SMART PIPES
AN ON PROGRAM CASE STUDY

BOX 1 EXECUTIVE SUMMARY

Key findings

The Smart Pipes project has produced the following outputs:

- Predictive data analytics for preventative maintenance of infrastructure assets including water pipes
- An advanced failure prediction tool for water pipes

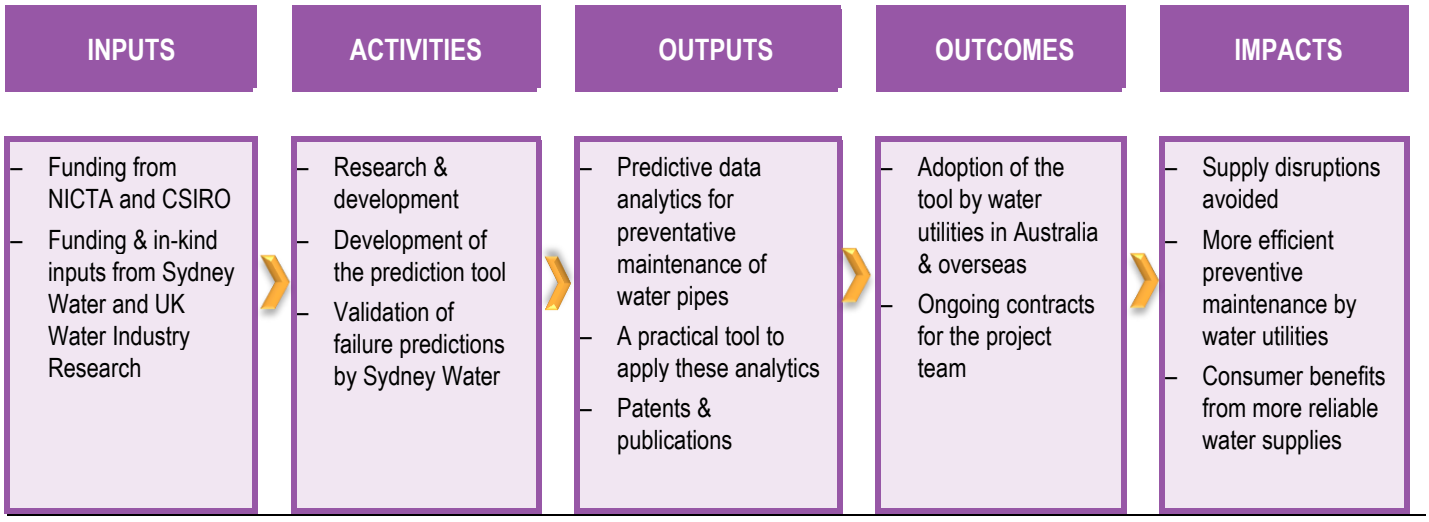
The functionality of the tool has been validated through its use by many water utilities (both in Australia and overseas). The quality of the science used to develop the tool was recognised in 2018 when the project received a Eureka Prize. Patent applications have been filed covering the technology used for the tool.

Role played by ON program

The project team's participation in the ON program Influenced their commercial thinking on the project and encouraged them to consider other applications of the tool. The net benefit or net present value of the ON program in relation to Smart Pipes is estimated at $41 million in 2018-19 dollars, with a benefit cost ratio of 301.2.

This case study uses the evaluation framework outlined in the CSIRO Impact Evaluation Guide. The results of applying that framework to the Smart Pipes case study are summarised in **Figure** Error! No text of specified style in document..**1**.

FIGURE ERROR! NO TEXT OF SPECIFIED STYLE IN DOCUMENT..**1** SMART PIPES CASE STUDY – IMPACT FRAMEWORK DIAGRAM



SOURCE: ACIL ALLEN

1.1 Purpose and audience for case study

This case study describes the economic, environmental and social benefits arising from the Smart Pipes project.[1]

This evaluation is being undertaken to assess (to a range of stakeholders) the positive impacts arising from the Smart Pipes project's participation in the CSIRO's ON program. This case study can be read as a standalone report or aggregated with other case studies to substantiate the impact and value of the ON program activities as a whole relative to the funds invested in these activities.

This information in this case study is provided for accountability, communication and continual improvement purposes. Audiences for this report may include Members of Parliament, Government Departments, the ON program, CSIRO and the general public.

1.2 Background

Condition assessment of water pipes is an expensive and disruptive process, with water utilities typically inspecting just one per cent of its network assets every year. Each year more than 7,000 critical water main breaks occur in Australia. Australian water utilities currently spend $1.4 billion per year on reactive repairs and maintenance.

Using data-driven techniques to make intelligent predictions about failures helps to prioritise the selection of pipes for condition assessment, reduces costs and minimises disruption to water supplies and the community. The cost of preventative maintenance is only 10 per cent of the reactive repair cost.

The Smart Pipes team has developed technology that uses data analytic techniques to predict failure probability, offering a solution to accurately predict water pipe failures resulting in effective preventative maintenance and a reduction in customer interruptions.

FIGURE ERROR! NO TEXT OF SPECIFIED STYLE IN DOCUMENT..**2** THE ADVANTAGES OF USING THE SMART PIPES TOOL

SOURCE: ZHANG M 2015, MAKING THE DATA WORK FOR YOU

1.3 Impact Pathway

1.3.1 Project Inputs

The total cost for the Smart Pipes project has been estimated by ACIL Allen to be of the order of $1 million. Data61, CSIRO and Sydney Water contributed to these costs: A detailed breakdown of the support for the development of Smart Pipes is not available.

1.3.2 Project activities

The Smart Pipes project was developed initially within NICTA (now Data61 as part of CSIRO).

[1] Since the initial preparation of this case study the name Smart Pipes has been changed to Exbyte.

Role of the ON program

The project team's participation in the ON Program has helped them to develop an approach to commercialising the Smart Pipes tool though a contract services model. The team has worked with water utilities in Australia and the United Kingdom in developing the tool for areas of interest to water utilities.

1.3.3 Project outputs

The methods for failure prediction developed by the Smart Pipes team have resulted in outcomes that have been proven to be more than twice as accurate as the current industry standard (the Weibull Method). Failure prediction and risk assessment projects are delivered across the following phases:

- Data pre-processing and visualisation
- Multi-factor analysis including water main attributes, geographic locations, weather, soil, pressure, water quality, unstructured data, etc
- Data-driven short/long-term water pipe failure prediction with confidence estimation
- Optimisation and risk assessment based on incorporation of constraints such as geography, constructability, cost and consequence of failure, and budget constraints

The primary deliverables of the Smart Pipes process are:

- A listing of all pipes in a network ranked by probability of failure, over a prediction period that can be defined by the end user
- A 'risk-rated' ranking incorporating end user defined cost, consequence, budget and other constraints deemed to be key to allocation of scarce resources
- Geographic Information System representation of risky pipes and regions, with the ability to overlay critical client or community assets and locations
- Clarity as to the factors that are most influential in the effective prediction of failure in a network
- Identification of the next set of data, or external data (e.g. weather, soil, foliage etc.) that, if sourced, would likely increase the accuracy of failure prediction
- Configuration and deployment of Data61's cloud-based Failure Prediction and Risk Assessment Platform to suit the needs of the user
- Establishment of an ongoing data management process that enables the end user to take control of the timely update of their failure prediction and risk assessment process.

Publications

The following are some of the publications associated with the Smart Pipes project:

- P Lin, B Zhang, T Guo, Y Wang, F Chen 2016, "Interaction Point Processes via Infinite Branching Model", The 13th AAAI Conference on Artificial Intelligence
- Y Wang, B Li, Y Wang, and F Chen 2015, "Metadata Dependent Mondrian Processes", The 33rd International Conference on Machine Learning
- P Lin, B Zhang, Y Wang, Z Li, B Li, Y Wang and F Chen 2015, "Data Driven Water Pipe Failure Prediction: A Bayesian Nonparametric Approach", The 24th ACM International Conference on Information and Knowledge Management
- B Li, B Zhang, Z Li, Y. Wang, F Chen, D Zhang, and D Vitanage 2015, "Multi-level Data Analytics for Risk Water Pipe Selection", IWA Leading-Edge Strategic Asset Management (LESAM)
- B Li, Zhang, Li Z, Wang Y, Chen F and Vitanage D 2015, "Prioritising water pipes for condition assessment with data analytics", Australia's International Water Conference & Exhibition (OzWater)
- Z Li, B Zhang, Y Wang, F Chen, R Taib, V Whiffin, and Y Wang 2013, "Water pipe condition assessment: A hierarchical beta process approach for sparse incident data", Machine Learning (ML)

Patents

The following patent applications have been filed:

- B Li, Y Wang, F Chen, and Y Wang 2015, "Group Infrastructure Components", application filed (N14 014-PROVAU)
- Z Li, Y Wang, and F Chen 2014, "Bayesian nonparametric method for infrastructure failure prediction", WO 2014/085849 A1
- B Zhang, Y Wang, and F Chen 2014, "Extended Hawkes process for infrastructure failure prediction", application filed (N14 012-PROVAU)

— B Zhang, Z Li, Y Wang, and F Chen 2012, "Determining a health condition of a bridge", application filed (N12 023-PCT)

Awards

To date the Smart Pipes project has been recognised by four awards, namely:

— 2018 Eureka Prize for Excellence in Data Science: Fang Chen, Yang Wang Zhidong Li, Bin Liang and Jianjia Zhang
— 2018 Research Innovation Award. Australian Water Association NSW
— 2018 National Research Innovation Merit Award. Australian Water Association
— 2016 Water Professional of the Year, awarded by Australian Water Association NSW: Fang Chen, for exceptional leadership and achievements in helping water sector through innovative solutions

Innovation / commercialisation

Smart Pipes' innovation lies in the design of the tool, which is data driven and takes into account information and data relating to a number of relevant factors.

1.3.4 Project Outcomes

The Smart Pipes team has worked with water utilities and research organisations worldwide, including Sydney Water and United Kingdom Water Industry Research (UKWIR) to complete data analysis for 27 global utilities. This has been applied to 9 million pipes spanning 525,000 kilometres and involving 700,000 failure records.

1.3.5 Adoption

The adoption of the tool by more than 27 utilities around the world has led to significant savings to water utilities and benefits to consumers from improved reliability of supply.

Role of the ON program

The ON program helped the Smart Pipes team to develop their commercial thinking. The Smart Pipes team is now generating approximately $1 million per annum in research contracts from water utilities. As a result of participation in the ON Program, the team is considering other applications of their approach.

1.3.6 Impacts

Deloitte Access Economics reported in 2015 that the Smart Pipes technology could deliver $2.6 billion over the following ten years.[2] The benefits from cost reductions were estimated to be approximately $298 million per year in 2013-14. This estimate assumed a take-up rate of 50 per cent in the water industry and 35 per cent take-up in the gas industry and used a 7 per cent discount rate.

1.4 Clarifying the Impacts

1.4.1 Counterfactual

In the absence of the Smart Pipes tool, water utilities would continue to rely on the current Weibull Method which has about half the accuracy of the Smart Pipes tool.

1.4.2 Attribution

ACIL Allen considers that an appropriate attribution of the benefits from this project is 95 per cent to NICTA/Data61 and 5 per cent to Sydney Water.

[2] Deloitte Access Economics 2015, Benefits from NICTA's research to the Australian economy, report to NICTA, 11 February 2015

1.5 Evaluating the Impacts

1.5.1 Cost-Benefit Analysis

Costs

The costs to the Smart Pipes team of participating in ON program activities are estimated to be $25,000. The overhead costs of the ON program that have been apportioned to the Smart Pipes project total $267,184. Both sets of costs are assumed to be incurred in 2018.

The key costs involved with the implementation of the Smart Pipes technology are the software design and installation costs. Given there is already existing technology in use, hardware would already be in place and only upgrade requirements would incur an additional cost. The ongoing costs would be similar to that of existing systems.

Benefits

Reduction in water pipe maintenance costs

To estimate the benefits of the Smart Pipes tool in relation to a reduction in the costs of maintaining water pipes and in the costs of pipe failures in Australia, ACIL Allen has drawn on and updated the modelling previously undertaken by Deloitte Access Economics (DAE) for NICTA in 2015.[3]

The DAE approach to estimating the direct benefits of the Smart Pipes project was to:

— Estimate the overall expenditure on pipe maintenance by water distributors in Australia

— Estimate the possible reduction in this cost with the use of the Smart Pipes technology.

Detailed information on Sydney Water's operating expenditure by category had indicated that approximately 47 per cent of annual operating costs are attributable to pipeline maintenance. The water pipeline maintenance costs for Sydney Water were estimated to be $617 million in 2013-14, which were extrapolated to the water pipeline system across Australia to be $2,074.8 nationally in 2013-14.

The reduction in maintenance costs associated with the introduction of the Smart Pipes technology was estimated using modelling results based on a trial conducted by NICTA. The trial examined the predictions made under the existing Weibull model and under the NICTA (Smart Pipes) model, and then compared these predictions to actual failures in the following year.

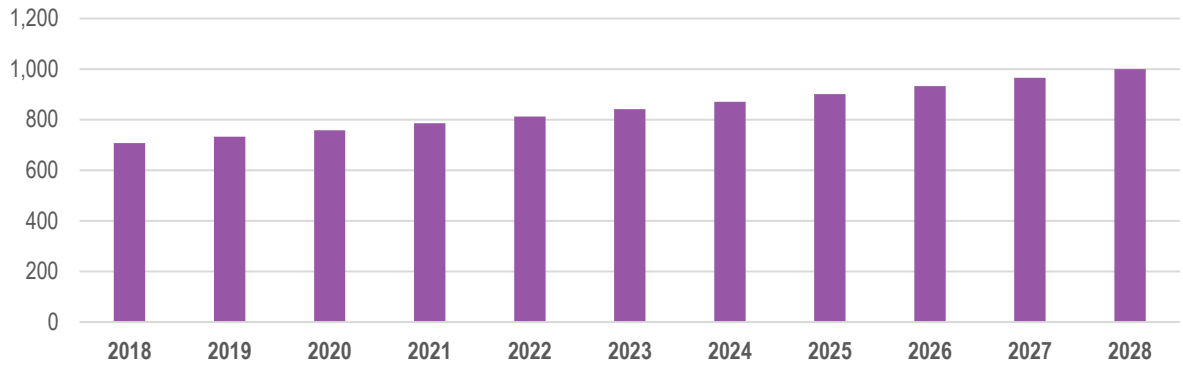
The results of the trial indicated that, when inspecting 1 per cent of the network, NICTA's technology identified more breakages than the existing technology. Specifically, the Smart Pipes tool predicted 35 out of 70 breakages in pipes, compared with 17 out of 70 for the Weibull model.

The average repair cost for a break was estimated at $509,363 in 2013-14 dollars, a weighted average between the minimum cost of $175,000 and the maximum cost of $5 million. Exploration costs (which was higher with Smart Pipes) was estimated to be $25,000 per km. Under these assumptions, the net cost reduction following implementation of Smart Pipes technology was estimated at 21.7 per cent.

The potential water pipeline maintenance cost savings from the application of Smart Pipes technology across Australia (in 2018-19 dollars) is shown in **Figure** Error! No text of specified style in document.**.3**. This is based on DAE (2015), adjusted for inflation between 2013-14 and 2018-19. The total potential maintenance cost savings increase at the rate of 3.5 per cent a year.

[3] Deloitte Access Economics (2015), *Benefits from NICTA's research to the Australian economy*. The DAE (2015) study also analysed potential benefits from the application of Smart Pipes technology to gas pipelines. However, discussion with the Smart Pipes team indicated that there has been limited adoption of the technology among gas utilities in Australia or overseas.

FIGURE ERROR! NO TEXT OF SPECIFIED STYLE IN DOCUMENT..**3** POTENTIAL WATER PIPEINE MAINTENANCE COST SAVINGS ACROSS AUSTRALIA FROM SMART PIPES TECHNOLOGY, FY2018 TO FY2028 ($M, 2018-19 DOLLARS)

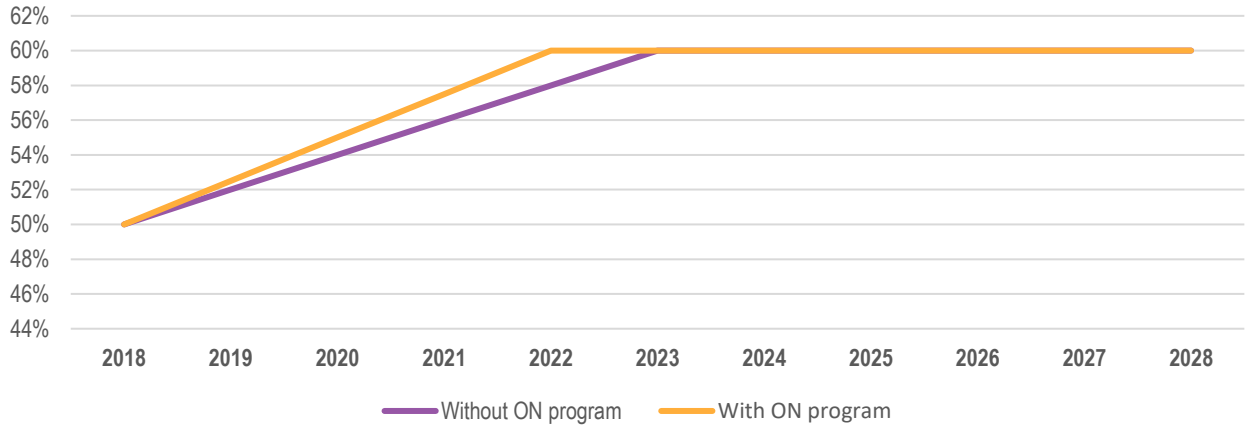


SOURCE: ACIL ALLEN CONSULTING, BASED ON DAE (2015)

In the cost-benefit analysis, it is assumed that participation in the ON program will accelerate the adoption of Smart Pipes technology by water utilities across Australia. In particular, it is assumed that the adoption rate will rise from 50 per cent to 60 per cent over 4 years from FY2018 with participation in the ON program, compared with 5 years without participation in the ON program (see **Figure** Error! No text of specified style in document..**4**).

Under these assumptions, the benefit of Smart Pipes technology in terms of reduced water pipe maintenance costs and pipe failure costs in Australia is estimated to be $3.66 million in FY2019, $7.58 million in FY2020, $11.78 million in FY2021, $16.26 million in FY2022 and $0 thereafter.

FIGURE ERROR! NO TEXT OF SPECIFIED STYLE IN DOCUMENT..**4** SMART PIPES ADOPTION RATE BY WATER UTILITIES IN AUSTRALIA, FY2018-FY2028 – WITH AND WITHOUT ON PROGRAM



SOURCE: ACIL ALLEN CONSULTING

Revenues from service offerings to overseas water utilities

In addition to reducing water pipe maintenance costs in Australia, participation in the ON program is also expected to increase the effectiveness of the Smart Pipes team's marketing of its services to overseas water utilities.

For the cost-benefit analysis, it is assumed that *in each year* from FY2019 to FY2023, participation in the ON program will result in an additional 2 overseas water utilities purchasing one-off consultancy services from the Smart Pipes team, of which 50 per cent will choose to purchase repeated services in subsequent years.

The pricing for one-off consultancy services is assumed to be as follows: USD30,000 for data review, USD45,000 for factor analysis and USD75,000 for failure prediction. The annual service fee for subsequent years is assumed to be USD125,000. To convert these revenues in Australian dollars, an exchange rate of AUD 1 = USD 0.71 has been used.

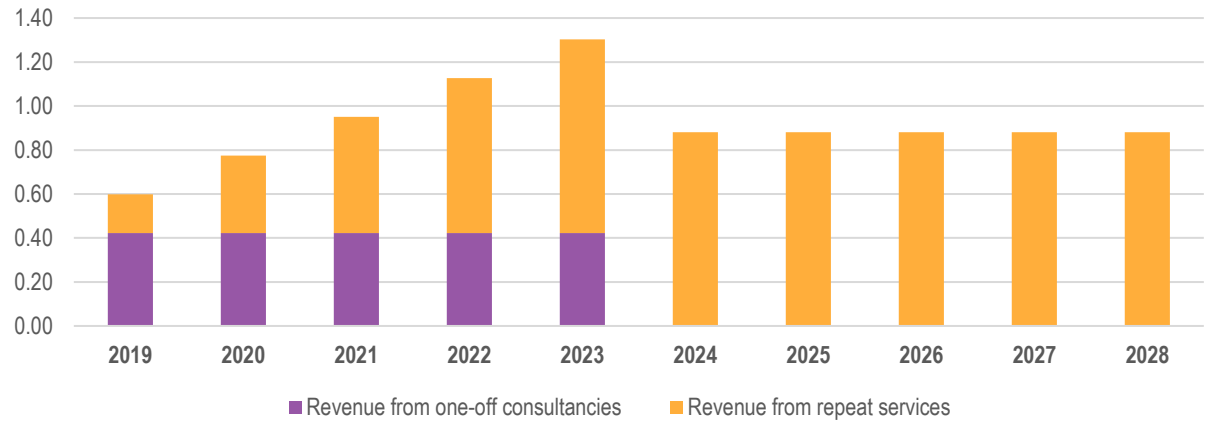
The projected additional revenue from service offerings to overseas water utilities as a result of the Smart Pipe team's participation in the ON program is shown in **Figure** Error! No text of specified style in document.**.5**.

Assessment of benefits against costs

The present value of ON-related costs is estimated to be $319,277 in 2019 dollars under a 7 per cent real discount rate. The present value of benefits from the application of Smart Pipes technology by water utilities in Australia and from additional service offerings to overseas water utilities as a result of the ON program is estimated at $41.13 million in 2019-19 dollars under a 7 per cent real discount rate.

The net benefit or net present value (NPV) of the ON program in relation to Smart Pipes is thus estimated at $40.82 million in 2018-19 dollars under a 7 per cent discount rate. The benefit-cost ratio (BCR) is estimated at 128.8.

FIGURE ERROR! NO TEXT OF SPECIFIED STYLE IN DOCUMENT..**5** ADDITIONAL REVENUE FROM SERVICE OFFERINGS TO OVERSEAS WATER UTILITIES DUE TO ON PROGRAM, FY2019 TO FY2028 ($M, 2018-19 DOLLARS)



SOURCE: ACIL ALLEN CONSULTING

Sensitivity analysis

Adoption rate of Smart Pipes technology by water utilities in Australia

In the central case of the cost-benefit analysis, it is conservatively assumed that the adoption rate of Smart Pipes technology by water utilities in Australia will rise from 50 per cent to 60 per cent over 4 years from FY2018 with participation in the ON program, compared with 5 years without participation in the ON program.

Suppose that the adoption rate of Smart Pipes technology by water utilities in Australia rises from 50 per cent to 70 per cent over four years from FY2018 with participation in the ON program, compared with 5 years without participation in the ON program. Then the BCR will be 236.3 instead of 128.8.

Services provided to overseas water utilities

In the central case of the cost-benefit analysis, it is assumed that in each year from FY2019 to FY2023, participation in the ON program will result in an additional 2 overseas water utilities purchasing one-off consultancy services from the Smart Pipes team, of which 50 per cent will choose to purchase repeated services in subsequent years.

Suppose that in each year from FY2019 to FY2023, participation in the ON program will result in an additional four overseas water utilities purchasing one-off consultancy services from the Smart Pipes team, of which 50 per cent will choose to purchase repeated services in subsequent years. Then the BCR will be 149.5 instead of 128.8.

Suppose instead that in each year from FY2019 to FY2023, participation in the ON program will result in only 1 additional overseas water utility purchasing one-off consultancy services from the Smart Pipes team, of which 50 per cent will choose to purchase repeated services in subsequent years. Then the BCR will be 122.4 instead of 128.8.

Discount rate

A real discount rate of 7 per cent was used in the central case of the cost-benefit analysis. Under a 4 per cent discount rate, the BCR rises from 128.8 to 141.8. The BCR falls to 117.7 under a 10 per cent discount rate.

1.5.2 Potential future impacts

In the future, this technology may be applied to gas and oil pipelines. This could result in significant benefits from losses avoided and a result of fractures and lower overall maintenance costs.[4]

1.5.3 The ON program's role

The ON program helped the Smart Pipes team to commercialise their technology for assessing the probability of water pipe failure. Their business model draws on learnings from participation in the ON Program. The Smart Pipes team is now generating approximately $1 million per annum in research contracts from water utilities. As a result of participation in the ON Program, the team is considering other applications of their approach noted above.

[4] Deloitte Access Economics 2015, Op cit.