

Data-driven Solutions for Deficient Roads

In recent years, technological advances have provided opportunities to develop smarter and safer transportation systems. One such opportunity is the crowdsourcing of roadway data. With the introduction of various sensors in vehicles and smartphones, road data can now be obtained at a fraction of the cost of road profiling approaches or existing smartphone applications.

[Carbin](#), a smartphone-based crowdsourcing navigation app and data analytics tool developed by the MIT Concrete Sustainability Hub (CSHub) and UMass Dartmouth, has leveraged these technological advancements. Using methods from peer-reviewed research, Carbin allows drivers to gather affordable and precise road quality data that can help Departments of Transportation (DOTs) make smarter, more sustainable paving decisions. Future CSHub research will use this data to infer pavement material types and propose optimal maintenance strategies. Carbin has become a foundational tool for CSHub's study of the built environment—and could help guide future infrastructure investment.

Seamless Crowdsourcing

There are more than 8.5 million lane miles of roads in America and 135 million worldwide. Assessing much of them, however, often proves unfeasible via current methods: laser profilers can cost over \$150 per lane-mile while existing smartphone crowdsourcing tools remain challenging to scale and tend to focus entirely on potholes—which are insufficient for predicting deterioration.

Due in part to these cost and implementation barriers,

Key Takeaways:

- Road quality data is essential for planning maintenance but remains scarce and expensive. Carbin offers a more affordable and accurate means of data collection.
- Carbin has thousands of users worldwide and works with all vehicle telematics devices.
- The app's optimized algorithms work with lower frequency data to reduce the cost of data storage and transfer.
- The mapping approach provides a manageable platform for DOTs to monitor road conditions and compare them with historical data.
- Carbin could eventually inform network analyses and help optimize pavement maintenance decisions.

many city and state DOTs use less comprehensive visual inspections that can't inform network-wide analyses. The federal government, on the other hand, provides funding to profile and analyze high-occupancy roads extensively. This has contributed to Interstate highways enjoying better road quality than their state and local counterparts—despite the latter comprising the vast majority of the nation's total network.

To provide state and local DOTs with data for network analyses, the Carbin team developed a crowdsourcing method based on the speed, acceleration, and anonymous location data gathered by smartphones and vehicles. Using original algorithms, Carbin converts phone measurements into established metrics, such as international roughness in-

dex and traffic density, that can help model road surface profiles and pavement deterioration. These metrics also enable Carbin to estimate vehicle excess fuel consumption from poor road quality—which can comprise 15% of total consumption on certain pavements—regardless of fuel or vehicle type. These estimations are then displayed on [a global map](#) and, for areas with abundant data, [on more detailed dashboards](#) (see **Figure 1**).

This approach is both state-of-the-art and accessible. Its methods, documented in the *Proceedings of the Royal Society* and *Data-Centric Engineering*, process data at scale already collected by millions of vehicles connected to various telematics devices. The result is a fully crowdsourced system that can initiate collection as soon as a vehicle begins to drive while using less than 1Mb per hour of input data.

There are two versions of the Carbin app. The standard mobile app is publicly available on [Google Play](#)

and the [App Store](#) (**Figure 2a**) while another version is designed for fleets (**Figure 2b**). The fleet app offers a simpler interface than its counterpart, works in the background, and requires no internet access. Moreover, it allows users to adjust how and when data is collected and processed, which can benefit DOTs and fleet companies who may wish to minimize data collection costs.

From Collection to Construction

Beyond crowdsourcing, Carbin aims to become a platform for conducting network-wide analyses and, eventually, planning road repairs. These potential features were explored in a case study of Cambridge, Massachusetts. Using Carbin data and CSHub asset management research, CSHub conducted a network-wide analysis of Cambridge and planned maintenance across the network over 20 years. The study found that the Carbin/CSHub approach could improve environmental



Figure 1. Interactive and searchable map for monitoring road conditions in Greater Boston featuring data collected by Carbin. [Explore the map.](#)

and performance outcomes. Though further development is needed, such findings indicate Carbin’s promise as an asset management tool.

Carbin will soon capture metrics besides road quality and excess fuel consumption. As it measures how vehicles respond to pavements, the app has the potential to ascertain pavement material type. This could expedite network analyses and allow Carbin to consider material-related properties, like surface reflectivity and pavement stiffness, in life cycle assessments. Carbin could also inform [Vision Zero](#) efforts. Currently, the roadway

and traffic information necessary for improving road safety [remains scarce](#). Carbin could provide that vital data on a much wider array of pavements.

Carbin allows DOTs to relate pavement networks to the vehicles that drive on them—which, until recently, has proven impossible. This has made it a key research tool for CSHub and a promising analytics device for roadway data collection companies. Through further development, Carbin could become equally essential to DOTs as they meet the demand for [smarter, more interconnected road networks](#).

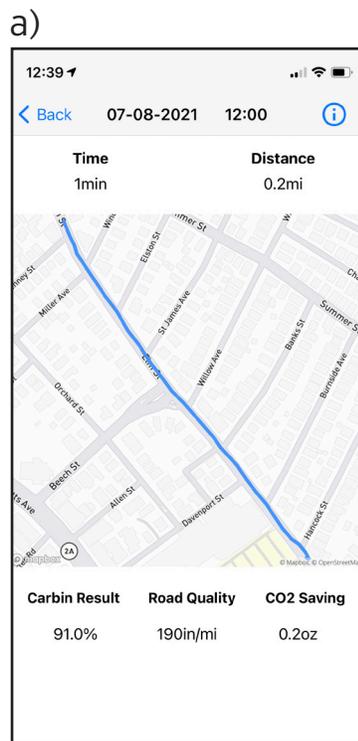
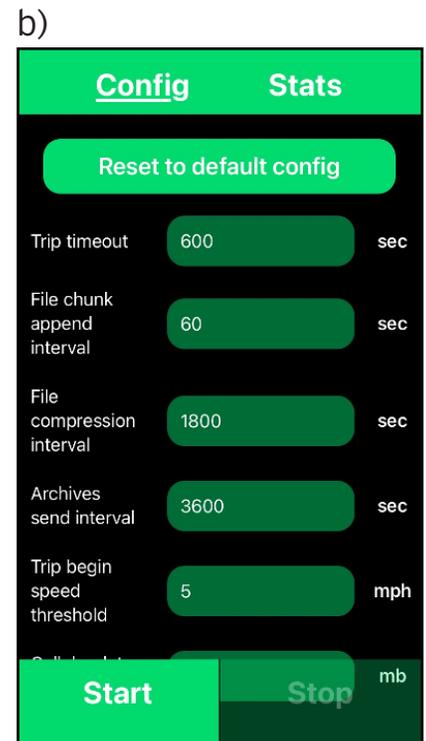


Figure 2. Carbin features an approachable and informative interface for both a) mobile and b) fleet users.

a) The mobile app offers a navigation function that can direct users to their destination while automatically deriving road quality metrics for the trip. This trip is then mapped (visible as a blue line) and the recorded metrics are displayed. Users also have the option to record without using the navigation function.

b) The fleet app, which is available on request, allows users to adjust numerous settings, including the speed at which the data collection begins, the intervals at which data is sent to the server, and the time at which data collection ends after the vehicle has stopped moving.



Related Links:

- [Carbin Interactive Map of Greater Boston](#)
- [Global Map on Fixmyroad.us](#)
- [CSHub Network Asset Management Research](#)
- [CSHub Pavement Vehicle Interaction Research](#)
- [CSHub Carbin App Research](#)

Citation:

Roxon, Jake. (2021). "Carbin: Crowdsourcing Road Conditions at Scale," Research Brief. Volume 2021, Issue 6.

References:

- [Proceedings of the Royal Society](#)
- [Data-Centric Engineering](#)

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