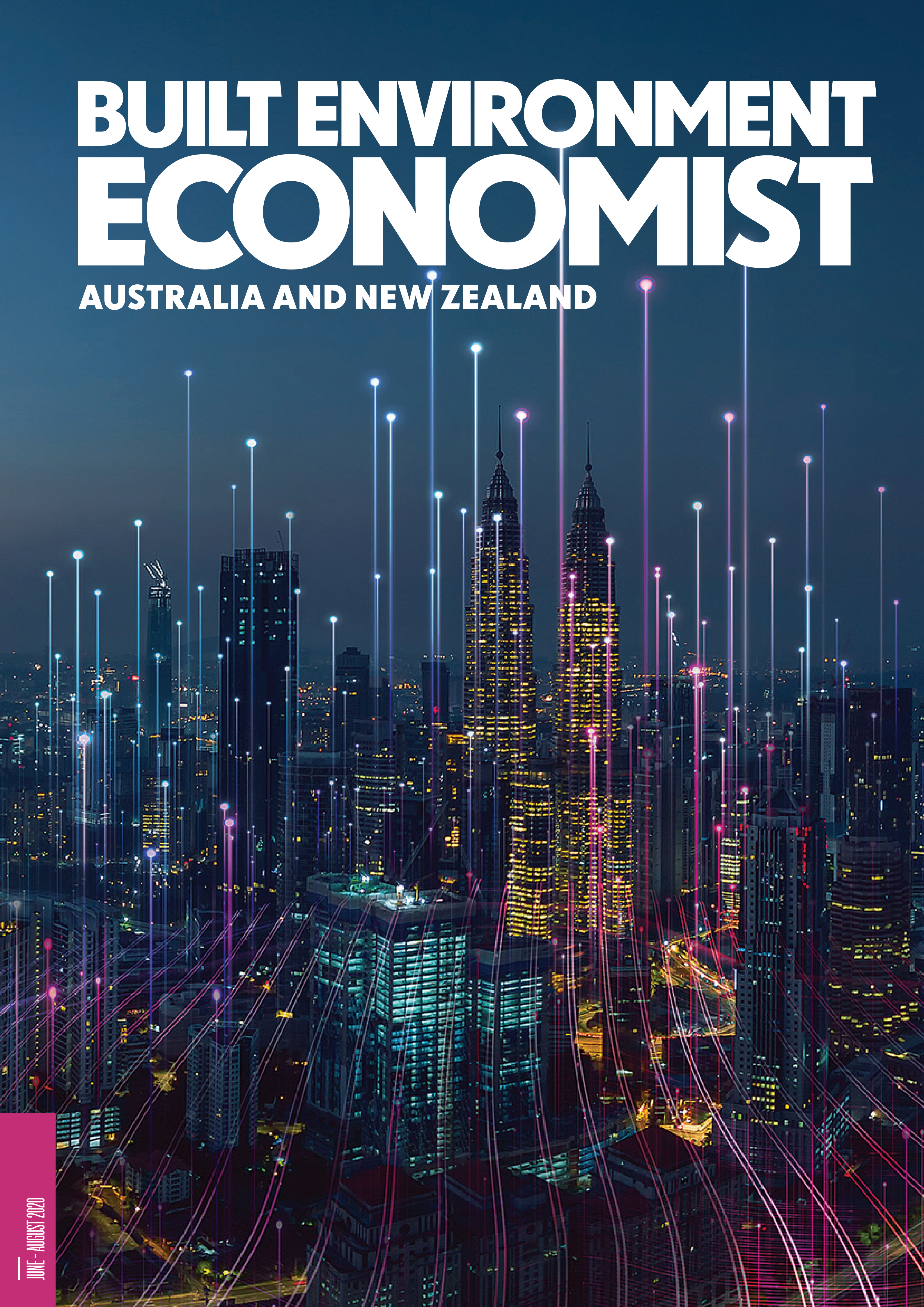
BUILT ENVIRONMENT ECONOMIST

AUSTRALIA AND NEW ZEALAND



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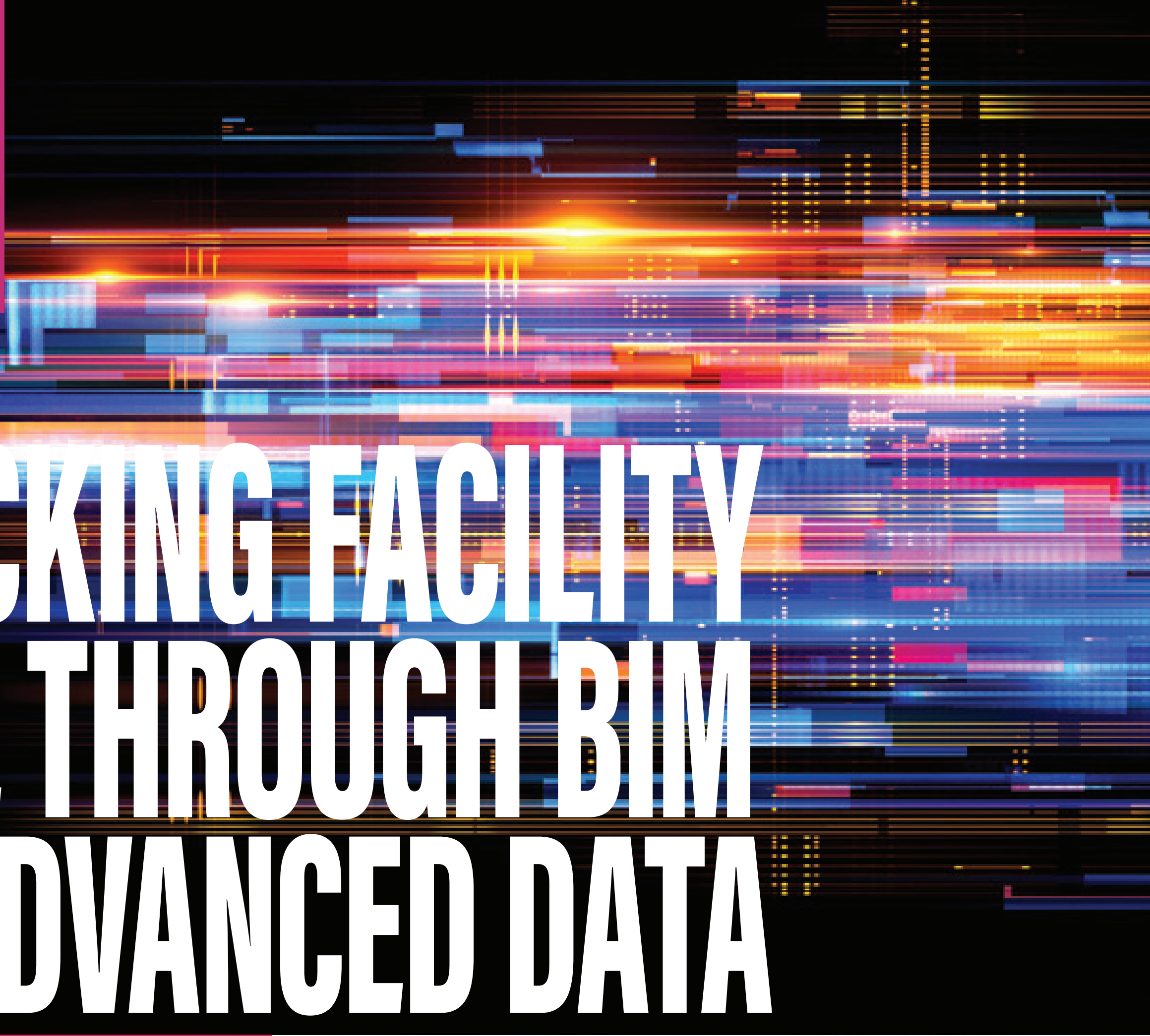

UNLOCKING FACILITY VALUE THROUGH BIM AND ADVANCED DATA ANALYTICS

By Peng Wu, Rodney A. Stewart, Rebecca Jing Yang and Keith D. Hampson

The rapid development of a wide spectrum of new technologies, such as machine learning, internet of things, building information modelling and geospatial methods, have made the acquisition and processing of big data much easier and more accessible in recent years. These new technologies open the door to developing an automated and integrated approach that harnesses both human experience and big data to enable decision making in regards to data-driven asset management to unlock facility value.

Recognising the benefits of these technologies, the Sustainable Built Environment National Research Centre (Project 2.64) aims to demonstrate the capability and value of building information modelling and machine learning, which are believed to have great potential in the built environment sector.

BUILDING INFORMATION MODELLING

Building information modelling (BIM) refers to a catalyst for a major construction paradigm shift towards digitalisation in the construction industry. BIM is a set of technologies and solutions that enables three-dimensional (3D) representation of geometric and non-geometric (functional) attributes of building elements. Its objective is to improve the collaboration of different stakeholders in the architecture, engineering, and construction (AEC) industry and enhance its productivity and management throughout the constructed facility's entire lifecycle[1].

BIM BENEFITS

Implementation of BIM offers numerous benefits for stakeholders and clients throughout all stages of the project by decreasing construction and post-construction maintenance net costs, delivering quality project outcomes, minimising negative impact on the environment, and improving productivity and coordination across multiple disciplines[2].

Through a detailed examination of 33

[1]Ghaffarianhoseini, A., Tookey, J., Ghaffarianhoseini, A., Naismith, N., Azhar, S., Efimova, O. & Raahemifar, K. 2017. "Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges". Renewable and Sustainable Energy Reviews, 75, 1046-1053.

[2]Gonzalez-Caceres, A., Bobadilla, A., & Karlshøj, J. 2019. Implementing post-occupancy evaluation in social housing complemented with BIM: A case study in Chile. Building and Environment, 158, 260-280.

international case studies, a total of 31 potential benefits have been achieved. Some of the significant benefits that can be achieved include[3]:

1. Asset management labour utilisation savings. For example, in the case of Stanford Neuroscience Health Centre, California a 60% to 70% reduction in time spent on maintenance and repair was achieved through BIM's 3D visualisation[4].

2. Better change management in the Pyrmont Bridge project, Sydney. In the past, building inspectors had to undertake the annual condition assessment process of the 7,500+ structural components of the bridge via a manual paper-based process consisting of paper, pens and digital cameras. With a cloud-based 3D BIM based solution, a mobile inspection app was used to enter the data automatically synced with a 3D model used for bridge inspections[5].

3. Faster regulation and requirement compliance. The use of BIM in the A556 road project in the North West of England enabled a quick compliance check with the UK Government planning process (Planning Inspectorate), as well as compliance with industry standards such as BS 1192:20072[6], BS11000-1:20103[7], BS7000-44[8], PAS1192-25[9], ISO 90016[10], ISO 550007[11], ISO 120068[12] and ISO 167399[13].

4. Better programming/scheduling. In the Wynyard Quarter Innovation Precinct in Auckland, digital dashboards quickly and clearly tracked the contracting team's progress in uploading the required asset management data throughout the construction process. This gave the project management team real visibility of the progress of completed asset information and handover deliverables, helping to ensure that 100% of critical digital information was available at project completion[14].

REMOTE HOUSING AND BIM

Construction projects face a lot of challenges by their nature as they are highly complex, uncertain, and can sometimes be hazardous. These factors can result in errors across different lifecycle stages of construction projects and can cause higher net costs, delays and unsatisfactory project outcomes.

When it comes to projects in regional locations, these challenges are exacerbated, generally due to the remoteness of the project and coordination difficulties between more sparsely located stakeholders and suppliers contributing to the project[15].

An economic evaluation was conducted to assess the benefit of BIM for small remote housing projects with a group of experts from housing agencies and contractors, with a focus on the monetary savings and benefits of BIM-enabled operation and maintenance in remote housing projects. The evaluation showed that the most critical assets requiring attention and constant condition assessment in remote regions are air-conditioning, building structure components, internal and external finishes, and site upgrades. It was also found that the primary monetary benefits derived from BIM-enabled asset management for the detached public and government housing in remote communities would come from reduced site visits to inspect reported asset failures and conduct condition

[3]For a complete list and description of BIM benefits and enablers, please visit the full research report available at: https://sbenrc.com.au/research-programs/2-64/

[4]Sacks, Rafael, et al. (2018). BIM for Owners and Facility Managers: BIM Handbook, John Wiley & Sons, Inc., Hoboken, New Jersey, pp. 130–174.

[5]Sahlman W. (2015). Best Practice Asset Management BIM – Pyrmont Bridge Case Study. Available at: http://buildingsmart.org.au/wp-content/uploads/BIM-Pyrmont-Bridge_28APR2015-s.pdf [accessed 20 March 2019].

[6]BS1192:2007 Collaborative production of architectural, engineering and construction information – code of practice

[7]BS11000-1:2010: Collaborative business relationships: a framework specification

[8]BS 7000-4:2013: Design management systems: Guide to managing design in construction

[9]PAS 1192-5:2015: Specification for security-minded building information modelling, digital built environments and smart asset management

[10]ISO 9001: 2015: Quality management systems – requirements

[11]ISO 55000: 2014: Asset management – overview, principles and terminology

[12]ISO 12006:2015: Building construction – organisation of information about construction works

[13]ISO 16739: 2013: Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries

[14]BIMINNZ (2016). Unlocking the value of BIM for asset management. Available at: https://static1.squarespace.com/static/57390d2c8259b53089bcf066/t/5ab08c8a0e2e72e816fb2ac0/1521519765483/Think+piece+on+BIM+as+asset+management+tool.pdf [Accessed 10 March 2019

[15]Sidawi, B. 2012. Remote Construction Projects. Problems and Solutions: The Case of Sec, 48th ASC Annual International Conference Proceedings, Birmingham, UK, April 11-14, 2012.

assessments, reducing costs from poor design or using unsuitable material, non-compliance with codes and standards, lack of maintenance, and age, normal wear and tear.

Experts suggest that by implementing BIM, the average savings by detecting unsuitable material or design, and non-compliance with codes and standards are between 15-25%. Such cost savings can be achieved due to the closer control over the assets during the design stage.

The following key benefits are also identified for BIM implementation in the operation and maintenance stage of small public housing projects:

- resource saving within the client delivery organisation,
- resource saving for contractors,
- reduced number of incidents with severe damage or damage caused by the fault of another element,
- improved statistical data collection and evaluation,
- a single easy-to-use "eco-system" within the organisation,
- better understanding of assets,
- improved asset management operations, and
- enhanced quality of maintenance services for public houses.

IMPLEMENTING LIFECYCLE BIM

This project also proposes a model for the implementation of BIM through the lifecycle of newly built houses in remote regions. Such a model ensures a maximum amount of information to be collected and this would be an ideal point to start the gradual adoption of BIM. The model includes a design model with the required Level of Detail (LoD) 350, followed by a construction model used before and during the construction phase, and an as-built model with updated BIM elements to match an actual building. The asset information model and subcontractor model can also be created with the desired level of information for facility and asset management.

These factors can result in errors across different lifecycle stages of construction projects and can cause higher net costs, delays and unsatisfactory project outcomes.

AUTOMATIC ROAD PAVEMENT MARKING DETECTION

Pavement markings and signs constitute the most fundamental way to communicate with road users and they are, in most cases, the most effective way to regulate, warn and guide traffic.

Aiming at unambiguous comprehension and immediate response, markings are highly standardised. Four major types identified in existing manuals/standards include: (a) longitudinal lines; (b) transverse lines; (c) other markings; and (d) raised pavement markers. White is the most commonly used colour for most pavement markings.

Unfavourable visibility of these markings occurs on some occasions, for example, when the road is wet or dusty or when there are occlusions by traffic. Also, extensive traffic wear leads to the deterioration of pavement markings even though long-life materials have been introduced. For this reason, inspections are often required to check the current worn conditions of roadway markings, inform managers of major changes and support a scientific maintenance program. The availability of extensive pavement video and archives collected from in-vehicle cameras provides an opportunity to exploit this video data for generating inventory data automatically, which will better support road management practices.

THE MACHINE LEARNING METHOD

Today, artificial intelligence is gaining significant attention from academia and industry. Its capability to save tedious manual work, automate image processing, and generate reliable detection results has been widely recognised.

In this industry-driven Sustainable Built Environment National Research Centre project, a machine learning technique has also been developed to achieve automated and efficient lane marking detection. Three functions have been achieved, including:

1. identify different types of lane markings in each frame;
2. estimate their worn condition; and
3. identify the presence of audible markings.

The developed vision-based line marking detection method consists of four steps, namely, image pre-processing, feature extraction, segmentation and lane marking classification. Image pre-processing aims to prepare the raw pavement images for subsequent analysis, by removing noises. Feature extraction seeks to retrieve colour and shape features of line markings, which will be used for detection. Segmentation extracts individual lane markings in an image so that they can be categorised respectively. Finally, classification exploits the extracted features of each lane marking for categorisation.

DETECTION RESULTS

For each lane marking instance in an image sample, its colour, line type, presence of audible markings, and worn condition estimation can be identified automatically (see Figure 1 below). The accuracy for detection of lane markings, including dividing line, barrier lines (both one way and two way) and edge line, is 96%.

CONCLUSIONS AND NEXT STEPS

This Sustainable Built Environment National Research Centre project completed in March 2020 has established the use of innovative approaches and technologies, including building information modelling, machine learning and whole-of-life costing to enhance value in the facility management process.

Specifically, this project has demonstrated industry value for housing, building and road transport agencies at various levels, including:

- A comprehensive list of BIM benefits and benefit enablers evidenced from 33 international industry case studies. It is an evidenced-based resource related to the tools, actions or processes that can realise and maximise the benefits of implementing BIM.
- Implementing BIM in remote housing projects. An approach to advance the use of BIM for remote regional government housing and related infrastructure to support proactive and efficient facilities management is proposed.
- An early machine learning proof-of-concept for lane mark detection for roadways. It is a computer vision technique that has the capability to save tedious manual work, automate image processing, and generate reliable detection results to inform road asset managers.

Moving forward, we encourage industry practitioners to implement these and other related digitally enabled models and work with industry researchers to develop, verify and implement pilot projects that will help the Australian AEC sector to realise the full benefits available from these emerging technologies. The research team have recently embarked on a new related Australia-wide Sustainable Built Environment National Research Centre project with industry partners titled *Project 2.72 -Leveraging an integrated lifecycle management framework – building and infrastructure sectors*.

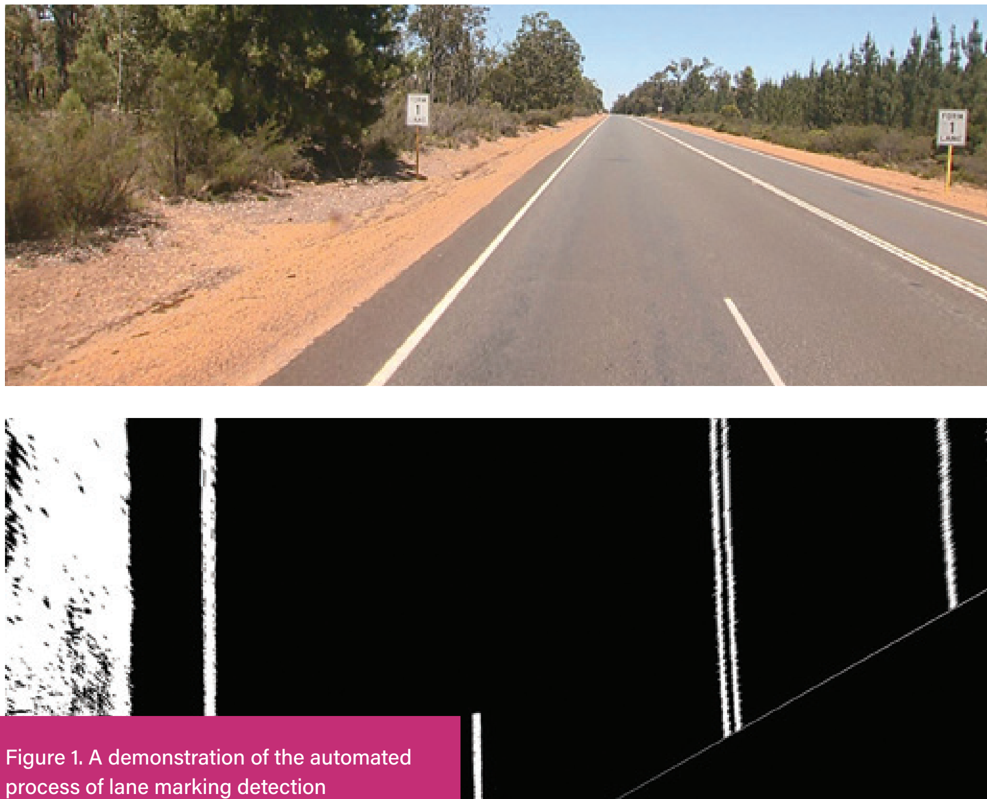

Figure 1. A demonstration of the automated process of lane marking detection

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