

Exploring the Use Cases of Digital Twins in Highway Maintenance: A Questionnaire

Dear participant,

I am Mengtian YIN, a Marie-Curie Future Roads Fellow at the University of Cambridge. I will conduct a research project on exploring the minimum viable product (MVP) of a digital twin for road inspection and maintenance and would like to invite you to participate in a survey. This survey aims to explore the potential use cases and values of road digital twins in highway maintenance.

The survey is in the form of a questionnaire study, which consists of 15 questions and is expected to take approximately 6 minutes. You are voluntary, and you can choose to terminate the survey at any time without negative consequences. The participants of this survey should be people who work in the highway industry relevant to the following areas: (a) road survey and inspection; (b) maintenance management; (c) information system/database operation; (d) strategy making and research innovation; (e) asset management; and (f) safety management. No personal data will be protected, as this survey is only used to investigate how industry people perceive the use cases, benefits, and challenges of implementing road digital twins for highway maintenance.

All information collected in this survey will remain strictly confidential. Individual details will not be disclosed or identifiable in this survey. Data will be kept for three years after publication of the first academic paper arising from the project, with precaution taken in relation to the storage of the data, e.g., locking up and protecting the data using passwords. If you have any questions about this survey, please feel free to contact Dr Mengtian Yin (email: my424@cam.ac.uk), Dr Varun Kumar Reja (vkr25@cam.ac.uk), and the DRF Programme Management team (drf-initiative@eng.cam.ac.uk). If you want to know more about your rights as a research participant, please contact the Cambridge School of Technology Research Ethics Committee at ethics@tech.cam.ac.uk.

Yours sincerely,

Dr Mengtian YIN

University of Cambridge

1. Participant Consent Form

Tick all that apply.

- ☐ I have read and understood the Participant Information Sheet.
- ☐ I agree to take part in this survey.
- ☐ I agree that the survey data can be shared and reused for future research.

Section 1: Demographics

2. 1. Your roles in highway maintenance

Tick all that apply.

- ☐ Road surveyor
- ☐ Road inspector
- ☐ Maintenance manager and worker
- ☐ Scheme maker and manager
- ☐ Administration
- ☐ Logistics coordinator
- ☐ Sustainability advisor
- ☐ Information system/database operator
- ☐ Data analyst
- ☐ Asset manager
- ☐ Safety officer
- ☐ Strategy maker
- ☐ Technology developer and researcher
- ☐ Quality controller
- ☐ Other: _____

3. 2. Your experience in the highway industry (in years)

Mark only one oval.

- ☐ 0-2 years
- ☐ 2-5 years
- ☐ 5-10 years
- ☐ Over 10 years

Section 2: Barriers in current practices

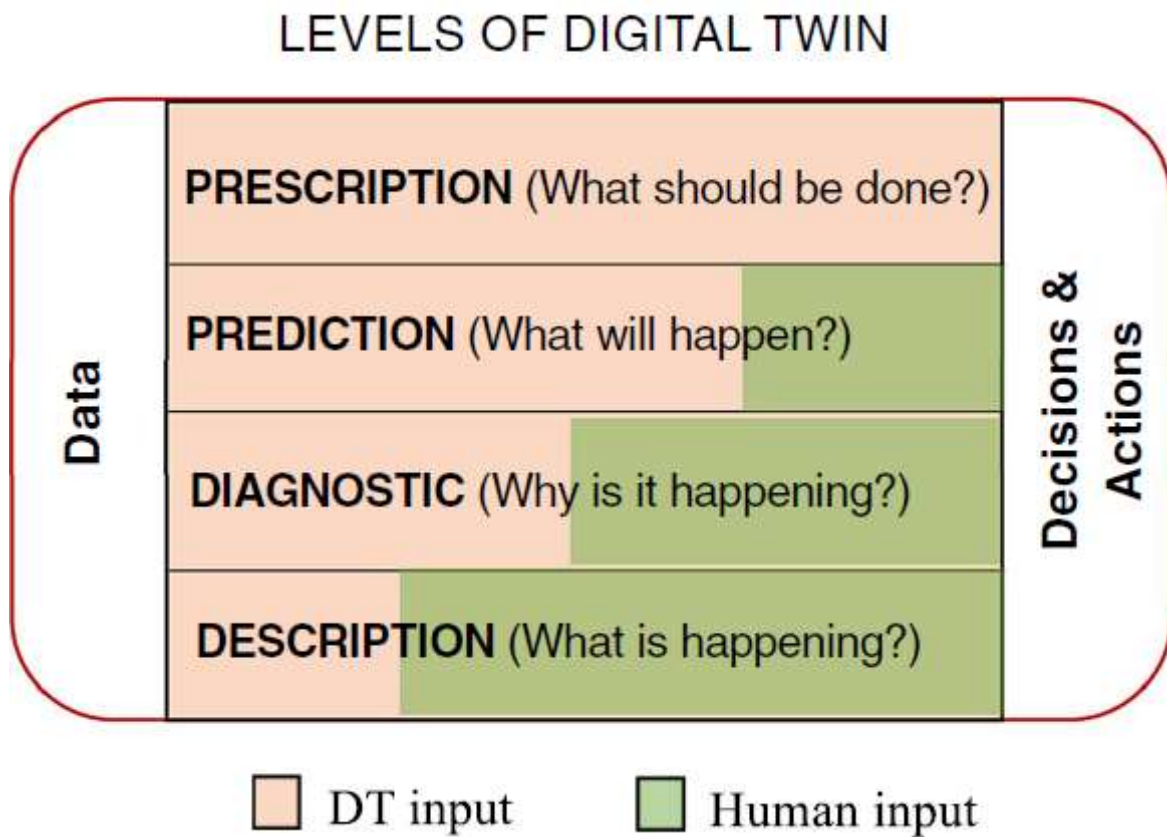
4. 3. What are the main challenges and barriers faced by your organization in highway maintenance operations? Please select all that apply.

Tick all that apply.

- ☐ Cannot obtain comprehensive road condition data.
- ☐ Hard to derive the optimal maintenance decisions under budget constraints.
- ☐ Lack of consideration for sustainability factors.
- ☐ The software systems are out-of-date and lack interoperability.
- ☐ The inaccuracy, incompleteness, and unreliability of asset information.
- ☐ Lack of precise evaluation of the costs, benefits, and risks of alternative strategies.
- ☐ Lack of effective data analysis tools for data mining from massive road condition data.
- ☐ Hard to predict the pavement deterioration and risk levels of road defects.
- ☐ Inefficient emergency response and safety management.
- ☐ Inefficiency in manual road rehabilitation, repair, and reconstruction.
- ☐ Other: _____

Section 3: Understanding and Current Use of Digital Twins in Highway Maintenance

In the context of highway maintenance, a Digital Twin represents a digital replica of the physical highway system, encompassing road infrastructure, traffic elements, environmental factors, and more. A Digital Twin mirrors the real-world state and behaviour of the highway and provides real-time insights, forecasts, and decision support based on advanced data analytics, simulation, and artificial intelligence.



5. 4. How familiar are you and your organization with the concept of digital twins and applications in infrastructure management?

Mark only one oval.

- ☐ Not familiar at all
- ☐ Somewhat familiar
- ☐ Very familiar

6. 5. Does your organization currently use digital technologies or solutions for highway maintenance? Please select all that apply:

Tick all that apply.

- ☐ Geographic Information Systems (GIS)
- ☐ Asset Management Systems
- ☐ Maintenance Management Systems
- ☐ Predictive Maintenance Tools
- ☐ IoT Sensors
- ☐ Building Information Modelling (BIM)
- ☐ Digital Twins
- ☐ Other: _____

7. 6. If your organization used or is currently using digital twins or similar technologies, briefly describe the context or project where digital twins were/are utilized.

Section 4: Perceived Opportunities for Digital Twins in Highway Maintenance

8. 7. In which phases of highway maintenance do you see that digital twins can take effect? Please select all that apply:

Tick all that apply.

- ☐ Scheme making and prioritization.
- ☐ Road assessment.
- ☐ Maintenance planning.
- ☐ Maintenance execution.
- ☐ Quality assurance and control.
- ☐ None of the above.
- ☐ Other: _____

9. 8. What features of a digital twin system do you perceive are important in highway maintenance? Please select all that apply:

Tick all that apply.

- ☐ Data storage and integration.
- ☐ Visualization.
- ☐ Data diagnostics (identify the anomalies, risks, and their causes in the condition data).
- ☐ Simulation (simulate the operations of alternative strategies and assess the effects).
- ☐ Prediction (predict future states of roads, such as deterioration and structural failure).
- ☐ Autonomous decision-making (generate suggestions to decision-makers based on performance indicators).
- ☐ Data security.
- ☐ Data transparency.
- ☐ Other: _____

10. 9. Which of the below digital twin-based applications do you perceive are important and valuable in highway maintenance?

Tick all that apply.

- ☐ A 2D/3D visualization tool that visualizes the dynamic road conditions.
- ☐ Predicting the deterioration and structure failures of road assets based on historical and dynamic road data.
- ☐ Information support to on-site inspectors and maintainers, such as providing underground road information.
- ☐ Network-level multi-year maintenance planning and scheme prioritization
- ☐ Generate optimal plans for road investigation and repair within a scheme-level maintenance project..
- ☐ Help routine maintenance planners make better maintenance strategies, considering multiple factors.
- ☐ Help safety office handle emergencies (e.g., traffic accidents) by giving suggestions for decision-making.
- ☐ Trace the carbon emissions of road assets and give strategies for material recycling.
- ☐ Autonomous road inspection and repair based on digital twins, autonomous vehicles, and robots.
- ☐ Monitor critical road sections to examine the pavement performance under extreme weather.
- ☐ Other: _____

11. 10. Please describe the potential use cases of digital twins in highway maintenance that you believe hold significant promise. Kindly mention at least two (or more).

12. 11. Please select the potential benefits you expect digital twins to bring to highway maintenance. You can select multiple options:

Tick all that apply.

- ☐ Cost Savings
- ☐ Improved Safety
- ☐ Enhanced Operational Efficiency
- ☐ Better Asset Lifecycle Management
- ☐ Reduced Downtime
- ☐ Improved Decision-Making
- ☐ Sustainability and Environmental Benefits
- ☐ Other: _____

Section 5: Challenges of Digital Twin Implementation

13. 12. Please select the primary challenges or barriers you foresee in implementing digital twins for highway maintenance. You can select multiple options:

Tick all that apply.

- ☐ Lack of Effective Ways for Data Collection
- ☐ Lack of Data Integration
- ☐ Data Privacy and Security Concerns
- ☐ High Initial Costs
- ☐ Resistance to Technological Change
- ☐ Skills and Training Gaps
- ☐ Lack of Standardization
- ☐ None of the above
- ☐ Other: _____

14. 13. Do you believe that digital twins will become a standard practice in the highway maintenance sector in the future?

Mark only one oval.

- ☐ Yes
- ☐ No
- ☐ Not sure

15. 14. When do you anticipate widespread adoption of digital twins in this sector?

Mark only one oval.

- ☐ Within the next 1-2 years
- ☐ Within the next 3-5 years
- ☐ More than 5 years
- ☐ Not sure

16. 15. At last, could you please provide any additional comments or insights concerning a road digital twin for highway maintenance (if any)?

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