OpenPATH and Itinerum Integration: A Case Study of Merging Open-Source Projects

Preprint

Jenna Ruzekowicz,[1,2] K. Shankari,[1] and Kyle Fitzsimmons[3]

1 National Renewable Energy Laboratory
2 Stanford University
3 HexMap

Presented at the Transportation Research Board (TRB) 101st Annual Meeting
Washington, D.C.
January 9–13, 2022

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Contract No. DE-AC36-08GO28308

Conference Paper
NREL/CP-5400-81549
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Suggested Citation
Ruzekowicz, Jenna, K. Shankari, and Kyle Fitzsimmons. 2022. *OpenPATH and Itinerum Integration: A Case Study of Merging Open-Source Projects: Preprint*. Golden, CO: National Renewable Energy Laboratory. NREL/CP-5400-81549. https://www.nrel.gov/docs/fy22osti/81549.pdf.

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National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

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This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. This work was supported in part by the U.S. Department of Energy, Office of Science, Office of Workforce Development for Teachers and Scientists (WDTS) under the Science Undergraduate Laboratory Internship (SULI) program. This work was also supported in part by the Laboratory Directed Research and Development (LDRD) Program at NREL. The views expressed herein do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

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ABSTRACT

Throughout the transportation sector, multiple mobility tracking platforms have been developed independently, in parallel, with similar use cases and infrastructure. Maintaining such platforms on an individual level can result in duplicated effort. Innovation within the field could be slowed by the limited resource of people working on extremely similar projects. We provide a case study in how such platforms can be combined with low effort and provide an example in the mobility domain of what the resulting integration points, modules and ownership may look like.

OpenPATH (formerly e-mission) and Itinerum are two examples of similar independently developed human mobility tracking platforms that extend beyond standard traffic data collection. Due to the open source nature of the projects, members from both teams decided to merge the functionality, thereby only hosting a single data collection process and limiting maintenance of separate intake platforms. On the front-end, specific questionnaire functionality from Itinerum, mainly the ability to display and return questions and results focused on sociodemographic attributes, was integrated into the OpenPATH user interface. On the back-end, an export pipeline stage was created to transport collected data back to the Itinerum database.

Upon completion, the OpenPATH application retained its original functionality while adding the ability to export data for future data sharing and creating an avenue to incorporate Itinerum hosted questions and answers. Itinerum benefits from the rich feature set and infrastructure of OpenPATH without losing needed elements such as the questionnaire component. This case study, within the transportation sector, illustrates the various configurations in which open source software can be developed, maintained and deployed.
Keywords: Itinerum, open source, OpenPATH, integration, transportation, smartphones, human mobility tracking

INTRODUCTION

Independently developed platforms that serve the same functionality result in duplicated effort over time as they require maintenance, modernization and reinvention. Throughout this case study, we provide an alternative path that merges platforms and highlights the use of open source software as a keystone in executing such a merger.

OpenPATH is an open source platform used to map human mobility through methods that extend beyond the standard mobility tracking practices, such as traffic cameras and large public transport tickets (10). Itinerum is another open source application that aims to track human mobility, making the raw data, execution, and motivation similar across both applications (3). Slight differences occur in the input data collected through Itinerum specific questionnaires. This individual user data tends to be less numerical and more qualitative, focusing on sociodemographic information. Similarities within the numerical data collected, and the use of smartphone sensors to track trips, allowed for the integration of Itinerum's questionnaire aspect within the OpenPATH infrastructure.

This paper demonstrates the integration, performed during the summer of 2021, in an effort to limit the resources needed to maintain two similar platforms and share data across these two communities. The integration was done in two steps. The first involved the back-end infrastructure, which needed to allow the data collected by the OpenPATH app to be sent over to the Itinerum database. The second involved the user interface modification of displaying the Itinerum questionnaire through the OpenPATH app and conveying the responses back to Itinerum. The finalization of the integration and further testing will allow the Itinerum native mobile application to be eventually retired.

Having two open-source applications that offer similar functionality, the merger limits the need to maintain both, integrating the apps without having to rebuild entirely. This re-use of resources demonstrates the potential for future integration with new mobility sector projects.

RELATED WORK

The literature dates back at least 15 years expressing the need for uniform data collection and similarities between developing application infrastructure. A 2007 paper by Stopher and Greaves predicted the need for a uniform travel diary method, noting the problems contemporary household surveys faced at the time. The paper called for the further development of GPS diaried data, the strategy used primarily today, however it also emphasized the need for uniformity across applications and diary infrastructure (17). Lane et. al. emphasized the need for abstractions stating, "It is useful for the research community to think about and propose sensing abstractions and APIs that could be standardized and adopted by different mobile phone vendors" (12). By doing so, the need to rebuild the sensing infrastructure shared from application to application could be eliminated.

A detailed outline of typical methods used to create infrastructure, present in applications such as Itinerum and OpenPATH, is present within Shen and Stopher's 2014 paper, *Review of GPS travel survey and GPS data-processing methods* (15). The paper details methods used by researchers that have since been implemented independently through projects such as Itinerum and OpenPATH. It is immediately noticeable that despite the diverse set of researchers, the methods employed were alike. Similarly, despite different use cases, the applications listed below follow the same methods, thus developing extremely similar application infrastructure, in an effort to obtain similar results.

A multitude of smartphone-based data collection systems have been employed that focus on travel patterns (13, 4, 5). Other researchers have focused on the use of smartphones to further infer travel mode and activity (14, 16). The combination of such research has led to a pseudo-consensus within the community regarding the current best methods to implement human mobility applications. However, as expressed before, this has led to the implementation of applications with similar functionality, a poor use of resources.

Directly within the transportation sector, an extensive number of applications already exist that have similar functionality as OpenPATH, including Itinerum. A non-comprehensive list of similar end-to-end applications is as follows: MOBIDOT (23), radar.io (25), MotionTag (30), BetterPoint (20), TravelVu (31), TrackandKnow (28), RMove (26).

Unfortunately, all applications, except OpenPATH and Itinerum, are currently closed source, not allowing outside individuals to examine the code base or benefit from the implementations. Outside of end-to-end applications, OpenPATH's sensing components are implemented as cordova plugins, allowing them to be integrated into any app. Similar software development kits (SDK) have also been implemented widely. A non-comprehensive list of similar SDKs is as follows: TransistorSoft Background Geolocation (29), Sentiance (27), Loco Kit (open source) (22), moprim (24).

Unfortunately, almost all listed SDKs are not open source, preventing others from using and benefiting from the exiting code. Further parallel examples exist with regards to traffic congestion tracking including the MIT VTrack project and the Mobile Millennium project (1, 18). All applications hinge on similar base infrastructure relying on the use of smartphone sensors.

At the time of this paper and to the knowledge of the authors, there are currently no merged open source projects within the transportation sector. However, such projects have been hinted at and indirectly called for by researchers and practitioners, in both industry and academia, hoping to standardize the data collection procedures across human mobility (17). This work provides a case study of how to integrate, instead of modernize, as human mobility tracking advances and platforms are tasked with keeping up.

BACKGROUND

OpenPATH (called "e-mission" at the time) was started in 2015 by K. Shankari at the University of California, Berkeley as a PhD thesis under Professors David Culler and Randy Katz (8). Motivated by the harmful carbon emissions of the transportation industry, Shankari created a platform which consists of an app that tracks individual human mobility, including not typically tracked transportation such as walks and bike rides, on an individual level. The project falls into the field of Computational Mobility, which applies the techniques of collecting human mobility data, analyzing and creating respective models and sharing those models to influence behavior and create infrastructure.

The OpenPATH model focuses on phone sensors as well as user input to gain a holistic view of mobility motivation and type. The use of travel diaries helps to categorize each trip that the app tracks, allowing users to input travel methods and motivation and correct assumptions made by the app. Data collection is categorized as follows: continuous sensed, including spatio-temporal and motion activity, continuous surveyed, to collect trip modes and trip purpose, and intermittently triggered collection for data on traveler perceptions.

Upon the conclusion of Shankari's PhD, OpenPATH was brought to the National Renewable Energy Laboratory. It is now being further developed and enhanced, as well as being used for internal NREL projects such as the 2020 CanBikeCO Mini Pilot. The pilot project aimed to encourage energy-efficient transportation during the COVID-19 pandemic. In this project, 13 bikes were provided to low-income households, and data tracks the impact of an alternative mobility option. The project also monitored the use and deployment of OpenPATH to track travel behavior (11). A custom version of OpenPATH was deployed with an added *game* feature (33).

The Itinerum platform was developed a few years earlier as part of a research project by Zachary Patterson from the Department of Geography, Planning, and Environment at Concordia University in Montreal (21). Originally developed for data collection of university affiliates, the Itinerum app has been extended for open use.

In 2014, a pilot project was hosted throughout the entire Concordia community with close to 900 participants (7). The study itself was a pilot to test the app and measure how students reached campus. Since then, the most significant use has been as a white-label application for the City of Montreal and partners (MTL Trajet), and for the Canada Food Study (19). The MTL Trajet data is now a relatively unique public data set of real-world trips collected by a public organization that has been made openly available.

As Itinerum became outdated, the infrastructure would have needed a rebuild. With regards to mobile apps, the current API and app requirements present a moving target in terms of staying within the accepted use guidelines and providing more efficient ways to sense information. Due to resource restrictions, updating the efficiency of sensing information has fallen behind, making the merger a high priority.

Background of software architecture

Using the smartphone as a digital instrument, OpenPATH follows a sensor-server-client architecture (**Figure 1**). The smartphone in our case acts as both a sensor, through the internal hardware such as advanced gyroscopes and accelerometers, and as the client with information being displayed to the user. The back-end server is tasked with storing data long-term, communicating to the client, processing the data, and aggregation.

The phone app

The front-end user interface architecture is built using the Apache Cordova mobile app framework. The app uses native plugins, dynamically linked libraries containing function implementations, for both iOS and Android, written in Java and Objective-C. These plugins are used to sense location and motion activity and store the data within an internal SQLite database. The same database is also used to store user labels such as the mode and purpose. The stored data is then synced to the server at the end of each sensed trip.

The phone component allows the user to control data collection and inputs. Working with the interface, users are able to display their personalized information such as the trip diary, the tour model and comparisons between other users through a game interface.

The server

The server side is written primarily in Python, making use of scientific processing libraries and exposing a REST API for client interaction. The server receives data from the client into an input cache, then saves the data to a user-specific section of the datastore. The datastore holds multiple timeseries, parsed by object type such as background location. The data is then run through the intake pipeline that generates and creates further outputs such as confirmed trips which can be displayed back on the phone. There is also the ability to query travel diary information for individual and group statistics.

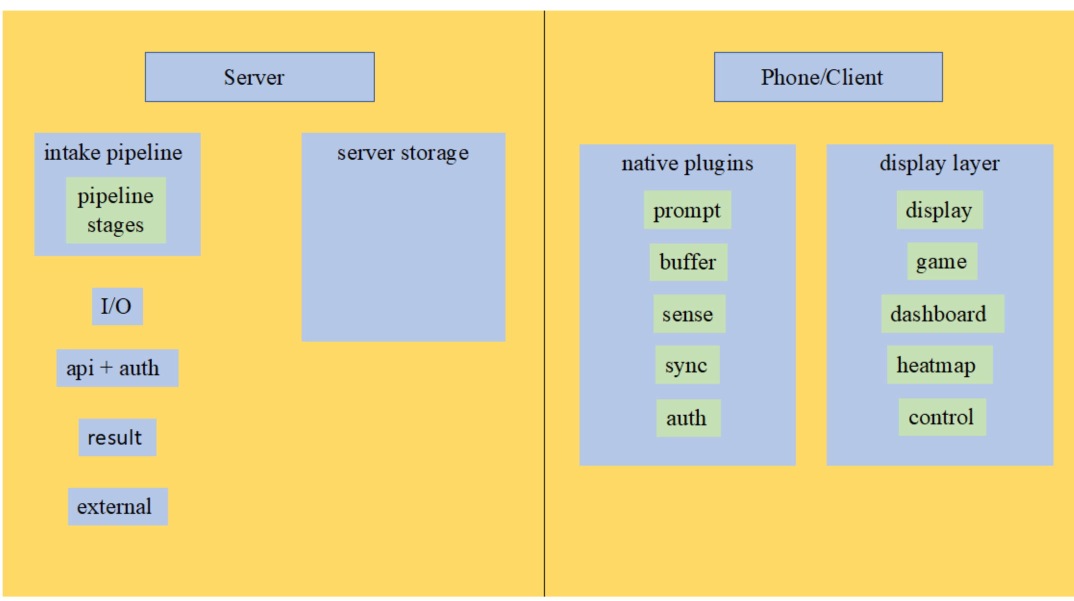

Figure 1. Breakdown of the OpenPATH architecture

Itinerum offers similar attributes, with the addition of a survey builder. The builder allows deployers to integrate questionnaires aimed at collecting non-numerical data into their analysis (**Figure 2**). After the integration, the questionnaire creation component is kept separate from OpenPATH, but the questionnaire itself will be shown in OpenPATH in an integrated fashion.

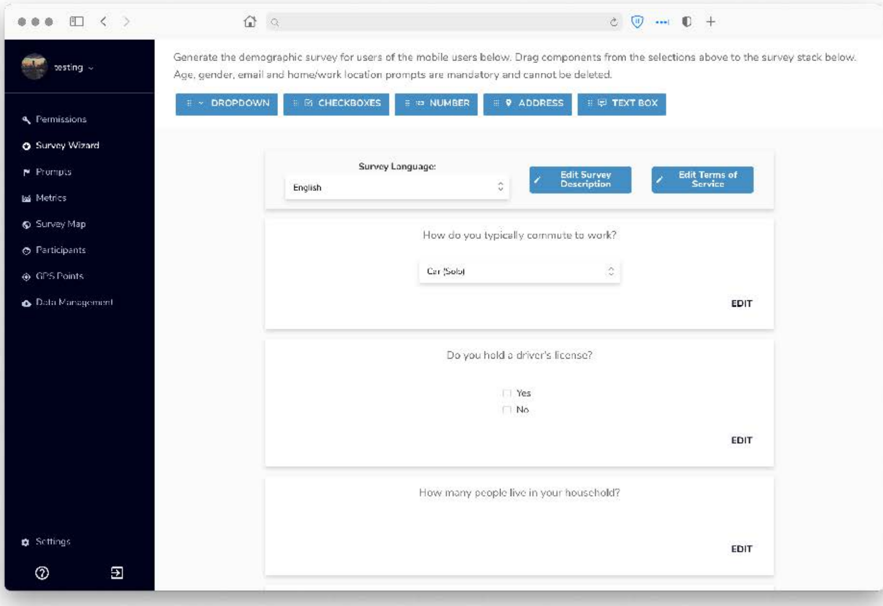

Figure 2. Survey Wizard component of Itinerum

IMPLEMENTATION

As previously mentioned, the integration of the Itinerum questions into the OpenPATH infrastructure was done in two steps. The first focused on the back-end integration involving the database hosted by Itinerum and the database hosted by OpenPATH. Itinerum will run their own instance of the OpenPATH server and will have full access to that database. The Itinerum-hosted OpenPATH instance will then export its data to a separate database in the existing Itinerum format, so that existing Itinerum functionality would continue to work.

Working on the opposite side of the application, the front-end user interface needed to incorporate the Itinerum-unique questionnaire into the OpenPATH app. Then the Itinerum application needed to receive the answers through the same mechanism as existing OpenPATH user inputs. In the long run, the Itinerum deployment will import synced OpenPATH data to PostgreSQL tables. These imported data will be as closely modeled to the existing Itinerum data structure as possible and similar analytics can hopefully be performed on both. The analytics will be a commercial service of HexMap, an attempt to offer the functions of Itinerum as a service. HexMap intends to make it easy for organizations to register, design surveys and receive data without having to run their own infrastructure. With respect to open source, HexMap could be seen as sponsoring the development of the open source software components while also developing some of its own commercial tools.

Back-end integration

The back-end integration started with an understanding of how trip data is collected and processed as it is added to the OpenPATH database. A pipeline process within the OpenPATH infrastructure, consisting of multiple stages, processes the data. Each stage is separately responsible for processing, labeling, sorting, analyzing or transporting the data. For example, an intake pipeline runs to pull data from the phone back to the OpenPATH database. Before reaching the database, the pipeline processes the raw data into confirmed trips, a way of segmenting the transportation data based on the timing of movements and areas traveled. The sorting into finalized confirmed trips is just one stage in the entire intake pipeline.

From there, we added a pipeline stage that exports all of the fully processed data in the form of a gzip file, saved to a local folder (**Figure 3**). Infrastructure on the Itinerum side then pulls said files from the folder, saving to the local Itinerum database. The final process was to move the export stage outside of the full intake pipeline. This allowed those who did not want to export the data to run the pipeline without doing so, and those who still wanted to export the data to call that stage.

Front-end integration

On the user interface side, the OpenPATH app needed to incorporate the Itinerum questionnaire and push the results back out to the Itinerum database. To do this, the integration component, written in Angular, pulls the questionnaire hosted by Itinerum using a POST request with several fields related to the phone configuration (**Figure 4**). It then recieves a JSON representation of the questionnaire. From there we merged ngReact and Angular to display the questions. Similar to the existing OpenPATH user inputs such as mode and purpose, the survey results are stored in the existing OpenPATH SQLite database and synced to the server. The Itinerum database then received the results through our newly created back-end sync process (**Back-end integration**).

Besides the questionnaire, the user interface remained the same, and allowed for the same app usage and data exportation that was established on the back-end.

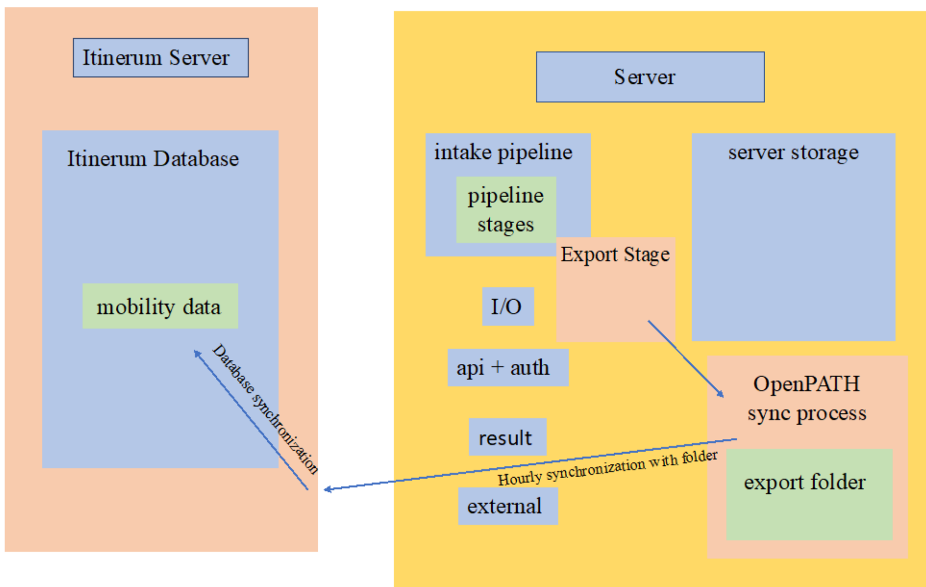

Figure 3. Location of back-end addition

DISCUSSION

The success of this project hinged mainly on the importance of both projects being open source. Open source software is software that is released under a license where the copyright holder grants users the right to use, study, change and distribute the software and its source code. Thus, open source software can be developed in a collaborative public setting. Permissive licenses place few restrictions on usage; the software can be used for commercial purposes. OpenPATH has always been under a BSD-3 license which is permissive.

Copy-left licenses such as the GPL are deemed strongly protective. In the case of Itinerum, all but the Android codebase falls under a GPLv3 license. The GPLv3 states that individuals may copy, distribute and modify the software as long as they track changes/date in source files. In addition, any modifications to, or software including (via compiler) GPL-licensed code, must also be made available under the GPL along with build & install instructions.

In general, having software that is open source allows individuals to pull code from online repositories and edit the infrastructure to suit their needs without having to construct applications from the start. Many open source repositories have been implemented and tested through other organizations or individuals, allowing users to have some level of confidence in the code they are pulling. In the case where testing infrastructure exists, users can make changes to the pulled code and continue to run tests that confirm the basic functionality and ensure reproducibility, a key feature of scientific studies.

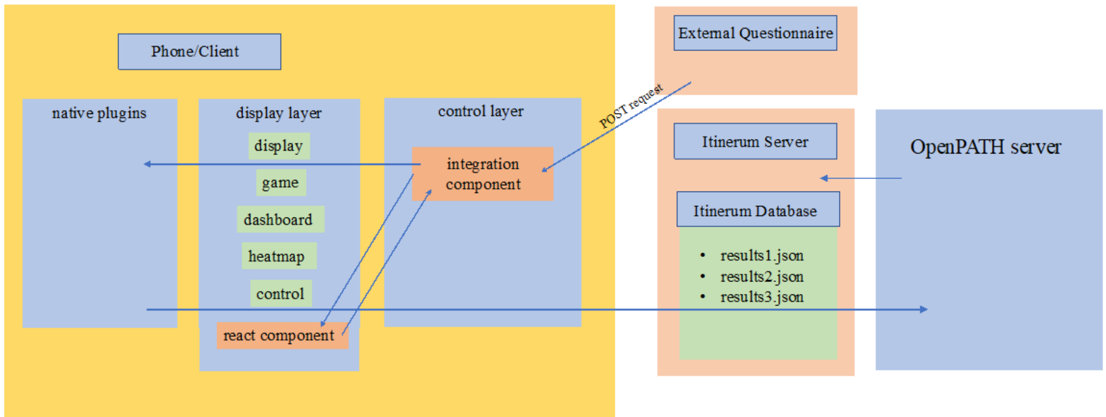

Figure 4. Location of front-end addition

In the context of general publications and data driven projects, open source usage is growing. Not only do open source projects allow full transparency, they allow unbiased peer confirmation of results and security claims. The mobile app ecosystem often lacks transparency, asking users to allow permissions and insert personal information without knowing the full intentions. OpenPATH is an example of a platform that safely uses personal location data and does so while offering full transparency to users. Especially within the transportation sector, individuals are skeptical of allowing their phone to track their location. Transparency of the infrastructure allows for confidence in the project motivations (6).

Linus's Law within software development states that "with enough eyeballs, all bugs are shallow," and in open source apps, with enough app installs, all phone-specific issues should be shallow as well (32). Publishing code is a way to benefit from free reviewing, testing, and usage. By OpenPATH and Itinerum being open source, both resources have been cloned, changed and tested by individuals not directly involved in the project. These individuals then often return to the existing documentation to make comments, ask questions and push developers to enhance their work and build generalizable solutions. This pipeline for critique furthers the transparency claim, allowing individuals to publicly highlight areas of code they fear could exist with poor intentions (2).

In our context, the integration of Itinerum into the current OpenPATH infrastructure proves that open source is beneficial even in the transportation sector. To our knowledge, this is the first mobility sector project of its type, where two independent projects with separate existing deployments were merged together. Without the open source nature of both Itinerum and OpenPATH, the code bases would have been inaccessible, and neither party would be able to explore the similarities or conduct an integration.

CONCLUSIONS

The integration of the Itinerum questionnaire into the OpenPATH infrastructure, and the export stage of the pipeline, is just the tip of the iceberg of possibilities between the two code bases. Additional implementations are possible at the sensing level. Features such as the sensing within the Itinerum code base could be added as a plugin for the OpenPATH base. This would allow deployers to choose which sensing infrastructure they would like to use. Additionally, there is now a structured example of how to integrate a questionnaire component into the OpenPATH application and return direct results to the host. Thus, consider the case where another University wishes to conduct a human mobility experiment on their group of students but needs to first collect their student ID numbers. The OpenPATH code base can be pulled, and an additional questionnaire option can be added with an already implemented example to follow. In the future, improvements to segmentation, inference or analysis can be shared and evaluated across both projects, conserving resources and accelerating improvements.

The use of the OpenPATH code base within other projects furthers the ultimate mission of collecting data on human mobility for behavioral changes and public infrastructure decisions that attempt to curb the harmful effects of excessive carbon emissions.

ACKNOWLEDGMENTS

This work was authored by the National Renewable Energy Laboratory (NREL), operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. This work was supported in part by the Laboratory Directed Research and Development (LDRD) Program at NREL. This work was supported in part by the U.S. Department of Energy, Office of Science, Office of Workforce Development for Teachers and Scientists (WDTS) under the Science Undergraduate Laboratory Internship (SULI) program. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: merger decision, high-level design and sample code: K. Shankari, K. Fitzsimmons; integration implementation: J. Ruzekowicz; draft manuscript preparation: J. Ruzekowicz. All authors reviewed the results and approved the final version of the manuscript.

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