Building compelling business cases for digital water metering

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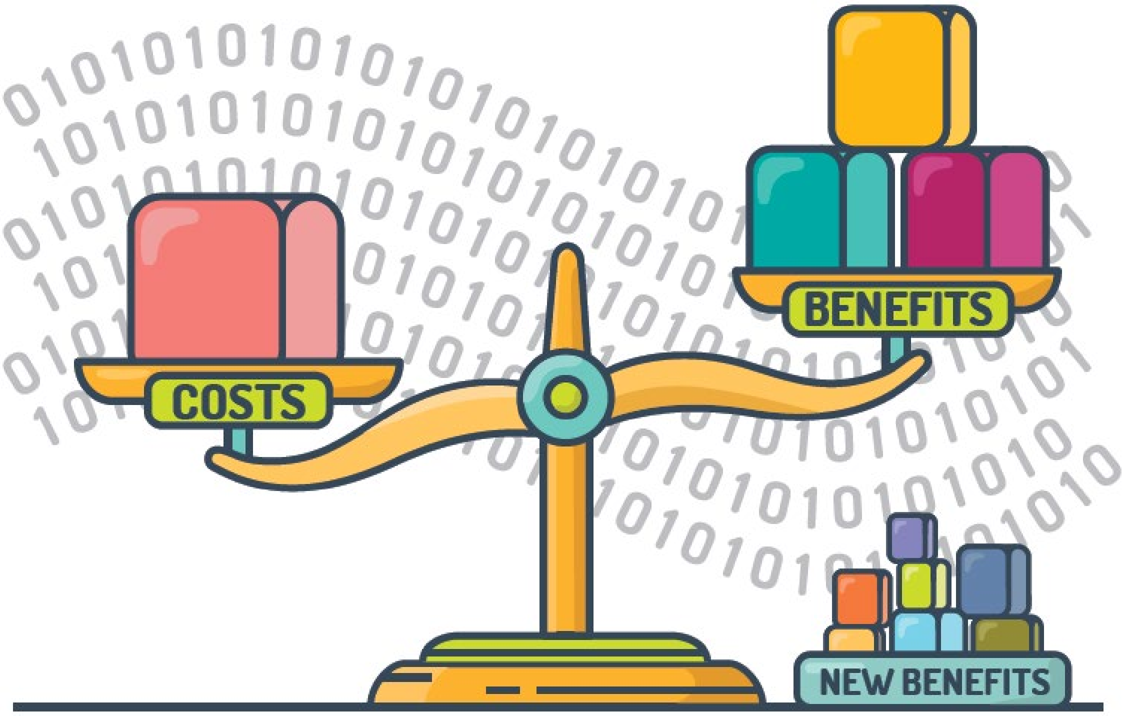

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Key Takeaways

- Business cases often strain to identify enough benefits to cover costs for digital water metering (DWM), consisting of advanced metering infrastructure (AMI) and data analytics.
- An Australian study in 2020 identified 77 benefits of DWM potentially generating cost savings and customer satisfaction improvements.
- Modelling software makes projections of monetary savings over the DWM project life cycle and considers customer satisfaction improvements linked to DWM deployment.
- Leasing meters may provide lower entry costs, shifting risks to the supplier and avoid lock-in of today's technology for long periods to achieve acceptable returns on investment.

Introduction

Water utilities need compelling business cases for digital water metering (DWM) that center on advanced metering infrastructure (AMI). After reviewing the literature and surveying sets of experts and Australian water customers, we developed a stochastic modelling tool to quantify the benefits of DWM. While some aspects of costs are discussed, this model provided in this article focuses exclusively on DWM benefits.

While successfully deployed around the globe, only a handful of water utilities in Australia have moved to DWM, usually where deferred system augmentation or water conservation needs existed or in areas with limited meter access. Many of the larger metropolitan water utilities have taken a cautious approach, running trials in discrete situations to better inform their business cases. This reserve is driven in part by rapid changes in DWM technologies and business cases that lack a compelling narrative. Further, some negative consumer sentiment regarding digital metering was created by poor rollout from the electricity sector.

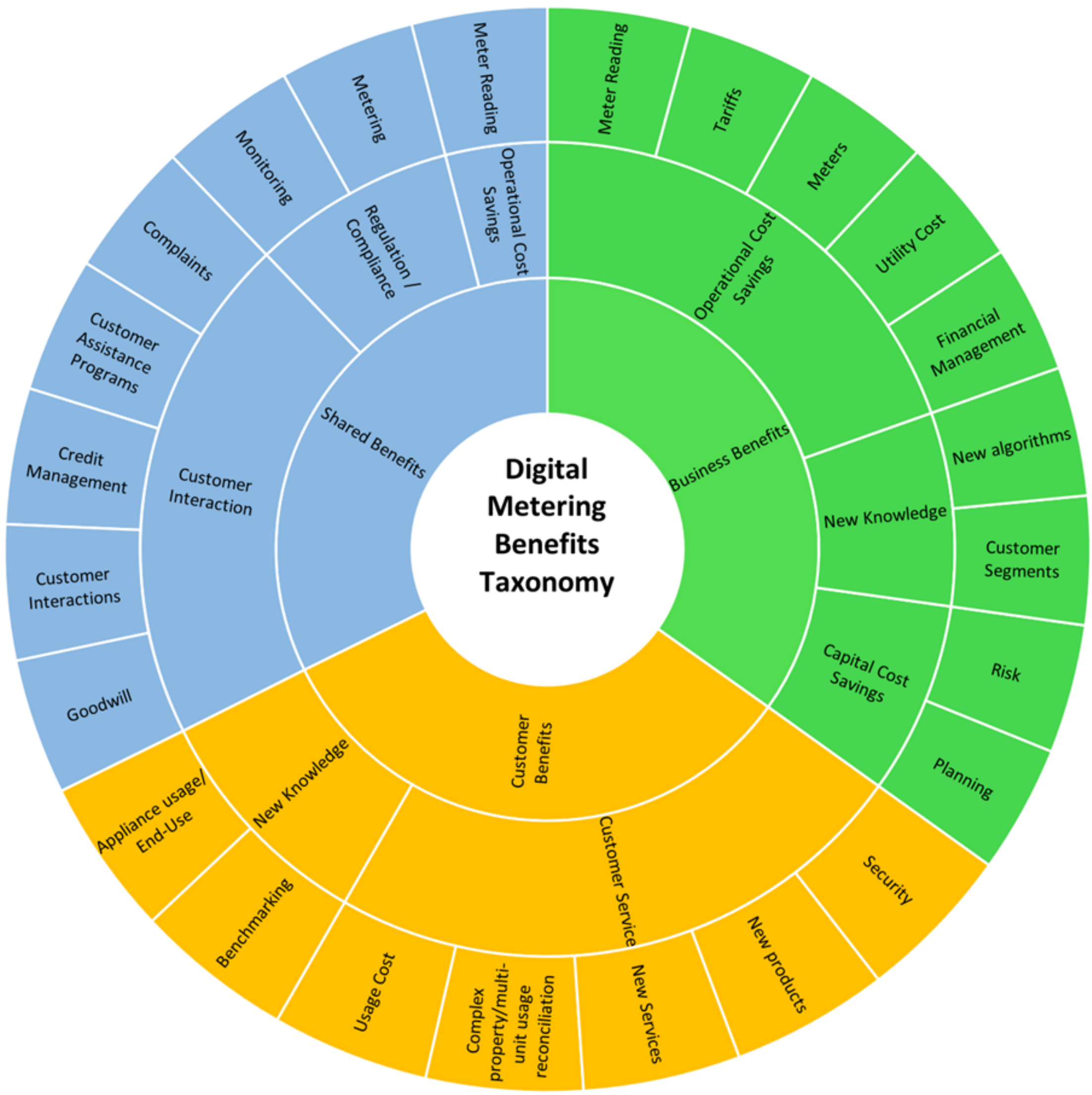
Reports from DWM projects provided insight into the possible cost savings and lower water demands. This comprehensive catalogue of benefits will support utilities exploring DWM and follow Messner's advice to prepare "a robust cost–benefit analysis, together with an evaluation of risk … (and) focus obsessively on turning perceived intangible benefits into hard numbers" (Messner 2013).

Modelling the Benefits of DWM

The DWM literature was reviewed for applications and benefits to water utilities, consumers, or the environment (Monks et al. 2019). We also examined publications including water utility annual reports, policy documents and pricing submissions to regulators, reports by Government departments, regulators, consumer advocates, and related and ancillary industry groups.

In addition, several interviews were conducted with industry staff. The literature review findings were reviewed by Australian water industry experts for their opinions on the likelihood of achieving similar results (Monks et al. 2020a). Using hypothetical scenarios based on DWM benefits, a second survey was conducted in which water customers were asked to score their levels of satisfaction (Monks et al. 2020b).

Through these steps, a taxonomy for the benefits of DWM was created (see Figure 1), requirements for project success were identified, and the probability distributions of benefit value were made. This article describes a stochastic model for the benefits of DWM and presents the results of an application of the model to a large water utility.



Adapted from Monks et.al. (CC BY 4.0)

FIGURE 1. Taxonomy of Digital Water Metering Benefits by Beneficiary, Business Category, and Subcategory

In the absence of a consistent empirical dataset covering the likelihood and extent of all benefits and customer impacts, data was collected directly from industry experts and customers. Krueger et al (2012) provide a detailed discussion on modelling through the use of expert opinions while Morgan (2014) raises some issues with the process.

Each cost and benefit in a business case can be expressed as a single expected number (Rees 2015); but this deterministic approach fails to capture the uncertainty of the inputs and outcome, and any risk analysis is confined to qualitative methods. However, risk-based modelling of a business case can inform management decision making, shifting the emphasis to a range of outcomes supported by confidence levels.

Model Development

After identifying the benefits of DWM, the next step was to assign each an extent and a likelihood (based on frequency distributions) along with a value based on customer satisfaction improvements from surveyed opinions. The quantitative analysis of survey responses identified two distinct patterns of cost savings, one for cost of water supply benefits and the other for charges and operational costs, and separate risk models were created for each.

A benefit valuation model, DWM360, was iteratively developed by applying it to a full-scale water utility (see Figure 2). Changes that may be required to a utility's systems, processes and resources that would enable the benefits are incorporated into the model as configurable flags. Using Monte Carlo simulation, savings are calculated as a probabilistic range of outcomes for each tangible benefit, then aggregated to the project level.

For benefits that could improve customer satisfaction, the improvement was estimated over multiple time periods reflecting real-world adverse events that affect individual customers sporadically.

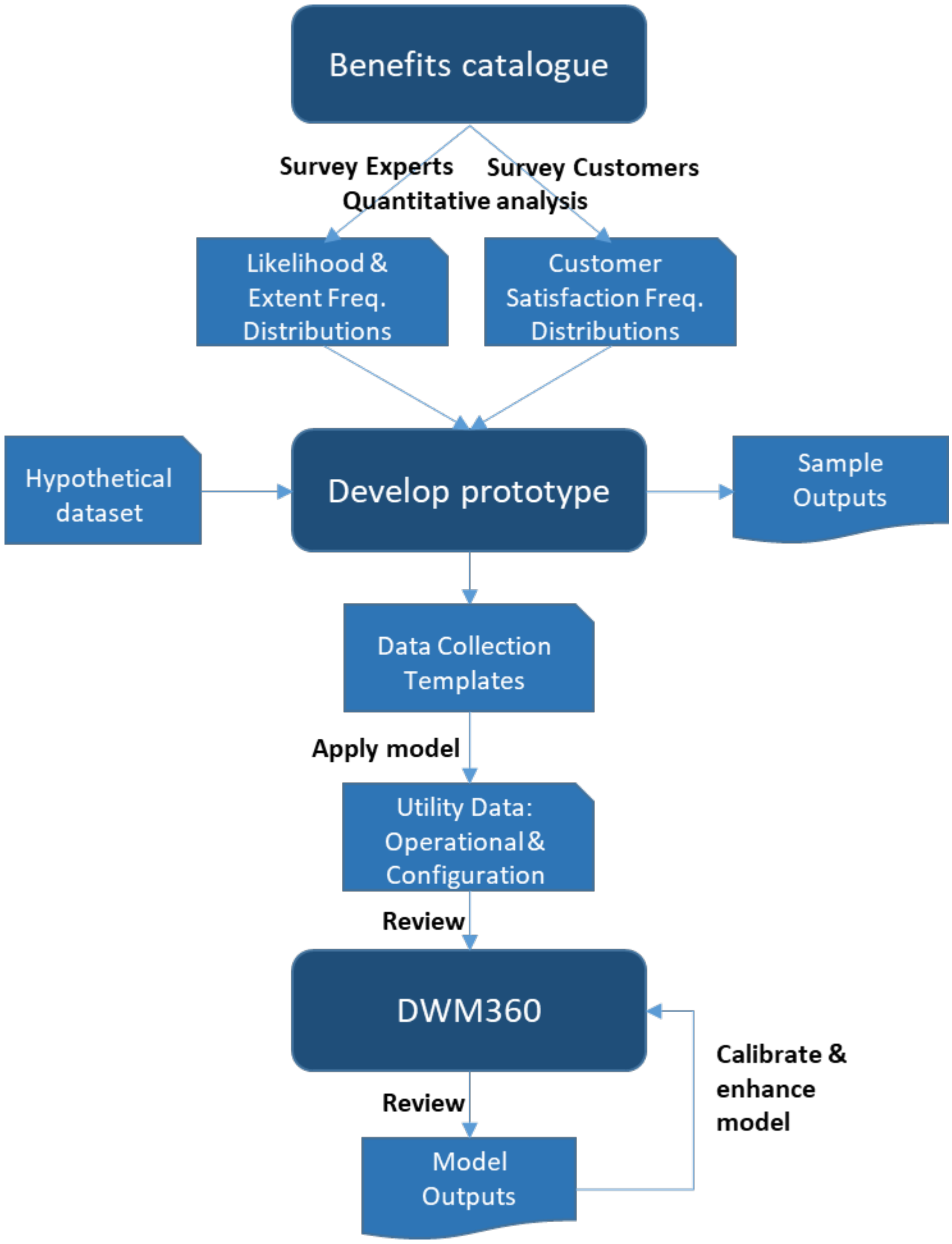


FIGURE 2. Model Development and Water Utility Application

Model Architecture

The model DWM360 generates probability densities of plausible savings outcomes and customer satisfaction improvements from DWM and subsequent improvements to other systems, processes, and resources. The @Risk add-on to MS Excel from Palisade was used as the simulation engine for the model and is illustrated in Figure 3. The model provides flags to act as switches on benefits and process changes so that business case developers can exclude irrelevant benefits and unaccepted changes. The flags also enable scenario modelling. Business case developers can also add new benefits, adapt listed benefits, or modify the probability distributions to reflect their specific conditions.

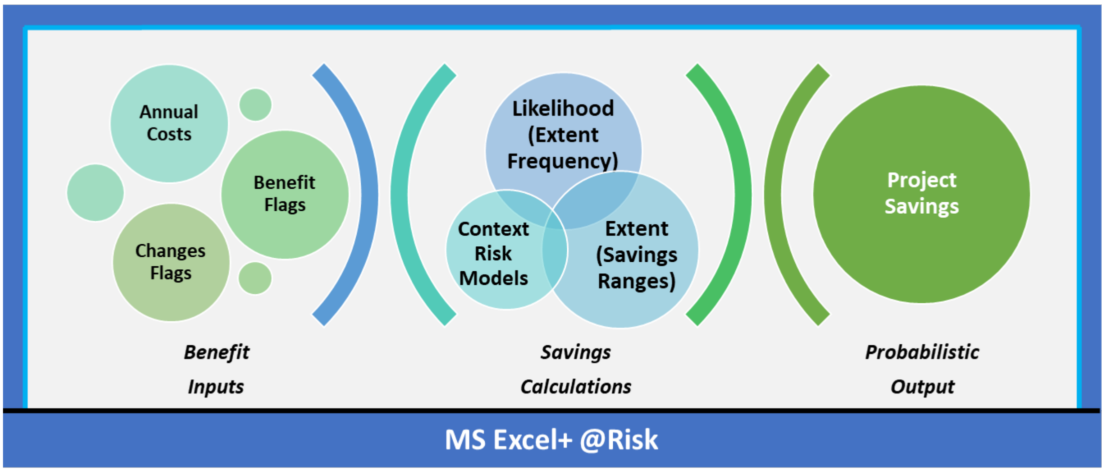


FIGURE 3. DWM360 Model Architecture

The model parameters are introduced in the following display box (see Figure 4).

Benefits, *i* : the model lists all *n* benefits grouped by beneficiary and category suggested by the taxonomy.

Relevant benefits, b_i : not all DWM benefits may be relevant to a water utility. Each benefit has a flag, b_i to indicate that it is relevant, 1, or not relevant, 0.

Enabled benefits, e_{ij} : For each benefit, *i*, there are a number of pre-requisite systems, processes and resources, *j*, to enable the benefits to be available. These are flagged by e_{ij}, and where enabled are set to 1, or 0 if disabled. All pre-requisite enabling flags for benefit *i* must be 1 for the benefit to be available, that is, min(e_{ij}) must equal 1.

Benefit likelihood, l_i : Even though the pre-requisite changes may be in place, and relevant to the water utility, each benefit may have a chance of not being realised based on the frequency distributions. The likelihood, or probability, of a benefit being realised, is, l_i, and, therefore a probability of not being realised of 1-l_i. The experts survey identified five levels of likelihood, '{0..4, where 0 means Disagree (ie. no chance), and 4 means Absolutely (ie. highly likely)}. Based on the frequency of opinions for each benefit at each level, $\{k_{i0}..k_{i4}\}$, likelihood is calculated as,

$$l_i = \sum_{y=1}^{4} k_{iy} \,/\, \sum_{y=0}^{4} k_{iy} \quad (1)$$

FIGURE 4. Model Parameters

Evaluating the cost savings

The cost savings module takes annual costs for each benefit and applies the appropriate risk model based on its context according to the benefit's likelihood and potential savings distributions. The details are displayed in Figure 5.

Project savings, S: is the aggregate of savings generated by each benefit, s_i.

Annual Costs c_i: for each benefit, i, the benefits are calculated on annual gross monetarised costs to the water utility. Care is required to avoid double counting of costs across benefits. For example, counting staff in call centres and back-office areas needs to consider full-time equivalents (FTE's) to accurately account for multiple people who may work on a benefit related task (eg. billing complaint handling) for a fraction of their workday. When a cost involves fixed charges and is not completely eliminated by the benefit, care is required to only include the variable component of the cost.

The calculation described in equations 2, 3 and 4 generate the probability density of savings for a configuration of the model.

$$S = \sum_{i=1}^{n} s_i \quad (2)$$

where,

$$s_i = c_i . b_i . \min(e_{ij}) . Ber(l_i) . f_X(x,t)_i \quad (3)$$

and,

$$f_X(x,t)_i = RiskGeneral(m_t, n_t, [p_{t1} .. p_{t5}], [f_{i1} .. f_{i5}]) \quad (4)$$

Where Ber() is the Bernoulli function, and RiskGeneral() is the @Risk built-in continuous function over the range m_t to n_t for the relative frequency points f_{i1} to f_{i5}, with value p_{t1} to p_{t5}, and t_i is the type of benefit or context for the benefit, {Cost of Water, Charge/Operational cost, (local context(s)),...}. It should be noted that some benefits, i, may have interdependence on another benefit, j, being achieved which should be reflected in the model such that $Ber(l_i)$ should be set to $Ber(l_j)$.

FIGURE 5. Cost Savings Calculations

Customer satisfaction improvements

Surveys can provide snapshots of customer satisfaction at a point in time, and adverse events that affect water services and subsequently lower satisfaction are often mitigated by water utilities through costly service recovery actions such as debt write-off, plumbing and financial assistance programs, and general advice on water use reduction. The model can forecast expected improvements to customer satisfaction resulting from DWM implementation without service recovery actions by the utility. The model's approach to estimating customer satisfaction improvements is shown in Figure 6.

Customer numbers: At the highest level, water utilities designate customers as either residential, R, or non-residential, Q, and apply different tariffs for services and usage.

Incidence Rates r_i and q_i : For each benefit, the percentage of customers impacted by an event type annually that DWM might eliminate, or reduce the impact of, is r_i and q_i, respectively. The proportion of customers who have received a benefit is expected to grow year on year, with some allowance for reoccurrence, as more customers suffer leaks, dispute bills, etc, and is calculated by

$1-(1-r_i)^z$ for residential customers (5)

$1-(1-q_i)^z$ for non-residential customers (6)

where z is the number of years

During a DWM rollout project lasting over many years, Y where $Y>0$, the proportion of customers who have DWM implemented at their property will change until the full rollout is achieved, the default annual rate is assumed to be $1/Y$. The customer base might also be expected to grow (or decline) at an annual rate, G.

Any improvement in customer satisfaction is dependent on benefits being relevant to the water utility, b_i, and enabled, $\min(e_{ij}) = 1$.

Customer Satisfaction Level Distributions

Customer satisfaction levels were recorded in the customer survey on the 0-10 scale with 0 being extremely dissatisfied and 10 being completely satisfied. The relative frequency of customer satisfaction levels before DWM benefits are received is $\{a_0..a_{10}\}$, and probability density

$\text{RiskGeneral}(0,1,\{0\%..100\%\},\{a_0..a_{10}\})$ (7)

The relative frequency of customers receiving the benefit, i, from DWM, scoring their satisfaction levels on the 0-10 scale, are, $\{d_{i0}..d_{i10}\}$.

Calculation of the overall customer satisfaction relative frequency at the end of any year, z, is a weighted average based on the incidence rate of each benefit event and those customers not to have received a benefit.

Total customers in year z,

$$C_z = (R+Q).(1+G_z) \qquad (8)$$

Customers who receive a benefit, i, by year, z

$$C_{zi} = b_i.\min(e_{ij}).(R.(1-(1-r_i)^z)+ Q.(1-(1-q_i)^z)) \qquad (9)$$

Customers who have not received a benefit by year z,

$$N_z = (R+Q).(1+G).\min(1,z/Y).(1-N_0)^z \qquad (10)$$

Where N_0 is the percentage of customers not to have received any benefit in the first year.

The overall relative frequency of benefit scores is,

$$d_{zu} = \sum_{i=1}^{n} d_{iu} C_{zi} / \sum_{i=1}^{n} C_{zi} \qquad (11)$$

and, the weighted customer satisfaction score is,

$$D_{zu} = (d_{zu}.(C_z-N_z)+a_u.N_z)/C_z \qquad (12)$$

where u = level index of the 0 to 10 scale

The probability density for the weighted customer satisfaction levels at the end of the year, z, is then calculated using the @Risk function, RiskGeneral,

$$\text{RiskGeneral}(0,1,\{0\%..100\%\},\{D_{z0}..D_{z10}\}) \qquad (13)$$

FIGURE 6. Customer Satisfaction Improvement Calculations

Applying the Model in Australia

To verify the model's capabilities, we sought a water utility that had almost completed its own DWM business case. A large Australian metropolitan water utility volunteered to participate but wanted to be de-identified in any publicly available documents.

Template documents were created to collect the necessary base data for the model. The two spreadsheets provided explanatory notes to guide the water utility and strawman values (Teigan & Bradley n.d) for each benefit intended to prompt discussion among stakeholders . Instructions for data collection emphasised the need to provide the annualised gross cost value and to avoid double-counting costs.

The water utility sought to implement a DWM solution across its service area over a six-year period and had established a business case with a positive net present value (NPV) over a 25-year period. The utility purchases treated bulk water and sewer services from a wholesaler. The wholesaler operates large, interconnected dams, a desalination plant, trunk network, trunk sewer and sewerage treatment and water recycling facilities. The utility plans to equip 800,000 customers with 20mm digital meters. The annual growth rate of customers in the service area is expected to run at just under 2%.

DWM project data collection

The business analyst to the utility's DWM project completed the data collection templates, often using information directly from their business case. Other data was derived from previous interviews and internal reports, and in some cases, the business analyst used best judgement based on experience. Configuration data was also gathered to adjust values to reflect the utility's expectations.

The business analyst and modeller reviewed all inputs to ensure the data was consistent and to avoid double counting. The utility did not review the model data and parameters because they were reviewed while the business case was prepared. Annual cost values were modified, where appropriate, to ensure they represented gross annual costs and not gross savings, and to align with externally reported data.

Model configuration and calibration

The model is configured by setting flags for each benefit and each enabling change to 'On' (default) or 'Off' in the calculation and then adjusting the standard distribution of likely extent. Benefits would be set off if they aren't applicable now, but they could be explored as a part of future service improvements. Each benefits' likely extent distribution can be adjusted based on the utility's view of future potential savings.

For this utility, the baseline model set monthly billing to Off as the utility considered bill prediction would be an adequate substitute to aid customer budgeting, at least initially. Once DWM was included in the system, the meter's battery life was estimated by the utility to be 15 years; because this should determine meter life, the frequency distribution for "Extending meter life through meter failure analytics" was effectively set to 0 as no savings were expected. This was also the case for "Reduced labour, parts and equipment resolving network and other NRW issues"; no savings were expected here because the utility intended to be proactive in this area so that additional costs would cancel out any savings. The four “goodwill” benefits were also not included because the utility thought its customers expected this kind of improved technology. Model calibration changed the ranges of %-savings in the risk models and customer satisfaction base frequency distribution. Because the utility already had an extensive NRW program, it expected to maintain losses at existing volumes, meaning NRW would reduce in real terms with network growth at approximately 2%. To reflect this, a custom risk model function was created for the “Reduction in wholesale cost of water” benefit (see Figure 7).

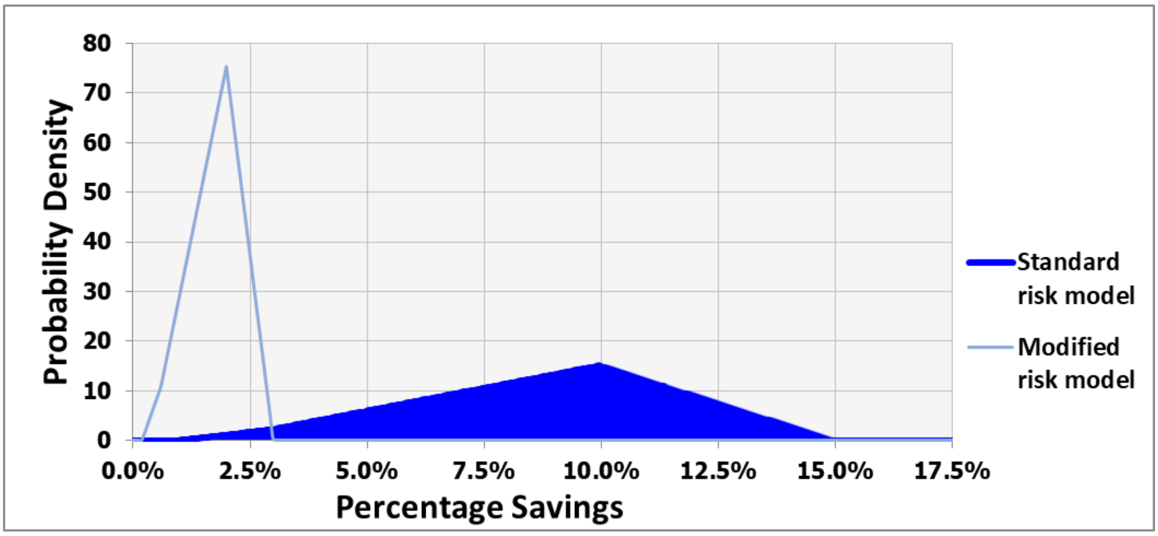


FIGURE 7. Probability density of the standard and modified Cost of Water risk models for the reduction in wholesale cost of water benefit

The risk model for Charges/Operational Cost savings was modified to align the model with the utility’s expectations of higher savings from meter reading and special readings (see Figure 8). This change also aligned with the expectations expressed by the utility’s experts in the Experts Survey.

Higher detection rates of water theft were expected to result in lower non-revenue losses, so the context of these water savings was changed to Charge/Operational Cost. In addition, the standard customer satisfaction frequency distribution for current satisfaction was adjusted positively to reflect the results from a recent regulator survey that showed the utility was starting from a relatively high position to start with (see Figure 9).

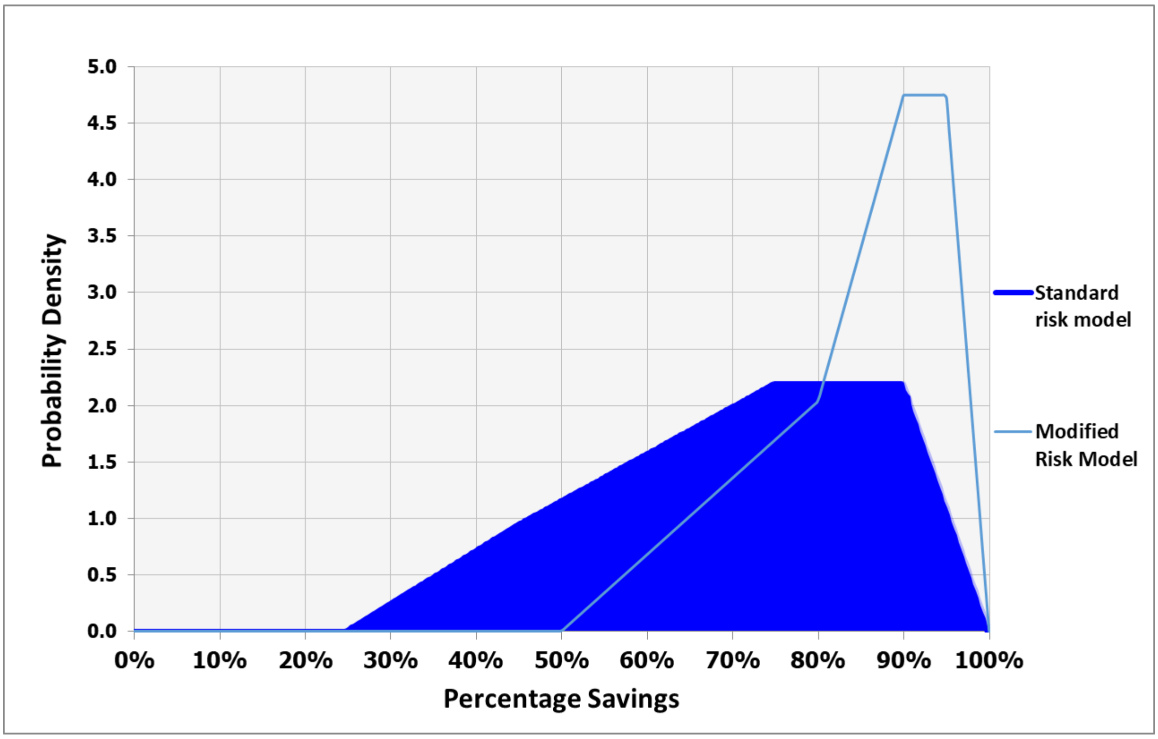


FIGURE 8. Probability density of the standard and modified risk model for benefits of context Charges and Operational Costs

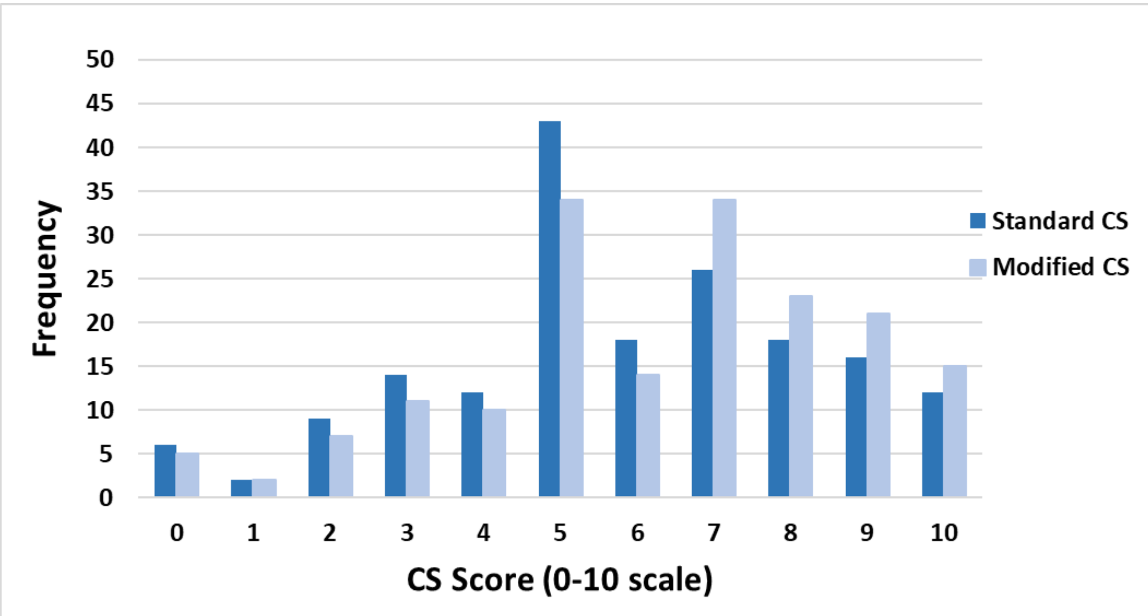


FIGURE 9. Standard and modified customer satisfaction frequencies

Results

The initial run of the utility's annual cost data in the configured and calibrated model on a single year estimated the utility could save 13% more than its original business case estimate. After a 25-year simulation that accounted for the rollout period and customer growth, the final estimate was a mean annual saving that was 7% higher than the utility's initial calculations. These estimated savings were consistent with the business analyst's expectations when the value of previously unrecognised benefits was included.

A run of 50,000 simulations of the model provided a probabilistic range of outcomes (see Figure 10). Savings are listed in Australian Dollars (1 AUD = 0.72 USD, October 2020). The model output shows a mean saving of $320.8M with 95% of achieving at least $223.9M, 50% chance of exceeding $325.3M and 5% chance of exceeding $405.6M.

The customer satisfaction improvements modelling provided some insight of what might be expected in the medium to longer term (see Figure 11).

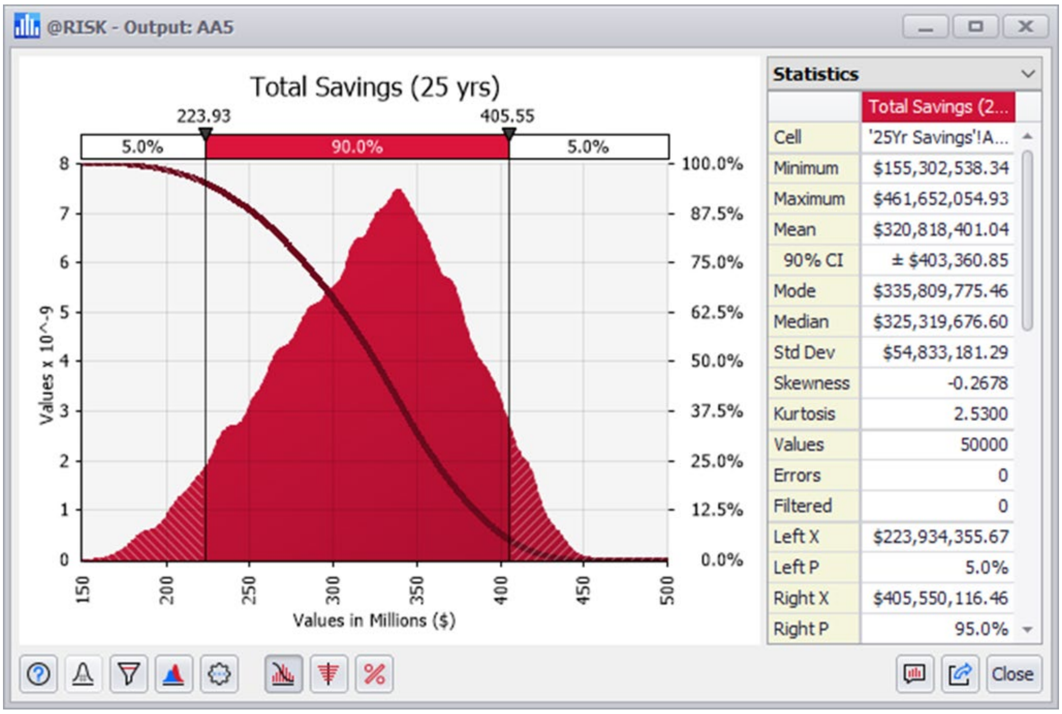


FIGURE 10. DWM360 Model output: 50,000 simulations. The probability distribution of gross savings over 25 years.

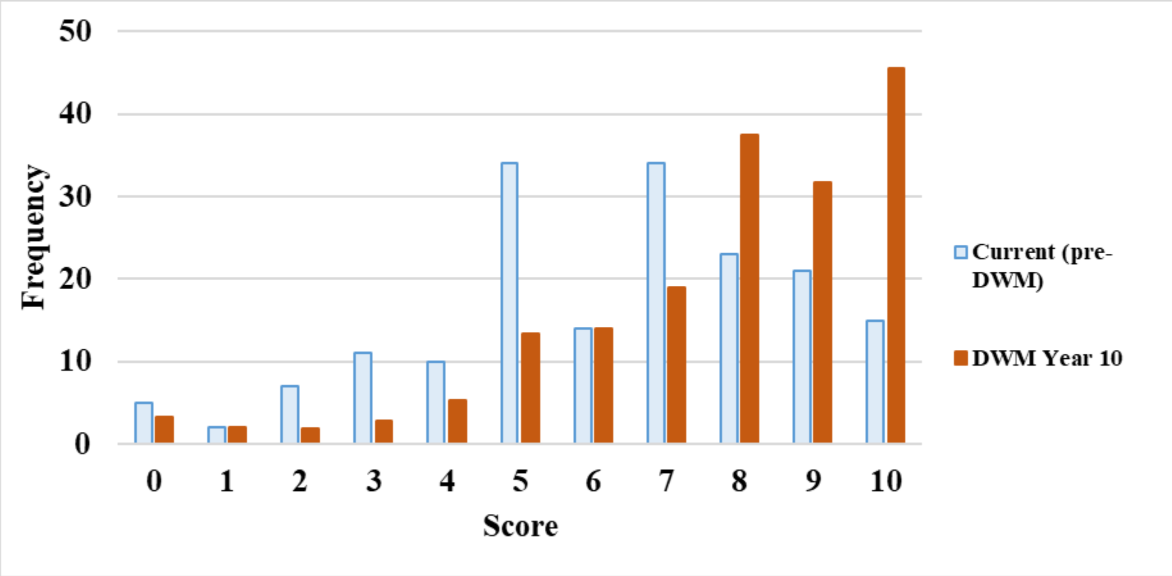


FIGURE 11. DWM360 Model output: Potential change in customer satisfaction from current levels (average = 6.3) to year 10 with DWM deployment (average = 7.7)

Meter Life

The case study highlighted that the utility did not expect to prolong the life of their digital water meters beyond the life of the utility's batteries. Even after some early failures were identified through the meter management process, mass replacement after 15 years was expected. The benefits of meter data analytics were not included as the utility believed it achieved sufficient benefit to cover its costs and gain a positive NPV. However, utilities in a less fortunate benefits position, or higher-cost position, should explore ways to extend the useable life of their meters.

Digital meters are presently around three times the cost of manual meters, before possible volume and contractual discounts. An unpublished study found the compliant working life of manual meters in Melbourne exceeded 20 years when excluding faulty installation, theft, damage, and withdrawal from service for compliance testing. For a fleet of just 100,000 meters, if meter replacement occurs at 15 years rather than 20 years, an extra 1,700 meters would be required annually with a lost annual benefit of around AUD$340,000 pa (at AUD$200 per digital meter).

The downsides of a 15-year battery life can be mitigated if:

- Parts are available, serviceability is possible, and both are cost-effective

- The working life of the rest of the meter is reduced to 15 years and the unit cost of the meter is dropped proportionately
- The working life of the battery can be extended by:
    a. Fitting a larger battery or putting batteries in parallel (Battery University 2020)
    b. Changing the frequency of reads to draw down the power in the battery more slowly
    c. Improving the energy efficiency of the microcontroller (Itron Ltd 2014, Hong and Lee 2019)
    d. Incorporating an energy harvesting system (Hoffmann et al. 2013).

As an alternative, vendors might offset any lessened benefit caused by shorter battery life by including additional services such as meter data analytics, data integration with external datasets such as weather, and customer portals with expanded features.

Regardless, battery life and meter life are product issues that are seen as barriers to DWM take-up by water utilities (Monks et al. 2020a). Water utilities see DWM as expensive and, while technically impressive, buying in today could lock them out of access to future advances or changing needs. On the other hand, vendors want clear statements of requirements, long-term commitments, and volume sales to enable attractive pricing and a reasonable return on their R&D investment.

Some vendors have already offered more flexible financial structures for DWM projects that might provide better outcomes for vendor and water utility. At least two projects have featured leasing arrangements: KC Water (2007) and Aguas de Alicante (2011). Leasing digital meters could significantly lower the CapEx requirement in favour of a higher OpEx, and this approach could include a "guaranteed" technology upgrade inclusive of a battery upgrade. Vendors would use their infrastructure capabilities for data collection and deliver either "software as a service", "data as a service" or a hybrid "software/data as a service" while gaining contractual certainty. Water utilities would receive the data they need, gain access to metering advances and push some risk back on the vendor. Customers could gain access to their usage and other data through a vendor-hosted portal or utility portal. Sustainability goals may be improved through lease transactions that facilitates a circular economy by providing the vendor with salvage rights at the end of the meter lease, enabling recovery, refurbishment and reuse (Ionaşcu and Ionaşcu 2018).

However, utilities might be reluctant to relinquish ownership control of their meters without clear and enforceable rights in the event of service failure or vendor bankruptcy, ownership of the data, as well as privacy and security provisions. Financing issues such as the cost of borrowing and asset write-downs may also influence a water utility's decisions. The lease vs buy decision has been explored by Messner (technology investments) and Schlenger (digital meter investments) (Messner 2013, Schlenger 2019).

Source Water

Because it purchases treated water from a wholesaler, the water utility in the case study understood its bulk water cost savings from any water demand reduction beyond their existing NRW reduction program. On the other hand, utilities that rely on groundwater face different potential cost savings along their supply chain. While deferral of capital works may be possible for growing demand situations and when assets are reaching end-of-life, operating costs for treated water production, storage and distribution and any purchase of emergency water supplies (e.g., desalinated water or tankered supplies) need to be determined. Based on the experience of other utilities, an allowance for deferral of capital works for future network maintenance augmentations might be included. Further, potential cost-effective solutions have been found using root cause analysis with additional local data from digital meters that could help resolve local supply issues without significant capital investment.

Considering Benefits Across the Business

As digital metering technology evolves, water utilities may struggle to build their own DWM business case, but in this process, they need to consider benefits from across their whole business and financial solutions that reduce risk, ensure delivery of benefits and provide flexibility.

A model for estimating digital meter benefits, DWM360, proved flexible and capable of generating plausible outcomes and quantifying benefits. Savings were calculated from operational data after the model was configured and calibrated to reflect the utility's situational context.

Applying the model to a full-scale utility raised issues that go to the core of business case development for DWM projects. The proposed solution must meet the needs of the water utility now and into the future while being financially sound. Expanding the range of benefits and measuring the potential improvements to customer satisfaction helps quantify the potential benefits, while the use of simulation techniques provides a probabilistic, risk-based range of outcomes.

Utilities that see DWM costs and risks as too great may consider leasing system meters as an alternative to ownership. Under this model, meter suppliers gain consistent sales volumes for providing both data-as-a-service to the utility and a feature-rich portal for customer self-service. Meter leasing may also support the sustainability goals of utilities by providing a circular economy for meters.

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