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Open access transport models: A leverage point in sustainable transport planning

Robin Lovelace [a,*], John Parkin [b], Tom Cohen [c]

[a] Institute for Transport Studies, University of Leeds, UK
[b] Centre for Transport and Society, University of West of England, UK
[c] Active Travel Academy, University of Westminster, UK

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ABSTRACT

A large and growing body of evidence suggests fundamental changes are needed in transport systems, to tackle issues such as air pollution, physical inactivity and climate change. Transport models can play a major role in tackling these issues through the transport planning process, but they have historically been focussed on motorised modes (especially cars) and available only to professional transport planners working within the existing paradigm. Building on the principles of open access software, first developed in the context of geographic information systems, this paper develops and discusses the concept of open access transport models, which we define as models that are both developed using open source software and are available to be used by the public without the need for specialist training or the purchase of software licences. We explore the future potential of open access transport models to support the transition away from fossil fuels in the transport sector. We do this with reference to the literature on the use of tools in the planning process, and by exploring an example that is already in use: the 'Propensity to Cycle Tool'. We conclude that open access transport models can be a leverage point in the planning process due to their ability to provide robust, transparent and actionable evidence that is available to a range of stakeholders, not just professional transport planners. Open access transport models represent a disruptive technology deserving further research and development, by planners, researchers and citizen scientists, including open source software developers and advocacy groups but, in order to fulfil their potential, they will require both financial and policy support from government bodies.

1. Introduction

A large and growing body of evidence shows that motorised transport systems are damaging to environmental sustainability and human health (e.g. Creutzig et al., 2015; De Nazelle et al., 2011; Han and Hayashi, 2008; Peake, 1994; Rouse and Smith, 1975). Transport models, by which we mean software for transport modelling rather than the theories that underlie them, were first developed to support growth in private car use (Boyce and Williams, 2015). In the context of the accelerating 'data revolution' (Kitchin, 2014) and rapid uptake of open source software (Dhir and Dhir, 2017), new technologies have enabled public access to actionable data about, and to some extent participation in, policy-relevant fields such as energy systems analysis and land use planning (Morrison, 2018; Pettit et al., 2014).[1] The topic of this paper is the meaning of and potential for open access models – models that are based on open source code that can be easily and freely used by the public – to support evidence-based decision-making and public participation in 21st Century transport planning.

In addition to technological developments, environmental imperatives suggest that changes are needed throughout the transport planning process. Despite mounting evidence of, and public debates about, crises exacerbated (if not caused) by motorised transport systems – such as air pollution and obesity – car-centric plans continue to dominate cities worldwide. A range of solutions have been proposed at the national level, including increased fuel taxes (Wang et al., 2013) the phase-out of internal-combustion engines (Burch and Gilchrist, 2018) and incentives to reduce demand at national levels (Cuenot et al., 2012; Raux and Lee-Gosselin, 2010).

* Corresponding author.
E-mail address: r.lovelace@leeds.ac.uk (R. Lovelace).

[1] The 2050 Energy Calculator hosted at http://2050-calculator-tool.decc.gov.uk/provides an example of a publicly accessible energy policy tool designed to inform debate around decarbonisation.

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Transport planning solutions have a major, if not primary, role to play in addressing the ‘root causes’ of the car-based ‘unsustainable transport paradigm’ (Kershaw et al., 2018), at regional, city and local levels. This leads directly and naturally to a consideration of transport (demand) models, which underlie many important aspects of transport planning at sub-national levels (Hollander, 2016). Evidence-based policies and public participation in local policy processes have great potential to supplement established decision-making systems (Monbiot, 2017). What role can transport models play in this ‘participatory turn’ (Krivỳ; Kaminer, 2013) and the need for sustainable transition in transport systems? That is the topic of this paper.

Paradigm shifts — for example from ‘growth to equity and sustainability’ (Masser et al., 1992), ‘automobility to accessibility’ (Cervero, 2013), and from conventional (engineering-orientated) approaches to ‘sustainable mobility’ (Banister, 2008) — have been advocated in transport planning for decades. Yet the extent to which such ideas have influenced practice is debatable (Legacy, 2016). Measured in terms of global greenhouse gas emissions, transport planners and other decision makers with influence over transport systems are failing, with transport emissions growing faster than in any other sector.[2]

These observations raise the question of how academic calls for change, let alone paradigm shifts, can be realized in practice. The broadly defined field of ‘systems theory’ could offer some pointers in this direction (Van Assche and Verschraegen, 2008). A key finding from the application of systems thinking to the challenge of transitioning entrenched systems towards a post-carbon future is that identifying ‘leverage points’ over which practitioners have some influence is key (Beddoe et al., 2009).

The premise of this paper is that transport models represent such a leverage point, in which a comparatively small change (e.g. in the software or type of model used) can yield large changes ‘downstream’. In the case of transport planning, these downstream impacts would be a bringing together of transport planners and interested and informed citizens and could lead, rather than respond to, the action needed to address climate change, prioritize active modes, and plan for a future with greatly reduced private-car use.

The lineage of transport models that are in widespread use today can be traced back 1950s, so it is unsurprising that they have become increasingly complex while retaining core structural principles (such as the ‘four stage’ approach) that were originally developed to plan for growth in car use (Boyce and Williams, 2015). Another key feature of contemporary transport models is that they are generally proprietary and sold by a relatively small number of for-profit companies including Citilabs (developer of Cube transport modelling software), PTV (VISUM), INRO (Emme), Caliper Corporation (TransCAD) and Atkins Global (SATURN) (Ibid, p. 462).

Research into software business models reveals that the proprietary approach, taken by leading transport planning and software development firms, creates barriers to participation. This includes cost of licences, lack of cross-compatibility and limited extent of on-line communities (Dhir and Dhir, 2017). From a scientific and accountability perspective, the proprietary nature of these dominant transport modelling products is particularly problematic: because the ‘source code’ underlying closed source software cannot be viewed, they represent a ‘black box’ that is difficult to understand, let alone modify based on new insights. Free and open source software, by contrast, is conducive to community engagement, modification and reproducibility (Morrison, 2018).

Perhaps in response to such considerations, open source transport modelling software is thriving in academia, with transport modelling tools such as SUMO and MATSim gaining traction in some commercial settings also, as we will see in Section 4. In commercial transport planning practice, proprietary software still dominates (Boyce and Williams, 2015). Despite the benefits, open source transport models are no panacea, with ‘barriers to entry’ including: difficulty discovering the appropriate open source solution for a particular task (organisations developing open source software often have smaller advertising budgets than those developing proprietary software); a steep learning curve (meaning that open source solutions may require more time and human resource investment than ‘off-the-shelf’ proprietary options); and, critically, lack of an established ‘community of practice’. In other words, open source software for transport planning can be perceived as being just as inaccessible to many practitioners as proprietary software (Waddell, 2011).

Partly in response to the perception that open source software is not always user-friendly, the concept of ‘open access software’ was developed (Lindsay, 2014). Although the concept was first developed in that paper (as far as the authors are aware) with reference to Geographical Information Systems (GIS) software, the same motivations can be applied to transport models. In essence ‘open access’ goes beyond ‘open source’ in that users are not only given the *option* of viewing (potentially indecipherable) source code, but are *encouraged to do so*, with measures taken in the software itself, and the community that builds it, to make it more user-friendly. “The concept of open-access software is based on the idea that software should be designed in a way that reduces the barriers that often discourage or disallow end-users from examining the algorithm design and … encourages the educational opportunities” (Ibid.).

In this paper we build on this concept of ‘open access software’ to develop the concept of ‘open access transport models’. Our emphasis is more on public usability and less on education compared with Lindsay’s interpretation. Reflecting this emphasis, we define open access transport models as digital tools that are not only based on open source software, but which can easily be accessed and used by the public, with documentation and communication channels encouraging communication on using and further developing the underlying models.

The aim of the paper is to explore the meaning and potential for open access transport models in the context of contemporary challenges in applied transport planning, particularly the ‘participatory turn’ and the need for change in transport planning in the light of social and environmental considerations and imperatives. A practical example, the Propensity to Cycle Tool (PCT), is used as an example to discuss what an ‘open access transport model’ looks like in practice. We consider the limitations of the approach, opportunities for the expansion of open access models to other aspects of transport planning, and recommend further research and development. Although relatively small scale in terms of investment compared with physical infrastructure, we hypothesize that such new models represent ‘leverage points’ in the planning system.

The rest of the paper is ordered as follows. Section 2 provides the background to modelling in the transport planning process. Section 3 presents the nature and use of the Propensity to Cycle Tool. Section 4 discusses the value and contribution of accessible modelling for cycle planning, transport planning in general, and citizen participation. Section 5 provides summarizing conclusions.

2. Models in transport planning

2.1. The nature of transport planning

The planning and implementation of transport strategies requires counting, modelling and forecasting, with a historic focus on, if not bias towards, top down processes and motor vehicles (Boyce and Williams, 2015). Despite efforts to make technical aspects of transport planning more multi-modal (Lindsey et al., 2013) and specific models that were designed to be accessible (an example of which is described in the next section), transport planning overall, and transport modelling in particular, are undertaken by ‘experts’ (another term which is rarely defined in the literature) with specialist knowledge (Gudmundsson, 2011).

[2] See https://www.wri.org/blog/2019/10/everything-you-need-know-about-fastest-growing-source-global-emissions-transport.

Conversely, the rejection of (rather than engagement with) quantitative methods by some academic researchers has potentially reduced the influence of constructive criticism and calls for change (Manderscheid, 2016). Transport planning practice remains, despite forays at the margins into psychology and sociology, rooted in 'instrumental rationality', despite calls for it to become a more communication-driven field (Willson, 2001). The intrinsically technological nature of the transport planning process ensures that transport planning and transport planning research are largely based on a positivist worldview (Schwanen et al., 2011). Based on this literature, a premise of this paper is that models have a major role in shaping policies and even worldviews (how transport planning is perceived), including the extent to which it is a participatory enterprise.

Making transport planning more participatory can have unintended consequences. In the Scandinavian context, Næss et al. (2013) found many planning documents did not consider the full complexity of factors affecting urban systems, including density, residential and workplace location, neighbourhood design and diversity, and the effects of increasing road capacity. They argued that the 'communicative turn' in planning may have hindered sustainable planning policies by enabling knowledge that is 'local' and generally more subjective to override knowledge that is 'expert', through its emphasis on the planning process rather than outcomes. The phenomenon of local backlashes against cycling schemes ('bikelashes') may be interpreted as an illustration of this point (Cooper and Leahy, 2017). An interpretation of these observations could be that strong evidence for change needs to be widely distributed and understood throughout society, not just among decision-makers, to avoid local planning being dominated by an adherence to the status quo.

Conversely, Vigar (2006) found that when participants' views are elicited, there is no guarantee that they will meaningfully influence outcomes, suggesting a need for citizens to have access to tools that can support them to make more evidence-based and robust interventions in the planning system, in part by "speaking the language" of transport planning. The lack of common reference points can lead to failure in consensus building. An interpretation of these insights into the imperfect nature of transport planning, and citizen engagement in it, is that collaborative planning practices should use new (digital) technologies to help re-think the balance between professionals and stakeholders because they provide a means of making the process more inclusive whilst retaining its essential quantitative character (Goodspeed, 2016).

2.2. Systems theory: modelling as a leverage point in the planning system

Transport systems are complex, with multiple non-linear interacting parts that operate on different temporal and spatial scales. Recognising this, Chadwick (1978) advocated a 'systems approach' to planning, arguing that concepts such as "information, variety, entropy, feedback" can "make possible a convincing explanation of … cities". *A Systems View of Planning* critiques rigid interpretations of constructs such as the 'four-stage transport model' which has had a major influence on transport planning (Boyce and Williams, 2015) and, instead, advocates more flexible techniques. The planning process itself can be seen as a 'steering' sub-system (Van Assche and Verschraegen, 2008), which itself contains certain leverage points (political capital, models).

Another systems concept that is applicable to transport planning is 'lock-in', the forcing of particular outcomes because of structural factors that need to be addressed for change to happen (Beddoe et al., 2009). The concept of 'leverage points', "places within a complex system … where a small shift in one thing can produce big changes in everything", can help prioritize areas most likely to enable transition and focussing human resources effectively for systemic change. (Open access) transport models can be seen as such a leverage point in the planning system. The systems approach can also help understand the limits to action within the current paradigm, avoiding wasting effort within the dominant paradigm. see transition as an evolutionary process that develops "new goals, rules, and tools" within the current system "to transition away from unsustainable practices".

Neither Chadwick (1978) nor Beddoe (2013) focus on transport planning. However, taken together, they provide a theoretical framework, systems theory, with which the systemic barriers blocking change can be identified, navigated and potentially overcome. Systems theory is a broad approach that has informed some contemporary planning research, including in relation to the systems' concept of resilience (see editorial by Davoudi et al., 2012) and the role of planning in climate change mitigation (Davoudi et al., 2012; Williams, 2012). However, few examples in the literature discuss how systems theory can be put into transport planning practice (e.g. Van Assche and Verschraegen, 2008). From a systems theory perspective, open access transport models can be seen as potential leverage points that could overcome the inherent inertia and self-perpetuating negative feedback loops in the socio-technical, political-economic transport planning system. Before exploring what that means in practice, it is worth delving into the concept of open access models and defining them with reference to other transport planning technologies and techniques.

2.3. Toolkits, tools, planning support systems and models

There is clearly much overlap between, and some ambiguity in, commonly used terms for referring to technologies and formalised processes that support the transport planning process. We briefly defined open access models in Section 1, but how does the term relate to other types of transport planning support techniques?

At one end of the spectrum, policy 'toolkits' is a term often used to denote a series of steps or processes for approaching planning (including transport planning and infrastructure) policy decisions (McEvoy and Ravetz, 2001). Although the term can be used interchangeably with the term 'model', toolkits for planning for active modes have tended to be rigid and prescriptive in name and nature. The TRACE toolkit, a set of recommended steps to assess the potential of movement tracking services, and the Microsoft Excel-based Walking Route Audit Tool (WRAT) provide examples of this type of planning support technique.[3] A related term is 'audit', which refers to an established method used at early stages in the process of planning for categorising the quality of existing systems, a practice that has been criticised for not providing a compelling reason or vision for change (Babb and Curtis, 2015).

The term 'Tool' tends to be used as a broader term that can refer to a range of artefacts and processes from the formalised processes in toolkits, small design aids to large pieces of software (Marsden et al., 2010). Under this broad definition, transport models are a type of tool, that provide some explanation, and can indicate potential for change (e.g. in mode choice) rather than just visualisation and/or description of the transport systems. Open access tools go a step further, by enabling anyone to 'step into the shoes' of transport planners and explore the potential impacts of scenarios of change.

Overall, the literature suggests that tools and techniques used in transport planning are rarely participatory and may carry with them many pre-suppositions about the relative importance of different factors in the planning system, and in some cases a focus on a limited range of variables. A systems approach would seek out techniques with the maximum potential, that is to say 'leverage points', or 'places within a complex system … where a small shift in one thing can produce big changes in everything' (Meadows, 1999). Techniques that engage citizens can represent such leverage points. This is recognised in the Planning Support System (PSS) literature (Geertman, 2002; te Brömmelstroet and Bertolini, 2008). 'Toolkits' have tended to be

[3] See https://cordis.europa.eu/project/id/635266 for further information on the TRACES tookit and https://www.gov.uk/government/publications/local-cycling-and-walking-infrastructure-plans-technical-guidance-and-tools for more on the WRAT.

developed for active travel whereas fully fledged transport models, a tool at the heart of transport planning that has developed around motor traffic, are predominantly dedicated to motorised modes.

From a systems perspective, transport planners intending to make fundamental changes should also use techniques at the heart of the planning process, notwithstanding the well-known limitations of models. Givoni et al. (2016) identified four weaknesses: their complexity; the (false) confidence that they can give; their intrinsic limitations; and finally, and crucially, the lack of public accessibility, resulting from the difficulty in their comprehension and access to computer hardware, data and software to run the models, not to mention the fact that it may suit certain bodies to carry out modelling "behind closed doors". In this context both aspects of open access transport models address important limitations of models: free access to their source code encourages questioning and changing of model assumptions and 'hardcoded' parameters; ease of access and use (e.g. via a web tool) ensures public accessibility.

3. Open access transport models

This section describes what open access models could look like, with reference to Propensity to Cycle Tool (PCT). The PCT meets the two criteria of open access models outlined above: the source code can be viewed at https://github.com/npct/and the tool itself, which can be used by anyone with a web browser via the link https://www.pct.bike/, was designed to be easy-to-use. Although transport planners were the main target audience, people without transport modelling knowledge can explore potential future levels of cycling based on a range scenarios (Lovelace et al., 2017). The final part of this section describes a number of other transport tools, discussing the extent to which they satisfy our criteria of "open access".

3.1. The nature and purpose of the PCT

The PCT is built in open-source software (R), and made available to non-specialist transport planners and the public via the World Wide Web (www.pct.bike). The UK Department for Transport commissioned the creation of the PCT to help tackle the issue of a lack of nationally recognised modelling capability for cycling. The role of the UK government in the development of the PCT is a significant point to which we return.

It is not the purpose of this paper to provide a detailed technical account of the tool, but the data and the methodology behind the tool are robust and fully reported (in Lovelace et al., 2017). Behavioural estimates of mode split and number of trips are derived from origin-destination data, currently based on census journey to work data and travel to school data. The zoning is based on UK middle layer super output areas (MSOA) (mean population 7200). The travel network is based on OpenStreetMap, a crowd-sourced global database of geographic information which, for roads, is more accurate than official sources in many places, with improvements every day thanks to an army of volunteer mappers (Barrington-Leigh and Millard-Ball, 2017). Based on routes calculated by not-for-profit company CycleStreets.net, cycling potential is estimated as a non-linear function of distance and hilliness.

As they are based on national datasets, the results are comparable between different localities. The tool was originally based on commute trip data, representing 16% of trips – but 20% of travel by distance, and with a "disproportionate burden on the transport network" (Department for Transport, 2017a) – but can be extended to use origin-destination data for any trip purpose. Overall, 68% of trips in England are less than 5 miles and these have the greatest potential to switch to cycling (Lovelace et al., 2017). Enabling a higher proportion of these commute trips to be undertaken using a cycle through good planning has been generally absent from transport planning (Parkin, 2010),[4] but good cycle planning is increasingly being recognised as a necessary precursor to good infrastructure provision (Gallagher et al., 2014).[5] The tool is now extended and includes school trip data (Goodman et al., 2019). The tool therefore also now allows for scenarios specifically for another trip type that makes a large contribution to congestion.

A further substantial modelling update is being created linked with the PCT tool. This is called the Cycle Infrastructure Planning Tool (CyIPT), again funded by the Department for Transport, and will assist in identifying the most appropriate infrastructure to consider for cycle traffic based on the cycling flow forecast on a route and the speed and volume of motor traffic in adjoining carriageways.

3.2. The features and applications of the PCT

The PCT provides evidence on the level of cycling potential at multiple levels: areas, desire lines, routes and the route network. This allows local authority planners, transport planning consultants working for local authorities and developers, and also cycling advocates and the citizen in general to explore the geographical distribution of cycling potential in their local area under various scenarios. These scenarios include: 1) Government Target, representing compliance with the government target to double the amount of cycling by distance, "from 0.8 billion stages in 2013 to 1.6 billion stages in 2025" (Department for Transport, 2017b); 2) Gender Equity, the demand if there were gender equality in cycling levels; 3) Go Dutch, a more stretching target if the demand matched Dutch levels; 4) and Ebikes, a scenario that estimates cycling potential in a future with high update of electric bicycles (ebikes), building on Go Dutch. By readily enabling a number of scenarios to be compared quickly, users can assess future potential levels of use many times during the design process, in an iterative process.

A significant attribute of the tool is assistance with the 'visioning' (Tight et al., 2011) of different possible futures and its ability to help planners identify the areas and routes that would need to be considered as priorities to help meet those visions. An example of this is the scenario assuming Dutch levels of cycling being adopted by British Cycling when advocating for transformational investment in Manchester.[6] This approach represents a shift in thinking of the type advocated by Beddoe et al. (2013). This visioning approach is also in line with suggestions that transport planning needs to widen its horizons away from demand prediction and then provision for that predicted demand (predict and provide) to 'decide and provide' (Lyons and Davidson, 2016).[7]

The tool may also be used to highlight more geographically specific issues for the provision of cycling infrastructure. An example is the A1048, the Coast Road, from the centre of Newcastle-upon-Tyne on the north side of the River Tyne. The tool reveals high cycling potential (a

[4] Parkin, J. (2010) The planning required for walking and cycling networks. In: Banister, D. and Givoni, M. Integrated Transport: from policy to practice. Routledge/Taylor and Francis. Chapter 9.

[5] Gallagher, R. and Parkin, J. and (2014) Planning for cycling. London: Chartered Institution of Highways and Transportation ISBN 978-0-902933-52-1 https://www.ciht.org.uk/media/4461/ciht_-_planning_for_cycling_proof_v2_singles.pdf.

[6] The Chief Executive of British Cycling said that "The 'Propensity to Cycle Tool' shows that if residents of Greater Manchester were as likely to cycle as the Dutch we would increase commuter journeys ten-fold, leaving room on the road for people who had to drive. This level of cycling would lead to an estimated £1 billion per year saving to individuals and the local economy" (see https://www.britishcycling.org.uk/campaigning/article/20171102-campaigning-news-British-Cycling-responds-to-Mayor-of-Greater-Manchester-Andy-Burham-s–congestion-conversation–0).

[7] Lyons, G. & Davidson, C. 2016, "Guidance for transport planning and policymaking in the face of an uncertain future", Transportation Research Part A, vol. 88, pp. 104–116.

flow of over 2000 cycles in the peak hour assuming Dutch levels of cycling), and this potential could be released by the provision of appropriately comfortable, attractive and safe infrastructure. The route is one of those shown in Fig. 1.

3.3. Uptake of the PCT

The PCT has the features of a demand model (origin-destination demands, zones and a network). Its key features are accessibility and ease of use by non-modellers, and the ability to run a number of scenarios of different potential levels of cycling. Given that transport planning has relied on demand models to inform its decision making, the tool therefore is now allowing practitioners, and indeed interested citizens (including, for example, the Bath Cycle Campaign), the opportunity to place cycling on a similar footing to motorised modes within the transport planning process. Further, its ability to allow for rapid scenario testing moves it as a tool firmly into the domain of artefacts that can help in processes based on 'deciding and providing'.

The PCT has been used by 50+ Local Authorities to support the design of strategic cycle networks, many of which have used the tool to support their Local Cycling and Walking Plans (LCWIPs) in accordance with central government guidance.[8] It is unlikely that it would have been so extensively used had it not been formally endorsed by the Department for Transport as an aid to the cycle-planning process.

The Propensity to Cycle Tool reduces the 'barrier to entry' into the modelling process for those who do not have a professional background in modelling and for whom specialist modelling software is inaccessible. The tool may in the future encourage cycling to be embedded in transport planning at more strategic levels by opening up the possibility of representing cycling in multi-modal models such as the National Transport Model (Chatterjee and Gordon, 2006). As a further extension of its reach, the tool has the potential to be used in other countries with national level data sets on current modes of use, either just for commuting or for other purposes as well.

3.4. Other relevant transport models/tools

Other prominent (in terms of their presence in the academic literature) open source tools that have been developed in the field of transport planning include open source programs SUMO, MATSim and the online tool Streetmix.net. Each of these is based on open source software and can be used for transport planning but the extent to which they are open access is debatable, a debate that will help define exactly what differentiates open access transport models from models that are open source or simply available through an on-line interface. We defined open access models as models that can be easily and freely used by the public in Section 1. In simple terms, SUMO and MATSim do not meet this definition because they are difficult to use; Streetmix.net is not strictly a model, as defined in Section 2, but a simple (yet very useful) tool for structuring urban road cross-sections. Further discussion of each, with reference to the concept of open access models, will provide insight into how future open access models could develop.

SUMO, which stands for Simulation of Urban Mobility, is a 'microscopic' traffic simulation model that can be used to simulate trip numbers to different origins and destinations in localised studies (via the ACTIVITYGEN tool) and simulate the behaviour of individual entities, including cars, bicycles and pedestrians, along road networks and junctions to approximate real-time behaviour, including congestion (Lopez et al., 2018). SUMO is an advanced tool aimed at academic researchers and transport modelling experts (Behrisch et al., 2014), not the general public, so it is unsurprising that being user-friendly is not a priority. Installing the package alone is not straightforward, as indicated on the SUMO website which provides multiple versions for different operating systems and which states that "installing SUMO from source is not an easy task for beginner users". SUMO is also not easy to use, as highlighted in the online help page Basic/Computer skills which states that "To work with SUMO a few basic computer skills are needed (since Linux-users are probably familiar with these, all explanations refer to MS-Windows)".

MATSim, which stands for Multi-Agent Transport Simulation, is likewise aimed at advanced users, with the first section of the 'downloads' page titled "Use MATSim as a programmer out of an IDE". The 500+ page book describing MATSim contains many use cases of how the software can support a range of transport planning activities, but was clearly not designed with accessibility to a wide range of users in mind (Horni et al., 2016). This focus on advanced users is not necessarily a bad thing, and there can be trade-offs between making software user-friendly and useful for advanced users. In terms of uptake, MATSim has been used in a number of applied transport planning contexts (e.g. Horni et al., 2009; Novosel et al., 2015). Although MATSim (and SUMO) are clearly being used by many people, including in commercial transport planning,[9] and provide a level of transparency in their results because anyone can see their source code (hosted at https://github.com/eclipse/sumo and https://github.com/matsim-org respectively), accessible they are not (that is not to say future products building on these tools could not be open access, e.g. via a 'MATSim lite' that provides a user-friendly web interface).

At the other end of the spectrum is Streetmix.net, which provides a simple web interface for designing street cross-sections. Users are provided with an attractive graphical user interface that they can use to replicate the current layout of a street of interest, and then move things around to approximate a future design (Riggs et al., 2016). The tool minimises barriers to entry by providing guidance on the website. Although there is technical documentation that targets developers in the tool's source code (hosted at https://github.com/streetmix/streetmix), the technical details are helpfully hidden from the majority of users on their website. This ease-of-use has enabled the tool to be used on a number of projects (O'Hern et al., 2019; Silva, 2017; Thiel and Ertiö, 2018). There may be other open source and even open access transport tools and there are likely to be many more in the future. But the discussion above outlines both the great potential for open source software in transport planning, and limitations on usage by citizens (with the notable exception of Streetmix.net).

4. Discussion

The PCT has been in use for some time, following its launch as part of the Cycling and Walking Infrastructure Strategy (CWIS) in early 2017 (Department for Transport, 2017b). The tool provides an opportunity to examine how open access transport models can be used in practice. However, it is just one example of a very wide range of open access transport models that *could* be developed in the future, and may not be representative of the open access tools of the future. It has had a major impact on cycle planning in England already and provides insight into how the concept of 'open access software' (Lindsay, 2014) can be translated from the field of open source GIS to the transport sector.

Perhaps as important as the technical differences between PCT and the above examples is the tool's provenance: it was funded by UK's central government and subsequently given formal endorsement as a planning aid for local authorities developing their cycling and walking strategies. The endorsement from government helps to explain the extent to which it has been used. While open source transport models may be less expensive to develop than their proprietary counterparts, there is nonetheless a cost associated. While the diversity of open source

[8] See https://www.google.com/search?q=%22propensity+to+cycle+tool%22+site%3A.gov.uk for 30+ mentions of the tool on local authority websites.

[9] See, for example, mention of SUMO and MATSim on the websites of driving simulation company rFpro and TransportFoundary, respectively.

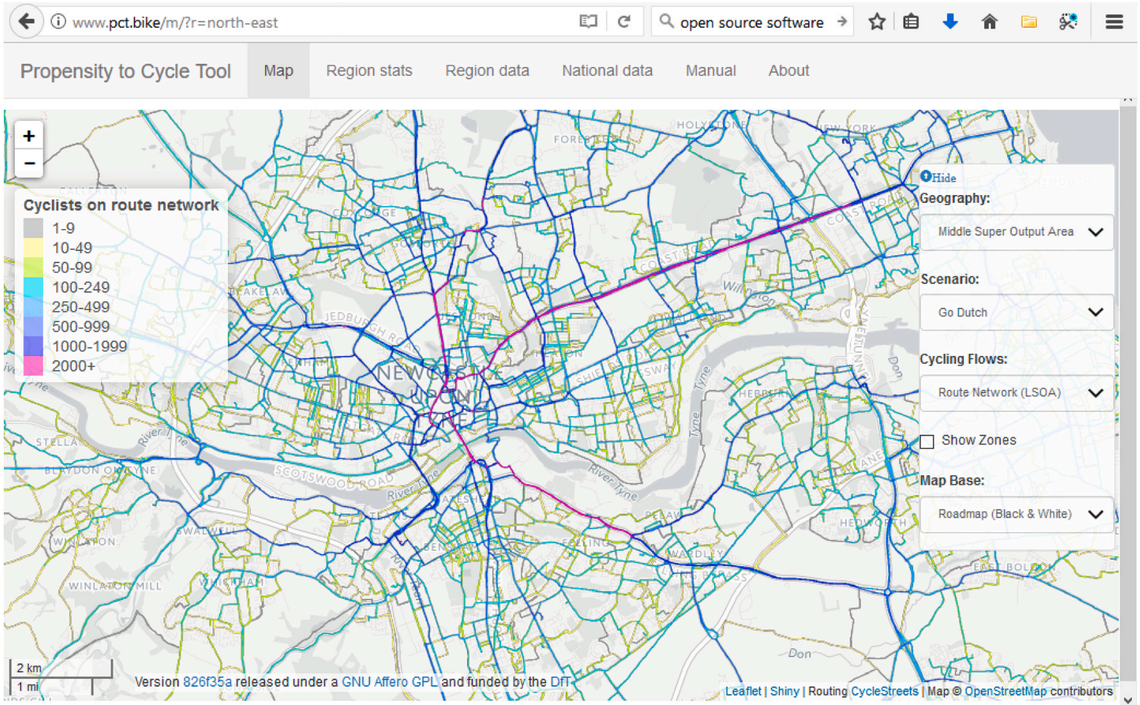

Fig. 1. The Propensity to Cycle Tool's visualisation of potential for cycling in Newcastle-upon-Tyne.

software suggests that funding is not necessarily a barrier, it is reasonable to claim that the open access transport modelling universe would be enriched by further targeted commissions on the part of public bodies.

4.1. Future open access transport models

The future of open access models is wide open at a time of rapid change in transport planning priorities, technologies and government targets. However, discussion of the PCT can provide insight into possible directions of travel. Discussion of alternaive software suggests two possible pathways, which are not necessarily mutually exclusive. The PCT could become more sophisticated and, like SUMO and MATSim, incorporate an explicit time dimension. This could enable it to be used for more detailed analysis of specific junctions, for example, but could make the tool more challenging to use. Conversely, the PCT's user interface could be modified to make it more user-friendly. One approach would be to create different versions of the PCT targetting different users, or even create different tools altogether, which meet different needs that cannot be satisfied by the tool. This concept of modularity in tool design, whereby each tool 'does one thing and does it well' is central to the philosophy of open source software (Gancarz, 2003). The concept of modularity can also support discussion of open access transport models overall, suggesting that many small tools that are well-integrated could be more effective than a few 'monolithic' tools that are incompatible. This raises the question: should a large part of open access transport model work focus on cross-compatibility rather than new features? That question is outside the scope of this paper, but could form the basis of future research.

To gain insight into another potential development pathway for open access transport models, it is worth looking outside transport. In the field of land-use analysis, an open access tool has been developed to assess the rate of urbanisation based on newly available computer hardware (high performance PCs), software (QGIS, an open source GIS) and datasets (high resolution satellite imagery), the Semi-Automatic Classification QGIS Plug-in (SCP) (Chapa et al., 2019). Aside from the clear potential for improved integration of land-use and transport planning tools (te Brömmelstroet and Bertolini, 2008) the SCP tool has some interesting features that highlight design options that could influence the nature of future open access transport models. In terms of user interface, the Semi-Automatic Classification tooldoes not run 'in browser' like the PCT, but instead plugs-into QGIS. This creates a barrier to entry compared with the PCT, requiring users to install software, but has the advantage of encouraging planners to use software that has been optimised for use with geographic data.

Indeed, a technical limitation of the PCT is that internet browsers were not designed for geographic analysis of the kind needed for local transport planning (including zooming into specific areas, selecting different geographic layers and drawing on the map, only the first of which can be done in the PCT). To overcome this limitation, the PCT integrates with open access data (one could argue that open access tools should only use open access data) by providing data downloads that enable transport planners to undertake analysis on their own computers. This provides flexibility for different types of users: well-resourced transport planning departments such as Transport for Greater Manchester will tend to use the PCT simply as a platform allowing download of cycle route and behaviour data, doing analysis on their own platforms, while less well-resourced organisations and interested members of the public can use the on-line interface. As outlined in training workshops that have been delivered on the Propensity to Cycle Tool both 'on-line' and 'off-line' approaches can be used in tandem.[10] A non-technical limitation of the PCT is that, despite being publicly available, the extent to which it is easy-to-use is open to debate.

The above discussion suggests that the nature of open access software is that it can and does develop organically based on how users are availing themselves of the tool, and how users themselves can see and suggest areas for improvement.

[10] The first exercise in a training document developed to support the use of the PCT is for users to explore the online interface, before progressing to download the data provided by the tool to analyse it in more detail on their own computers: https://itsleeds.github.io/pct/articles/pct_training.html.

4.2. Open access transport models and the "democratisation" of transport planning

We have discussed the potential of the PCT and similar tools to enable interested citizens to play a fuller role in transport planning. This reflects a context of cursory "participation" exercises in orthodox transport planning (Bickerstaff et al., 2002) as well as the observation that, for now, models continue to play a significant role in the transport planning process. Putting models in the hands of a broader group of stakeholders may empower them to contribute more successfully to the decision-making process, but it is unclear to what extent tools and open access models such as the PCT can foster the "democratisation" of transport planning. Even with access to participatory tools, many citizens will remain uninvolved in the transport planning process for a range of reasons (Fung, 2003), despite extensive support for sustainable transport interventions (e.g. Xenias and Whitmarsh, 2013).

There is no reason to see these caveats as grounds for pessimism. Rather, given transport's poor record of citizen participation, any improvement will be welcome. Further, given the overwhelming arguments in favour of a transport system based more on sustainable and active travel, the possibility that the PCT will produce outcomes that are not strictly "the people's choice" should be seen as acceptable, especially given that those outcomes will have emanated from a more democratic process than might otherwise have been the case.

5. Conclusion

This paper has explored 'open access transport models' with reference to Lindsay's (2016) principles of 'open access software', the literature on tools in decision-making and a case study of the Propensity to Cycle Tool. Based on prior work, we defined open access transport models as being open source *and* accessible. Both aspects of the definition have the potential to tackle fundamental limitations of established models identified by Givoni et al. (2016), including trust, transparency and public availability. At an institutional level, proprietary software still dominates and further work is needed if open access transport models are to become mainstream components of the planning process. Tools that are *open source* but not accessible (such as SUMO and MATSim) are hindered by the technical skills needed to install and operate them. Tools that are *accessible* but too simplistic to be considered 'models' (such as Streetmix.net) are hindered by their limited ability to support complex strategic plans.

The case study of the Propensity to Cycle Tool shows that open access transport models *can* be used to inform design and investment decisions. Part of the tool's success may be due to the fact that it is funded and endorsed by the national transport planning authority, the Department for Transport, suggesting that high-level buy-in and investment from established transport planning organisations may be needed for open access transport models to flourish in applied practice. The case study also suggests that there are limitations to the web browser as a platform for interactive transport models, something that can be partly mitigated by the provision of open access data resulting from the tool.

Despite the nascent nature of open access models in transport planning, and the institutional and technical limitations that hinder its development, the discussion highlight's the concept's potential. Technological progress and continual institutional change will present many future opportunities for open and publicly available tools for data handling, analysis and visualisation to enable more participatory and evidence-based transport planning. Of course, as with any attempt to make transport planning more participatory, there will be inequalities in who benefits from future models (Goodspeed, 2016). However, the concept of open access transport models can support the transport planning tools of the future to be designed in ways that at least provide the *possibility* for the public to scrutinise the inner workings of technologies that will inform decisions on the future of the transport systems they will use and even *participate* in the use of these tools to contribute to evidence-based policies and plans. The use of the PCT in unexpected ways, such as to support the advocacy group Bath Cycling Campaign, shows that open access transport models can widen participation in the planning process and help develop better solutions in the transport planning process.

There are a number of pathways for further development of open access transport models, and as such they remain in their infancy. Work is needed to integrate such tools into the wider transport planning process, to make established open source transport modelling tools more accessible, and to design, develop and deploy open access transport models that meet other policy needs, such as the facilitation of an increase in walking. There is great potential for this work to benefit the public, in terms of more efficient use of public funding (given the considerable cost of proprietary software licences), more accessible evidence to inform cost-effective interventions, and the empowering feeling of being part of the decision-making process. A substantial number of people are willing to work on open source projects as hobbies and passions in their spare time and contributing to tools can be a rewarding and educating experience. However, the example of the PCT suggests that investment is needed for open access transport models to fulfil their potential. We therefore conclude that for open access transport models to become mainstream components of transport planning in cities worldwide, they require endorsement and investment from governments and public interest organisations.

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Robin Lovelace: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Visualization, Supervision, Project administration, Funding acquisition. **John Parkin:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Tom Cohen:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Visualization, Supervision, Project administration, Funding acquisition.

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