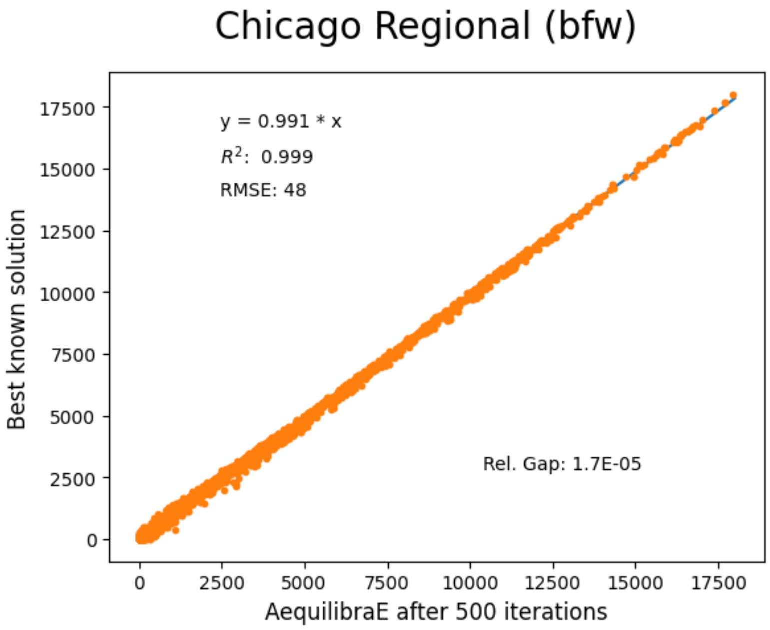
While single-class equilibrium traffic assignment (Ortuzar and Willumsen 2011) is mathematically simple, multi-class traffic assignment (Florian and Morosan 2014), especially when including monetary costs (e.g. tolls) and multiple classes with different Passenger Car Equivalent (PCE) factors, requires more sophisticated mathematics.

As it is to be expected, strict convergence of multi-class equilibrium assignments comes at the cost of specific technical requirements and more advanced equilibration algorithms have slightly different requirements.

As the detailed derivation of the multi-class traffic assignment problem under multiple algorithms is already available in the literature (Zill et al. 2019; Marcotte and Patriksson 2007), we focus on the correctness of the algorithms implemented against known instances. Unfortunately, the available test instances focus solely on single-class traffic assignment without additional penalties (e.g. tolls) (Stabler 2022), and present traffic flows converged to exceedingly high levels, often 1e-15.

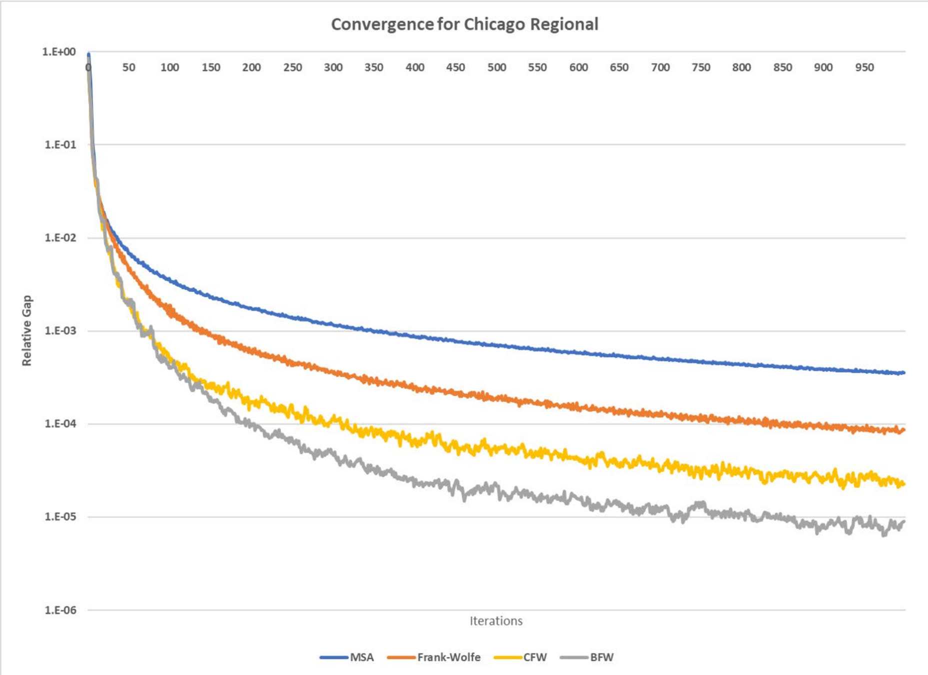
The comparison of the AequilibraE Traffic assignment against the reference results for the Chicago Sketch network **(Figure 1)** indicate the correctness of the algorithm, while the results from **Figure 2** show the clear advantages of the conjugate and bi-conjugate equilibration algorithms over the traditional Frank-Wolfe and MSA.

Figure 1: Chicago Sketch model converged under Biconjugate Frank-Wolfe[1]



[1] Source: AequilibraE Documentation

Figure 2: Convergence behaviour of all equilibration Algorithms in AequilibraE[1]



3.3. Other capabilities

Other software capabilities, such as the calibration and application of synthetic gravity models, Iterative-proportional fitting, and GTFS import to any network (i.e. modelling/simplified networks), as well as the ability of using all AequilibraE tools without an underlying AequilibraE model are also available.

4. Future work

The number of AequilibraE-based models around the world is growing, but use in Australia is still limited to the Queensland Freight model currently being developed. As most of the AequilibraE development team is currently based in Australia, development of tools that are required for its wide adoption in Australian cities is a priority, alongside the development of public transport tools currently being funded by French institutions.

5. References

Camargo P (2020) ‘Editing Transportation networks in GIS’, https://www.xl-optim.com/transponet/, accessed 28 April 2023.

—— (2021) ‘A Model from nothing. How far can get (and what can you do), with Open-Source and Open-Data alone’, *18th TRB Conference on Transportation Planning Applications, USA*, Transportation Research Board, Portland, Oregon.

Darin E, Kuépié M, Bassinga H, Boo G, Tatem AJ and Reeve P (2022) ‘The Population Seen from Space: When Satellite Images Come to the Rescue of the Census’, *Population*, 77(3):437–464.

Florian M and Morosan CD (2014) ‘On uniqueness and proportionality in multi-class equilibrium assignment’, *Transportation Research Part B: Methodological*, 70(Supplement C):173–185, doi:https://doi.org/10.1016/j.trb.2014.06.011.

Klinkhardt C, Woerle T, Briem L, Heilig M, Kagerbauer M and Vortisch P (2021) 'Using OpenStreetMap as a Data Source for Attractiveness in Travel Demand Models', *Transportation Research Record*, 2675(8):294–303, doi:10.1177/0361198121997415.

Marcotte P and Patriksson M (2007) 'Chapter 10 Traffic Equilibrium', in C Barnhart and G Laporte (eds) *Handbooks in Operations Research and Management Science*, Transportation, Elsevier, doi:10.1016/S0927-0507(06)14010-4.

Ortuzar J de D and Willumsen LG (2011) *Modelling Transport*.

Stabler B (2022) 'Transportation Networks', https://github.com/bstabler/TransportationNetworks.

Zhan X, Hasan S, Ukkusuri SV and Kamga C (2013) 'Urban link travel time estimation using large-scale taxi data with partial information', *Transportation Research Part C: Emerging Technologies*, 33:37–49, doi:http://dx.doi.org/10.1016/j.trc.2013.04.001.

Zill JC, Camargo P, Daisy NS and Veitch T (2019) 'Toll Choice and Stochastic User Equilibrium: Ticking All the Boxes', *Transportation Research Record*, 2673(4):930–940, doi:10.1177/0361198119837496.