BikeScienceWeb: a tool for bicycle-related urban planning

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Abstract. *BikeScienceWeb is a data science tool containing analytic resources for active urban mobility planning. The tool aims to enable specialists to carry out their analyses without the need for programming knowledge. BikeScienceWeb can be used to include and exclude layers of subject-related geolocation information, import custom layers, compare two maps with different scenarios, and evaluate bicycle travel flows using travel survey data. The tool is available for use at the São Paulo Traffic Engineering Company (CET) and for the general public. A survey carried out with specialists in urban mobility showed that 70% deemed the tool as easy to use, 76% deemed it as useful for planning active mobility, and 88% had an intention to use the tool for their activities.*

1. Introduction

The prevalence of motorized transportation in large cities across the world is a big challenge for the citizens' life quality. Traffic congestion, a sedentary lifestyle, noise and air pollution are common problems nowadays. In the last decades, several initiatives in cities around the world have been struggling with the car-centric culture to humanize the street environment [The World Bank 2015, Watts 2018]. The use of bicycles for commuting presents multiple benefits. For the cities, replacing motorized trips with cycling trips helps mitigate traffic congestion, decreasing air and noise pollution, and the amount of required parking space [Sælensminde 2004]. For the citizens, there are several personal benefits to both mental and physical health [Oja et al. 2011]. In Brazil, the National Policy for Urban Mobility was passed in 2012. This legislation aims to incentivize cities with more than 20 thousand inhabitants to establish their urban mobility planning, privileging active transport modes (i.e., pedestrians and cyclists), people with disabilities and mobility restrictions, and public transport. Thus, from now on, these cities must design and implement their own cycling infrastructure planning.

The BikeScience project is part of the National Institute of Science and Technology (INCT) of the Future Internet for Smart Cities (InterSCity). BikeScience is a collaborative project between the MIT Senseable City Lab and the InterSCity team that relies on the use of Data Science techniques for investigating active mobility issues and to support evidence-based public policies for bicycle and pedestrian modes. BikeScience is also the name of the open source tool that uses geolocated data to provide methodologies and analyses for monitoring, understanding, and planning the cycling infrastructure of cities. The tool was initially built using data from Boston's Bike-sharing system (BSS) to investigate bicycle mobility flows over the neighborhoods into the Boston Metropolitan area [Kon et al. 2022]. From then on, the tool has been expanded adding analyses from other cities, such as São Paulo and Philadelphia.

In São Paulo, we have a partnership with the public sector through the São Paulo Secretariat of Mobility and Transportation (SMT) and the São Paulo Traffic Engineering Company (CET). The BikeScience tool has incorporated analyses made along with the CET's specialists aiming to support the planning of the new cycling infrastructure [de Souza et al. 2021]. The BikeScienceWeb is an online version of BikeScience that aims to ease access for analysts and other interested ones through a web browser, serving as a Geographic Information System for bicycle mobility planning.

We assessed the BikeScienceWeb tool by carrying out a survey with urban mobility specialists. For this evaluation, we used the Technology Acceptance Model (TAM) [Davis 1989], which is a well-known model that measures how users perceive the usefulness and ease of use of a new technology, and their intentions to use it in the future. Most of the participants deemed BikeScienceWeb as easy to use, useful for planning active mobility, and showed intention to use the tool.

2. BikeScienceWeb

BikeScienceWeb [Pena 2021] is an open source data science tool that implements methodologies based on geolocated data to support analyses for active urban mobility planning. It is a specialized geographic information system (GIS) developed for the use of specialists in mobility, such as traffic engineers, urbanists, data scientists, cycling activists, and other interested people.

BikeScienceWeb derives from the BikeScience tool, which is composed of Jupyter notebooks. Using Jupyter to create analyses is great for people who know programming in the Python language. Thus, we can develop several analyses using the Python libraries faster, testing and modifying those analyses according to our needs. However, most specialists who are the key users of BikeScience may not know Python. By developing a web version of BikeScience, we allow those specialists to perform their own analyses through a web browser, interacting with the tool using an interface that contains maps, bicycle-related data, and filters. Moreover, the tool can be accessed from any device or operational system without the need to install any specific libraries. Currently, BikeScienceWeb is available for use within the São Paulo metropolitan area. However, it can be adapted to other cities, depending more on the available data that those cities can provide to the tool.

2.1. Main features

The tool was created with the help of urban mobility experts by eliciting requirements considered important by them. Its main features are described in what follows:

Analysis of bicycle trip flows: It is possible to identify places with high-, high-to-medium-, medium-to-low-, or low-density of bicycle trips. This is done by splitting the interest area into small parts. There are two splitting options: into a *rectangular grid* of $n \times n$ that can be adjusted by the user or into *the OD zone* - a subdivision proposed by the OD17 travel survey dataset (which will be explained in Subsection 2.2). The flows are based on the OD17 travel survey dataset. To create the trip flows, the tool sums up all trips that start in a grid cell and end in another cell, repeating the process for all pairs of grid cells (or OD zones, if this is the selected option). The trip flows are sorted in descending order according to the number of trips they contain and, then, the flows are split into quartiles. Thus, the first quartile has the 25% of trip flows with more trips, and so on until the fourth quartile [Kon et al. 2022]. The number of flows and trips varies according to the grid size. Thus, the first quartile contains cell pairs with a high density of trips, decreasing until the fourth quartile. The same process is done for the OD zones. Finally, the flows are shown on the map and the user can select the quartiles s/he wants to see. High-density flows are the thicker ones. By analyzing those flows, it is possible to identify places that need more attention when building new cycling infrastructure, or even to prioritize the maintenance of existing infrastructure.

Map layers: Several layers are available for use in BikeScienceWeb: type of cycling infrastructure (protected bike lanes, conventional bike lanes, and sharrows), high-capacity transport (subway, train, etc.), and accidents involving bicycles. The user can also upload their own layers for personalized analyses. Also, there are seven map layers available.

Filters: There are several filters the user can choose: periods of a day where trips start or end, trip duration, type of cycling infrastructure, gender, age, and family monthly income.

Additional map: Another map can be added for the comparison of two distinct scenarios. Each map has its own filters, allowing the user to compare, for instance, trip flows in different periods of a day.

2.2. Datasets

The analysis of bicycle trip flows is based on the 2017 Origin-Destination survey from São Paulo (OD17). Every ten years since 1967, the São Paulo Metropolitan Company (Metrô) carries out this travel survey in the São Paulo metropolitan area. This survey interviewed citizens about their origins and destinations on a typical working day, the trip reasons, transport modes, and also asked about their socioeconomic conditions, such as age, gender, and household monthly income. The OD17 presented 42 million trips in a full regular working day, of which 389 thousand were done by bicycle (around 0.9% of all trips). Most of the BikeScienceWeb filters are based on OD17 data fields.

Other datasets available on BikeScienceWeb are the infrastructure layers, including cycling infrastructure[1], OD zones[2], high-capacity transport[3], and accidents[4].

2.3. Usage examples

Figure 1 shows the BikeScienceWeb with an analysis of bicycle trip flows – the blue arrows, where the arrow side means the destination of a trip – in a grid of 60×60 cells. We can also see the cycling infrastructure: the red lines are the protected bike lanes, the orange ones are the conventional bike lanes, and the orange dotted lines are sharrows. The active filter options are trips that start in the morning (from 6 AM to 12 PM) and belong to the first quartile (tier 1). The flows are placed in the southeast region of the city São Paulo (the Mooca district). The uppermost flow represents 1100 trips. It suggests that the current cycling infrastructures could be connected to attend the high demand.

[1] http://www.cetsp.com.br/consultas/bicicleta.aspx
[2] https://transparencia.metrosp.com.br/dataset/pesquisa-origem-e-destino
[3] http://geosampa.prefeitura.sp.gov.br/PaginasPublicas/_SBC.aspx
[4] https://vidasegura.prefeitura.sp.gov.br/plataforma/

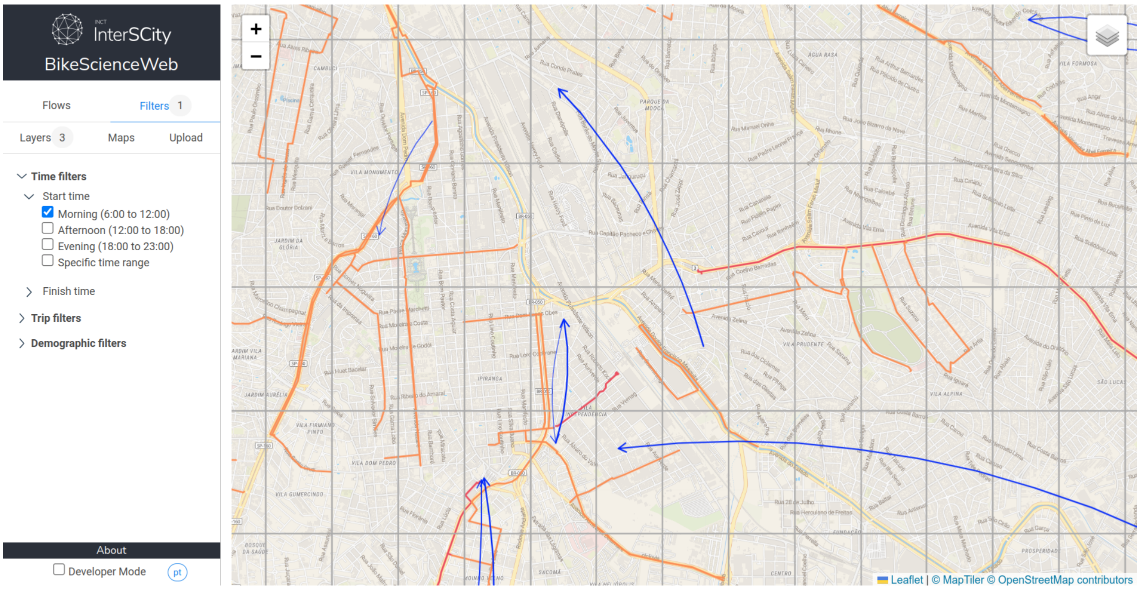

Figure 1. Morning trip flows in the southeast region of São Paulo – first quartile.

Figure 2 shows BikeScienceWeb with the two maps split into OD zones. The active filter options are trips that start in the morning and belong to the first and second quartiles (tiers 1 and 2). The map on the left shows a few trip flows from cyclists with a monthly family income of up to R$ 3,816 (around three monthly minimum wages in local currency – reais). The map on the right has trip flows from cyclists with a monthly family income greater than R$ 3,816. This is the western region of the city of São Paulo, which is currently one of the regions with the greatest coverage of cycling infrastructure. This region also concentrates a large number of financial companies. The maps make clear the absence of cyclists with lower family incomes who travel in this region during the morning.

The tool is available for use at its official website[5], and also its code repository[6]. More technical details can be seen in Thiago Pena's monography [Pena 2021].

3. Assessment

We carried out a survey with potential users of BikeScienceWeb to assess its acceptance and relevance for mobility analyses. The survey was devised using the Technology Acceptance Model (TAM) [Davis 1989]. TAM is an instrument widely used to evaluate how users perceive a new technology regarding its usefulness (PU), ease of use (PE), and their behavioral intention to use (BI) such a technology after having contact with it. The original TAM instrument has 10 questions: 4 for PU, 4 for PE, and 2 for BI. We opted to use 1 representative question of the three TAM constructs. Thus, we built a questionnaire that asked participants whether BikeScienceWeb can help users to be more efficient in their analyses (PU), whether the tool is easy to use (PE), and whether they intend to use it in future analyses (BI). The TAM questions were posed using a 7-point Likert scale from strongly disagree (1) to strongly agree (7). The questionnaire also has questions about the

[5] http://bikescienceweb.interscity.org/
[6] https://gitlab.com/interscity/bike-science-web

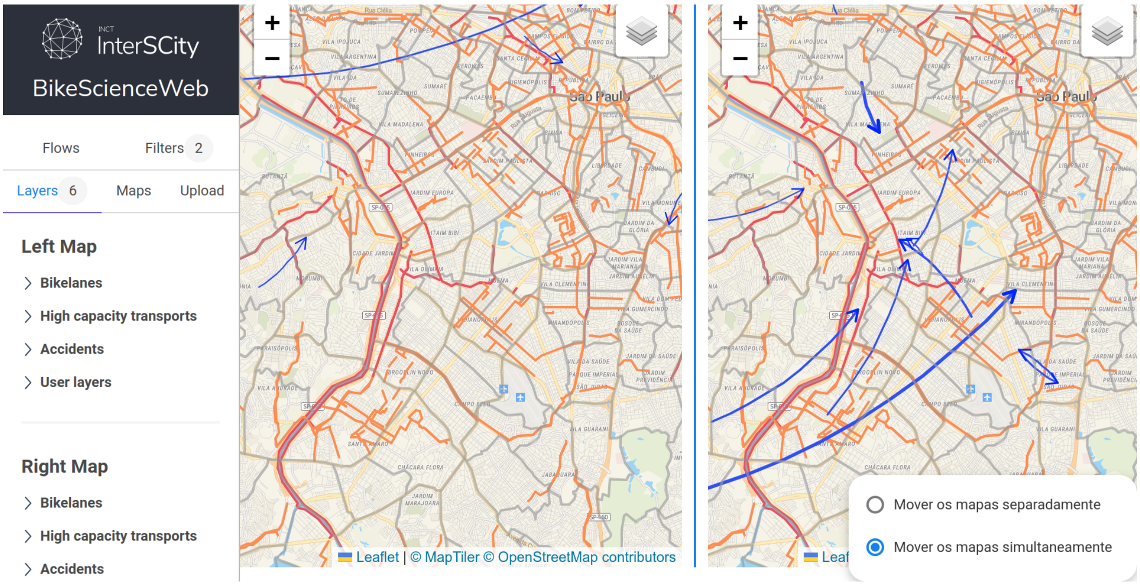

Figure 2. Morning trip flows in the western region of São Paulo – 1st and 2nd quartiles. The left and right maps are, respectively, cyclists with a monthly family income $<$ R$ 3,816, and those with a family income $\geq$ R$ 3,816.

professional profile, comments, and concerns regarding the tool. We did not ask for any personal information to keep the participants' privacy and anonymity.

We invited experts in urban mobility from the public sector and civil associations. We sent an invitation e-mail with the instructions to access the user guide and a link for the web form questionnaire. BikeScienceWeb has a user guide with instructions on how to use the tool, which is placed in the *About* menu. In total, 17 specialists took part in the study. Most participants are urbanists (10), followed by traffic engineers (3), and professionals from other areas (4).

The results show that most participants were positive in some agreement level regarding the TAM constructs. Figure 3 shows the answers to the TAM: 76% agreed that the tool is useful for planning active mobility, 70% deemed the tool as easy to use, and 88% had the intention to use the tool. The open answers brought several ideas about new features for the tool. Some of them were already implemented, for example, the comparison using two maps and the upload of personal layers.

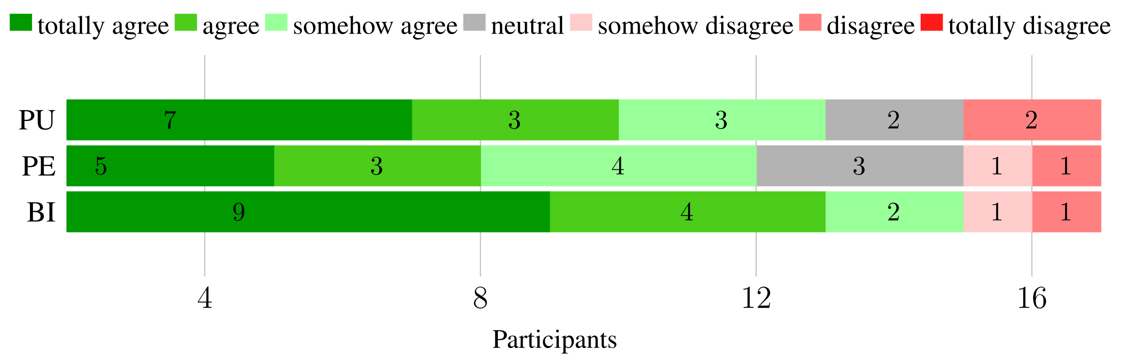

Figure 3. Answers to the TAM questionnaire.

4. Conclusion and future work

BikeScienceWeb is an open source tool for active mobility analysis, which intends to help urban planners in analyzing, monitoring, and decision-making regarding public policies for bicycle-related issues. By being available as a web application, it can be used on any device, anytime, anywhere, and it is independent of operational systems.

The tool assessment showed its potential for its intended usage, and been positively rated by most of the survey participants. It is available for use by specialists of the São Paulo Traffic Engineering Company and all those possible interested ones.

Currently, the tool is available only for the São Paulo metropolitan area. As an open source tool, it can also be freely adapted by those interested in building BikeScienceWeb for other cities. In future work, we intend to implement new functionalities for the tool: there are several analyses we are making in Jupyter notebooks that should be implemented in the Web version in the near future. Some of them are: creating bicycle routes between points of interest, exporting maps and charts, and analyzing potential new bicycle trips.

5. Acknowledgement

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