BIG DATA
CASE Study

WORLD BANK GROUP

Well-kept roads are needed to connect people to public amenities and reduce travel time, vehicle operation costs and crash risks

Revamping Road Condition and Safety Monitoring with Smartphones

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SUMMARY

Road agencies constantly face the challenge of developing cost-effective asset management strategies despite limited resources and modest understanding of road infrastructure conditions from users' perspectives. This project piloted an innovative solution through an app called RoadLab, developed using accelerometers in smartphones carried in moving vehicles. This automatically evaluates the roughness of road surfaces and identifies major damage, such as potholes. It also allows road users to manually submit reports of road accidents or safety hazards, along with precise GPS information. The crowdsourced data is analyzed to extract information on the condition of road surfaces users travel over. Developed in collaboration with the Belarus authorities, RoadLab gives road agencies comprehensive and frequent information on road surface condition over wide areas. This enables them to prioritize investments effectively for maintaining infrastructure, and to assess road surfaces before and after maintenance work. By promoting citizen engagement and enabling road agencies to respond more effectively to users' concerns, this approach also enhances government accountability. Built with the aim of scaling up, RoadLab can easily be modified to other countries and has the potential to become a key input for road network management worldwide.

CHALLENGE

Well-kept roads connect people to public amenities and reduce travel time, vehicle operation costs and crash risks. In order to maintain road networks, government agencies must develop cost-effective asset management strategies, but many have only limited resources and poor understanding of road infrastructure conditions from road users' perspectives. Potholes, rutted surfaces and missing manhole covers are among the hazards identified by road authorities for assessing road surface condition and informing decisions on the maintenance of road assets. However, collecting information on such hazards through conventional methods is costly and time-consuming, involving engineers physically identifying locations that require maintenance or examining surface roughness using road surface profilers. This requires significant resources in both time and labor, especially for large road networks.

As a result, road agencies often pay inadequate attention to road asset management. To maintain safe, efficient road networks and to improve infrastructure, the authorities need more affordable, uniform and immediate data on road condition. One approach is to harness road users to report the surface conditions and safety issues they encounter, simply by using an app in their smartphones as they travel by car. Automatic data collection with accelerometers in smartphones can give road agencies large amounts of information from the road users' perspective. This can facilitate quicker and more effective decisions on road asset management. However, existing road-reporting apps faced challenges affecting the reliability of their readings, such as what parameters to include in the evaluation algorithm, and the accuracy of their vertical acceleration detection. The need was for a reliable smartphone app that addressed these common issues and provided valuable reference for future app development.

Within 10 days, the team collected useful road surface information for 3,000km of road

INNOVATION

The project developed a smartphone app called 'RoadLab,' which in effect harnesses moving vehicles as probes that detect real-time road conditions by using smartphone accelerometers to monitor and report the roughness of travel over stretches of road. The app was developed in close collaboration with the national road management agency in Belarus, alongside the World Bank-supported development of the country's Traffic and Road Safety Coordination Center.

Learning from previous approaches

Through a review of existing road-reporting apps, the team identified key factors often overlooked but affecting the accuracy of road roughness estimations. These included the position of smartphones – especially if changed during driving – and the vehicle's speed and suspension type. They realized that the filtering and smoothing of raw data would need to be conducted carefully through machine learning to accurately differentiate bumps from abrupt braking, a swing of the vehicle or the user moving their phone. In addition, repeated reporting of extraordinary vertical acceleration values at the same location by multiple users could be used as a supplemental tool to the data processing and filtering model to identify abnormal road conditions.

To develop the app, the team divided roads into 100-meter segments, with GPS coordinates at the start and end of each. The system gathers and analyzes data from smartphones, and calculates the vertical acceleration and average speed within each segment. Regression models then link the road surface condition with vertical acceleration

and speed, and estimate the roughness in line with the global International Roughness Index, commonly used for measuring the roughness of road surfaces. This way, RoadLab estimates can be directly linked with existing road roughness measurements for comparison and updates. Reflecting the practice of Belarus road management agencies, RoadLab automatically categorizes road surface condition as excellent, good, fair or poor. It allows road agencies to set these threshold values themselves, given that what constitutes a poor surface or a major bump is highly subjective, and standards are also likely to vary across road agencies and countries. This allows maximum adaptation to local contexts.

Roadlab users must place the smartphone on a stable surface in a moving vehicle, such as the dashboard or mounted vertically in a cradle on the windshield. The app will automatically detect phone positions and strength of GPS signals and remind the user to place the device correctly in order to obtain reliable data.

A global solution

Several adaptations were made as a result of field tests to verify road conditions reported by the app. It was found that when the vehicle speed is lower than 30km per hour, smartphone accelerometer readings are less sensitive to road surface, therefore such readings are discarded to avoid false reporting. Similarly, when the smartphone is put in a pocket or directly on the seat of a moving vehicle, the correlation between accelerometer readings and road conditions and bumps is not accurate, so these readings too are excluded. These adaptations also help prevent overloading road agencies with raw data.

Although developed in Belarus, the app was designed as a global solution for road asset management. It was built with parameters easily adapted to suit other countries.

RESULTS

Belarus road agencies have readily adopted the RoadLab app to screen road surface conditions. The approach is much more cost-effective than traditional road-monitoring methods, and the authorities are currently working on integrating it into their own road asset management database and the system of the Traffic and Road Safety Coordination Center.

The app was tested by engineers from the Belarus road management agency, before being launched to the general public in the capital Minsk through a public campaign, including posters distributed to car-owners' clubs, whose members are keen to improve road conditions. Within 10 days, the team was able to collect useful road surface information for 3,000km of road. Analysis of this data compared with the International Roughness Index showed that the estimation from the smartphone app was reasonable. Despite the limited sample data size, the exercise clearly demonstrated the value of a big data approach to road surface analysis.

Following the pilot, minor refinements are being made to the app, such as inclusion of a chart showing measured road surface for the last 10km surveyed. A future option to make RoadLab more attractive to the general public might be to combine the standalone app with other apps that are more practical for travelers, such as navigation systems.

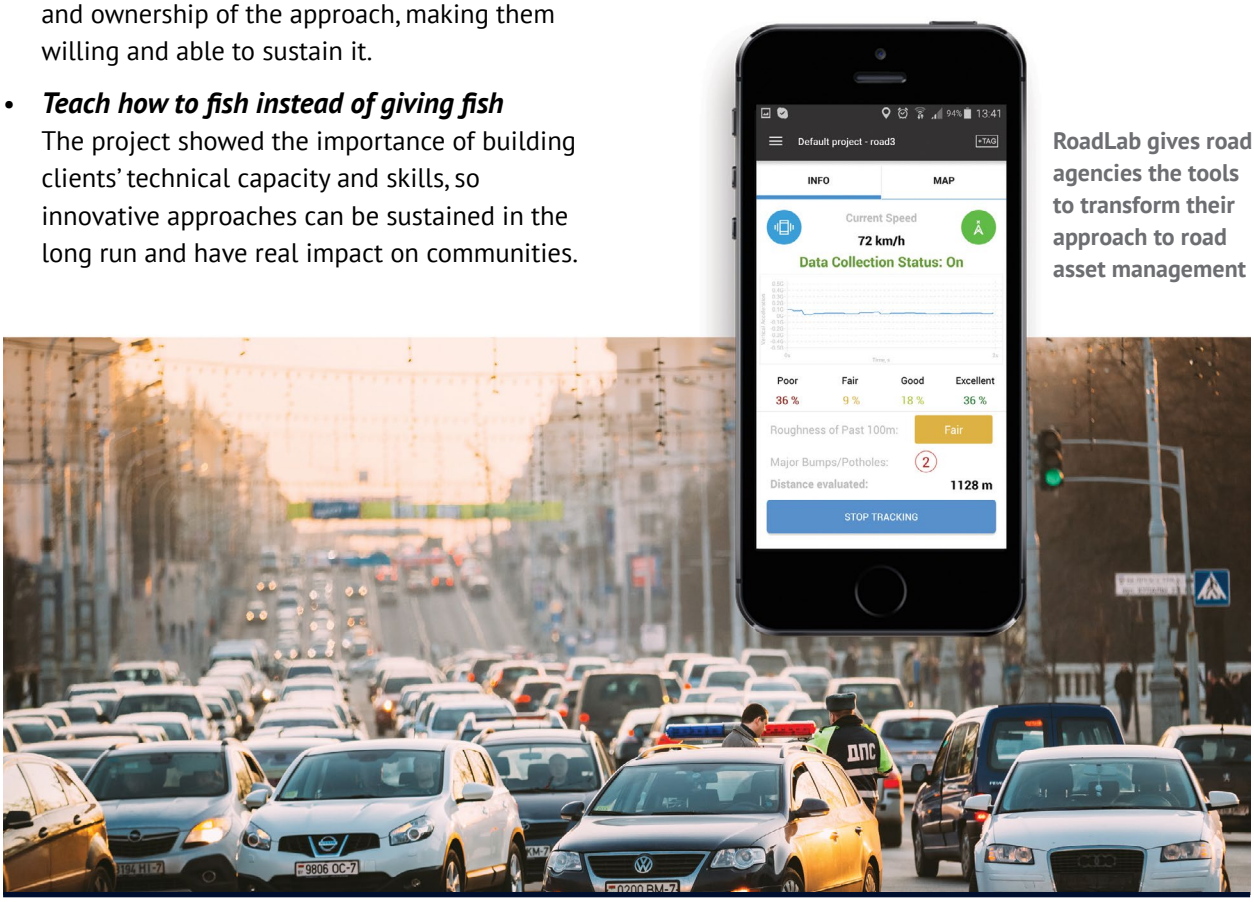
RoadLab gives road agencies the tools to transform their approach to road asset management. It delivers comprehensive and frequent information on road surface conditions over wide areas, enabling them to prioritize investments effectively for maintaining road infrastructure and to assess road surfaces before and after maintenance work. By promoting citizen engagement and enabling road agencies to respond more effectively to road users' concerns, the app also enhances government accountability.

The team is currently disseminating this innovative approach to other countries and regions for replication. With increasing usage of smartphones, they expect the initiative to grow into a key input for road network management worldwide.

LESSONS LEARNED

The RoadLab project underlined the importance of close client consultation and of thinking in new ways to see links and potential in existing resources.

- ***Consult clients throughout the project cycle***
  Successful client engagement was key to the project's success. By engaging and consulting with the Belarus road authorities, the team benefited from valuable end-user inputs, as well as developing the authorities' knowledge and ownership of the approach, making them willing and able to sustain it.
- ***Teach how to fish instead of giving fish***
  The project showed the importance of building clients' technical capacity and skills, so innovative approaches can be sustained in the long run and have real impact on communities.
- ***Approach existing situations from new angles***
  Researchers have used standalone accelerometers in moving vehicles to evaluate road roughness for decades. By linking wide smartphone ownership, people's use of phones for navigation, and the fact they all have accelerometers embedded anyway, a picture emerges of how phones could be used to extract information useful for road agencies. Through thinking more widely about GPS usage, the team is also now adding a tracing function to the app, so road networks can automatically be mapped digitally.



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