EMBRACING CHANGE THROUGH INNOVATION: THE PIPE-I ROBOT

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ABSTRACT

In an era where climate change coupled with aging assets pose significant challenges to infrastructure resilience and management, the need for innovative solutions is paramount. To embrace change it is necessary innovate and one aspect of this is adopting new data acquisition technologies. Doing so can open new insights into the previously obscure and inaccessible. An example of this is the new Pipe-i robotic scanner: a custom-made vehicle born from the need to safely enter hazardous culverts (see Figure 1 below).

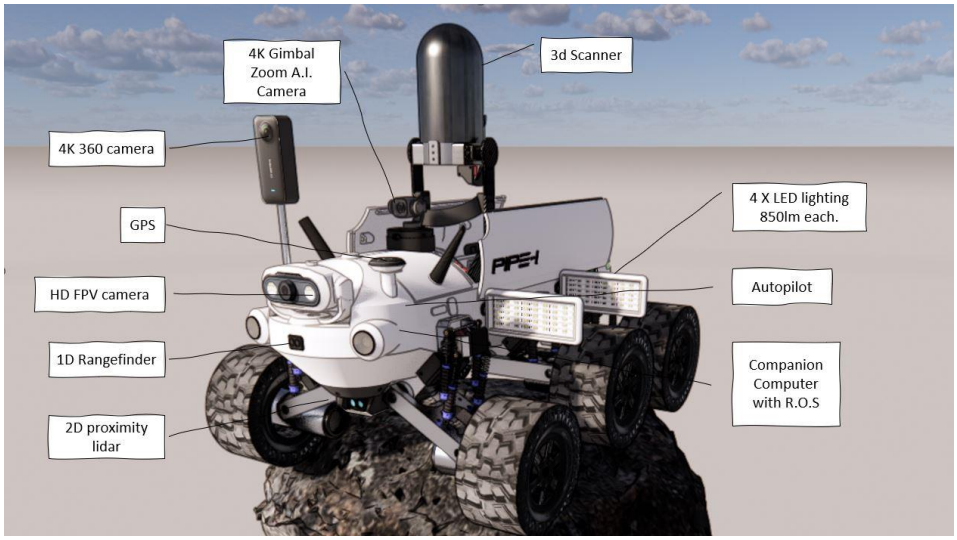

Figure 1: The Pipe-i robotic scanner.

Figure 2: Pipe-i robotic scanner on a recent culvert monitoring project

The Pipe-i is a good example of integrating rapidly advancing technology coupled with reality modelling and analysis. This innovative approach fuses advanced technology to boost traditional analysis that in turns feeds into better asset management. It offers a step

change in how at-risk assets are inspected; the data accessed and portrayed; and then how it can be spatially analysed. All of which adds perspective on infrastructure resilience.

Surveying is often done at the start of a project and surveyors can be the first people on a site confronted with critical safety issues, they must think of ways to access dangerous and restricted areas. Fortunately, new technology is making that possible in a far safer and more cost-effective manner than ever before.

Recently, Beca structural engineers requested a survey of a severely cracked and deformed culvert under State Highway 35 (SH35). The culvert had fractures in lots of different places and significant shape distortion could be seen but it was unclear how bad this really was and if the deformation was still active. It was clear that entering the culvert involved significant risks that would need to be repeated if it were to be monitored on an ongoing basis. Internal measurements for accurate cross-sections and high-quality images were clearly needed. Traditional methods in the market were weighted up and found lacking. Standard CCTV equipment could either not measure what was needed or could not handle the rough stream beds. There was no one-stop shop.

So Beca developed a prototype scanning vehicle, called Pipe-i. It is a semi-automated, remote-controlled robotic survey vehicle created to specifically deliver a lightweight Leica BLK360 3D scanner into in these challenging spaces. It was built from scratch with every part designed new. After well over a year of testing, development, and now multiple project deployments, it has shown to be a very useful tool to get comprehensive, highly accurate surveys while the surveyor stays safe. It is not hard to envisage the SH35 culvert repeating all over New Zealand, where ground conditions and old, aging assets vary so much. These assets are seeing increased pressures coming from climate change exacerbating end-of-life conditions and often they serve single access roads where failure can mean severing community lifelines.

Unsafe work environments in stormwater infrastructure are still a challenge for the surveying industry, and limited or even no access can cause project delays, elevate risk, and present increased difficulties in managing the asset. The delay of survey data can have big consequences and can be a key factor for a project, especially as it is often a critical design input or is needed to properly review failure risks or even understand the remaining design life realistically available. Without survey data, managers can be forced more into guessing, often with significant ramifications on cost. Essentially, if you do not know what you have, then how are you expected to properly manage it?

Pipe-i has proved to be considerably safer than traditional methods of inspection with several direct benefits:

1. **Elimination of a health & safety hazard.** Surveying work commonly takes place in challenging and high-risk environments and conditions. The simple act of not having to physically access a confined or dangerous space is an "elimination" of a safety hazard.
2. **A cost-effective solution.** Entry to some hazardous sites can only be obtained under confined space protocols, which can be costly and time-consuming to implement. Rather than investing in expensive training, Personal Protective Equipment (PPE), or outsourcing for what may be a one-off inspection, Pipe-i offers a ready and cost-effective solution.

3. **High data accuracy.** The strength of Pipe-i is being able to remotely maneuver a 3D laser scanner into a position and complete a 360-degree laser scan of that area, reposition and repeat. We can achieve a continuous scan with relative accuracies of +/-6mm which making it a powerful tool for identifying deformation.
4. **Monitoring change.** The ability to compare one-point cloud data set with another, is now a common monitoring technique for analysing deformation particularly in complex or unsafe environments. Obtaining point-cloud data with ease using Pipe-i enables a 'complete picture' output, where we can clearly measure, analyse, and represent any change between surveys over time.
5. **High definition 360° imagery.** Perfect for completing condition assessments, where you need a live camera feed. A recent culvert survey demonstrated this ability where the damaged part of the culvert was located using the live video feed, and then a laser scan was initiated, and its circularity assessed, and measurements of structural deformation taken. Photographic 360° imagery was then used to iterate for post survey engineering analysis.
6. **Resilient Design through Enhanced Data Capture.** The use of the Pipe-i robot in stormwater systems supports a focus on resilient design by obtaining and presenting more and more data accurately so the designer can fully review the asset and locate what is critical and where, without the nagging risk of having missed it. As it can reach and examine areas that are difficult to access, and return more data than traditional inspections, it results in more complete assessments, essential for managing and building resilient stormwater designs. This allows engineers to make smarter choices, leading to the creation and upkeep of more resilient structures.
7. **Communication.** The high-resolution data captured by the Pipe-i robot enhances communication among stakeholders and asset owners who are often not technical engineers. By providing clear and detailed condition visuals, the robot aids in enhanced and intuitive communication and understanding. This improved communication is essential for decision-making processes, ensuring that the most appropriate and effective resilience strategies are employed.

The SH35 culvert example found an asset that had become unsafe because of severe structural damage. Figure 3 shows the culvert and typical scan outputs.

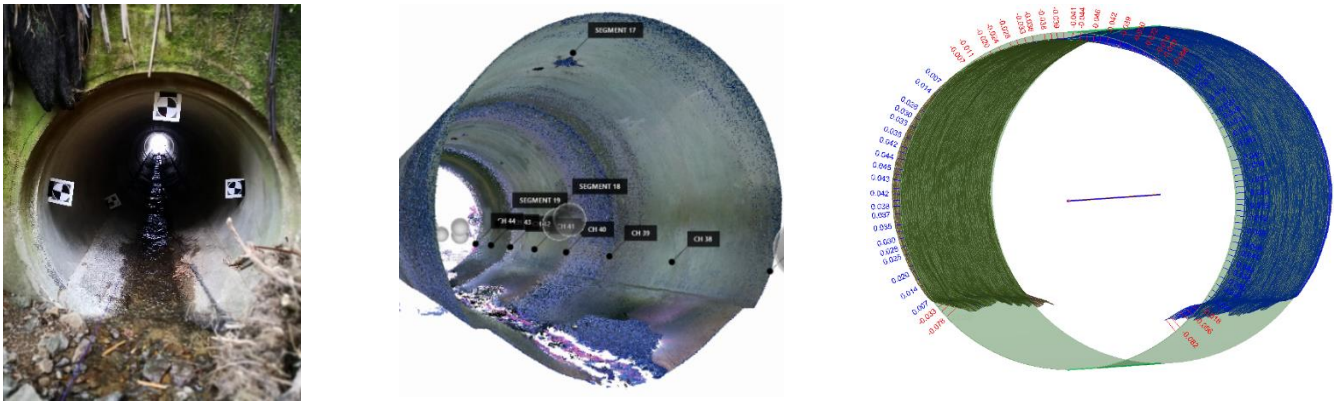

Figure 3: The SH35 culvert and typical Pipe-i scan outputs.

To track if the culvert was deteriorating over time, several scans were taken and compared. The deformation, shape and cracks were not found to be significantly changing over several years allowing a lined solution to be adopted and installed rather than a complete dig out and rebuild. Refer Figure 4 below.

Figure 4: The SH35 culvert: steel liner sections on the left and post install on the right.

In summary, the Pipe-i intersects technology, innovation, and reality capture. It is an example of how deployment of new technology can lead to more resilient designs and cost-effective management decisions. An especially relevant issue given climate change and disaster management demands being placed on aged infrastructure. The Pipe-i robot not only enhances the safety and efficiency of asset surveys, but it also contributes to the broader goal of creating more resilient infrastructure better able to withstand environmental challenges.

The Pipe-i robot gathers spatial survey data of stormwater assets while avoiding surveyors having to access dangerous or restricted areas: it removes the need for human entry, improving safety and providing far higher data quality and accuracy. It brings back clear and comprehensive condition information.

To conclude, the Pipe-i robot is a great illustration of how to adapt to change in the data thirsty stormwater industry where there is always a demand for more.

KEYWORDS

Pipe-i, 3D Scanning, Robot, Management, Innovation, Reality-capture, Surveying.