Enterprise risk and cost modelling in the water utility sector: A case study of Yorkshire Water

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Background

Big data

“There is a big data revolution, but it is not the *quantity* of data that is revolutionary. The big data revolution is that now we can *do* something with the data.” (King, G in Shaw, J, 2014).

Big data, “information of extreme size, diversity and complexity” (Gartner, 2014), is particularly prevalent throughout the water industry. The large asset bases operated by water and sewerage companies produce high volumes of process data. In addition there are a large range of external factors that impact the performance of water and sewerage companies. For example, the volume and distribution of precipitation combined with condition of catchments will affect the volume and quality of raw water available. Likewise, temperature and soil moisture deficit significantly impact leakage from water pipes. The size and complexity of this data makes understanding and managing the value chain of collecting, treating and distributing clean water and bio-solids challenging. Further, truly holistic decision-making relies on this process data being combined with financial and customer information to deliver best value for customers in a tightly regulated environment. Converting the high volume of data into high quality information that informs decision-making is a challenge that Yorkshire Water has been focusing on since 2010.

Prescriptive analytics

Prescriptive analytics (Figure 1) are a 5th generation modelling technology that allows organisations to exploit the insight and understanding developed through predictive analytics to optimise investment and operational planning (Gröger et al., 2014; Liberatore and Luo, 2010). Prescriptive analytics have rapidly risen in prominence in the last five years (Lustiz et al., 2010). This has been driven by the desire to translate the wealth of information within ‘big data’ and traditional business analytics into better decisions and ultimately increase value. The complexity of many businesses and sheer volume of data generated by telemetered systems means that prescriptive analytics is critical to optimise value chains for performance, cost and risk.

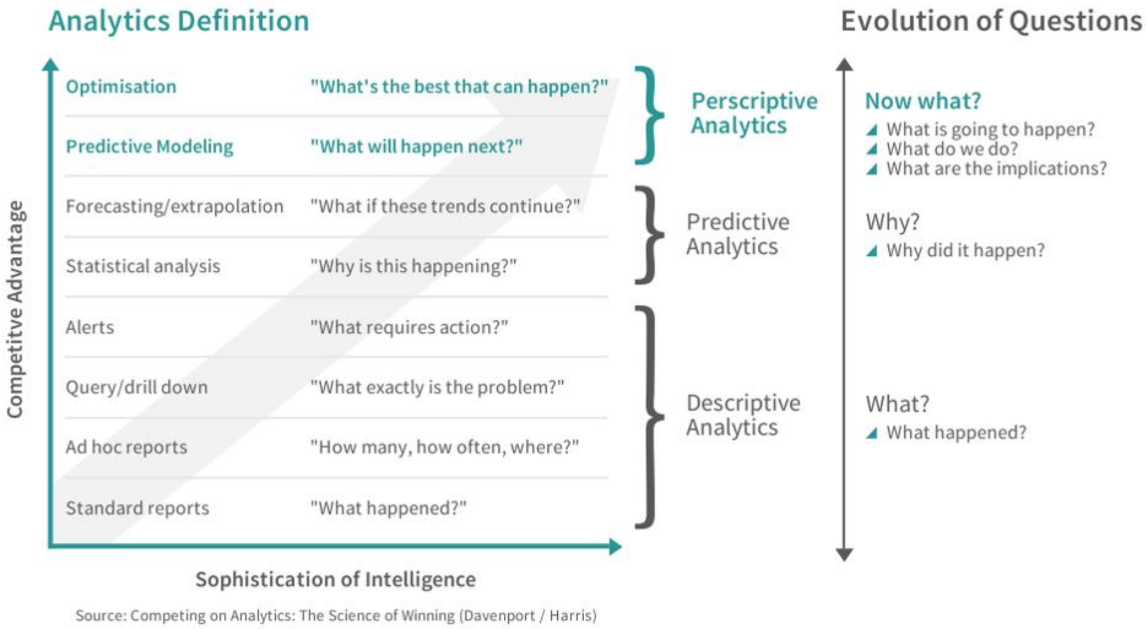


Figure 1: Definitions of analytics

Yorkshire Water partnered with BMA to embed prescriptive analytics into Yorkshire Water with support from Cranfield University. BMA utilised a technology developed by Riverlogic called Enterprise Optimizer® (EO) which is built on Constraint-Oriented Reasoning™ (COR). COR is a leading edge programming language that enables EO to quickly create high-value analytical solutions in complex problem domains. Problems are defined as constraints and can be expressed in intuitive ways such as graphically or through symbols and relationships. In EO users can quickly build integrated models without writing code or managing formulas. Unlike conventional modelling, COR automatically generates mathematical representations of all system constraints and their interactions. This enables users to easily change the problem they are solving without restructuring the mathematical representations or redefining input and decision variables. This avoids the need for specialised developers and allows users with engineering and financial backgrounds to build models and apply their expertise directly. It also allowed Yorkshire water to quickly & efficiently build an in-house capability to maintain and develop the models.

The second key capability of EO is its ability to represent an asset base, business processes and company accounts in a single representation. This allows us to view the impacts of decisions and investment options on operational performance, the balance sheet and on shareholder value. It also allows both operational and financial constraints to be applied within a single model solve.

Finally, the objective function need not be maximization of the net income (*i.e.,* profit maximization) although that is the default. For example, maximizing regulated capital value, minimising energy usage or minimising carbon emissions (or combinations therein) are all easily done. This was important to support Yorkshire water's commitment to a socially, environmentally and economically sustainable future.

Case study context: Yorkshire Water

Yorkshire Water manage the collection, treatment and distribution of water in Yorkshire, supplying around 1.24 billion litres of drinking water each day. At the same time they also collect, treat and dispose of about one billion litres of waste water safely back into the environment each day. To do this they operate more than 700 water and sewage treatment works and 120 reservoirs connected by over 62,000 miles of water and sewerage mains. Yorkshire Water must operate, maintain and upgrade their assets to provide safe and cost-effective water and waste water services to their current and future customers. They currently spend around £750 per household to maintain and upgrade their pipes and works to reduce the risk of bursts, low water pressure, incidents of discolouration, sewer flooding and odour problems. In addition Yorkshire Water are one of the region's largest landowners and provide recreational access to much of their land.

Yorkshire Water are regulated by a number of agencies including The Water Services Regulation Authority (Ofwat), the Drinking Water Inspectorate (DWI) and Environment Agency (EA) who together determine the quality of service Yorkshire Water must provide its customers and how much they can charge for that service. In addition Yorkshire Water are privately owned by shareholders who expect a return on their investment.

The environmental, regulatory and financial challenges within the UK water industry are drivers for innovation and performance improvement. Yorkshire Water and other utilities are continually looking for innovative solutions to better manage complex business environments. Predicting and managing performance, risk and cost across an integrated network of assets is one of the key challenges faced by Yorkshire Water. Advances in data gathering on process performance, risk and cost available (big data) and analytic capabilities to use that information are an area of significant opportunity and innovation that water utilities are looking to exploit.

Yorkshire Water's approach to business analytics has matured throughout the five year Asset Management Period (AMP) investment cycles. Figure 2 demonstrates this analytics journey for Yorkshire Water. Historically Yorkshire Water and other utilities have managed complexity through decentralised decision making, supported by lag indicators and retrospective data analysis to understand what happened and why. Descriptive analytics used included scorecards and reporting on past business performance such as compliance with Hazards & Critical Control Points (HACCP) or digester retention time. Where modelling and forecasting ability existed within Yorkshire Water it remained in the domain of specialised functions. This has resulted in a fragmented approach to managing risk, cost and performance across the value chain. While specific business functions such as water resource planning and asset investment planning had robust forward looking decision making capabilities, overall forecasts of risk, performance and costs were lacking or of too low a quality to meaningfully inform decisions that consider the value chain as a whole.

Throughout the most recent asset management period (AMP5) diagnostic analytics have been increasingly used with regular root cause analyses being carried out to understand why events have occurred. Development of improved data collection and reporting improved the understanding of performance and the speed of response to failure but fundamentally this approach is still reactive and retrospective. However, in order to move from a retrospective descriptive and diagnostic approach to proactive operational optimisation a more future-focused analytical capability is required. As AMP5 progressed Yorkshire Water has moved towards a 'production plant' mentality and increasingly considered its operations as a value chain where the products are potable water, treated waste water and treated bio-solids (sludge). As with any value chain the focus is on adding as much value throughout operations as possible. This cultural change within Yorkshire Water recognised that with siloed and static business plans and balanced scorecards in place it was difficult to identify knock-on effects and trade-offs within the value chain. It has been accepted that reliance on historic data resulted in a reactive approach to managing the value chain where effort focused on resolving past problems and made proactively spotting emerging challenges difficult. This cultural change has created the environment in which Yorkshire Water has developed its ability to leverage

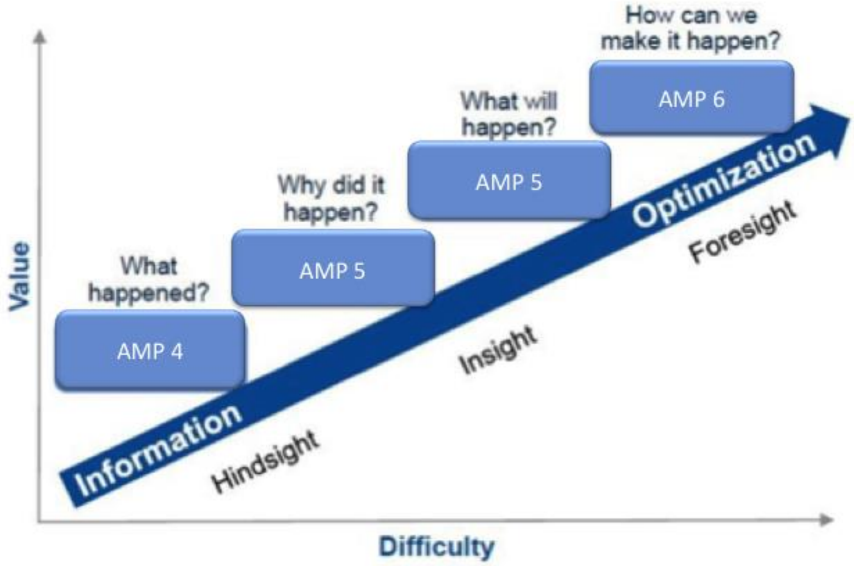


Figure 2: Gartner Analytics maturity model & Yorkshire Water progress

value from big data through prescriptive analytics.

In the early 2009 Yorkshire Water (Yorkshire Water) identified the need to develop an integrated risk, cost and performance modelling capability to represent and forecast the complex interactions between internal and external factors, regulatory performance commitments and business constraints. In 2011 Yorkshire Water began to work with Business Modelling Associates (BMA) and Cranfield University to develop a proof of concept project to demonstrate the benefits of an integrated modelling approach.

Yorkshire Water's vision was to overcome their reactive, siloed approach to business and risk modelling and build a capability for integrated risk, cost and performance modelling taking into account the entire asset base, accounting structure (including regulatory accounting and shareholder value), and the hydrological cycle from catchments and water sources through to waste water treatment and sludge disposal. This approach of utilising the big data available would enable proactive identification of constraints, upcoming risks and opportunities enabling better business planning, risk management and production planning (Figure 3). By centralising data into one coherent model, it also allows regional optimisation and prevents the classic silo thinking of traditional approaches to business planning and optimisation.

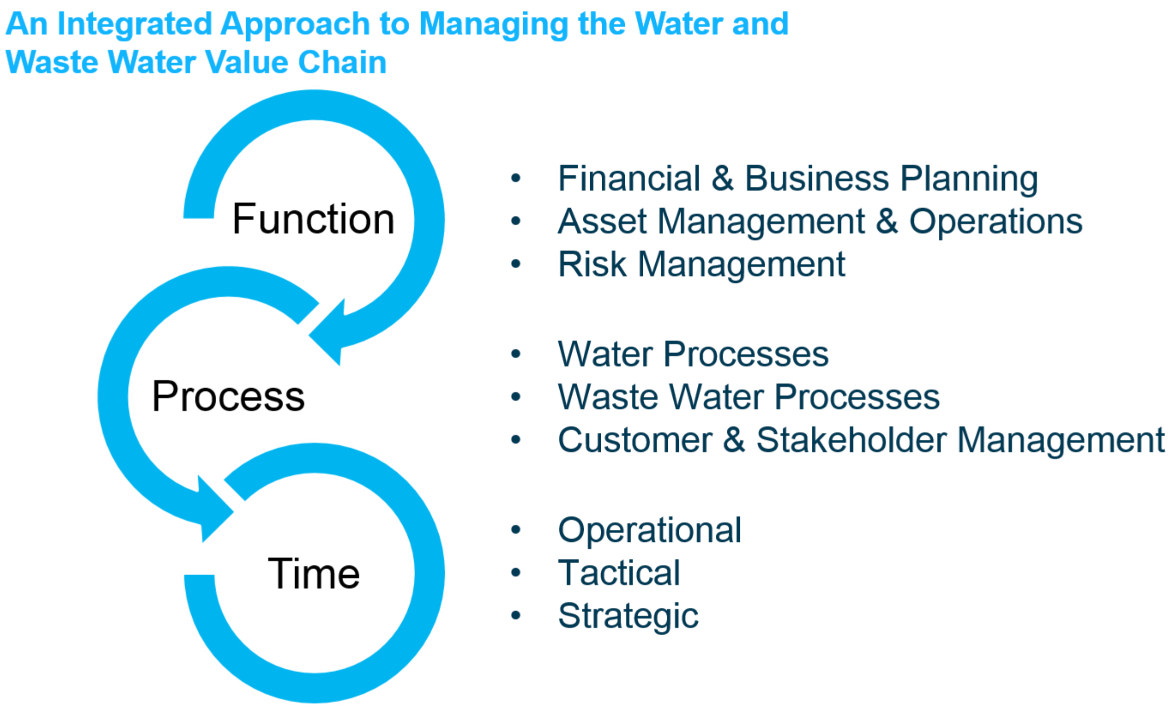
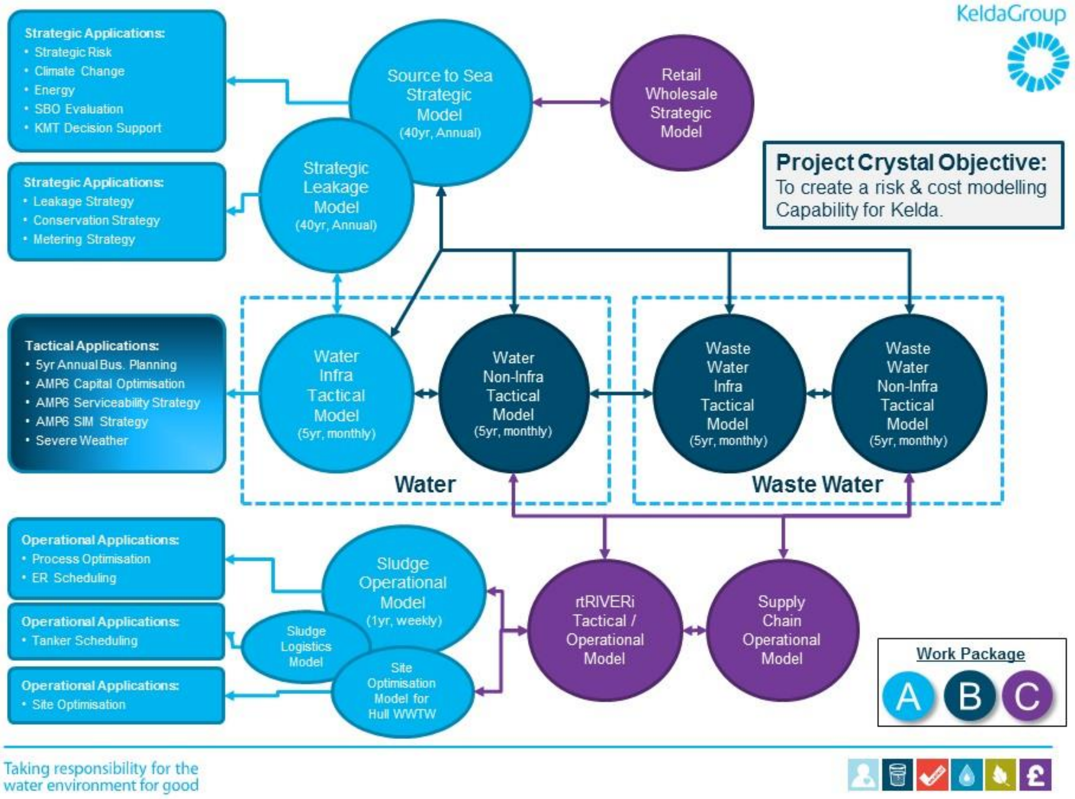


Figure 3: An integrated approach to managing the water and waste water value chain at Yorkshire Water

Approach taken by Yorkshire Water

Yorkshire Water have embarked on an ambitious project to develop a range of strategic, tactical and operational prescriptive models using EO as the core analytical and optimisation engine (Figure 4). Currently the strategic 'source to sea' model, tactical sludge treatment model and operational sludge and tankering models are now in use or in commissioning. Implementation of these models involved over 300 individuals, for example tanker drivers who receive daily work schedules produced and optimised by the EO sludge tankering model. Yorkshire Water's goal is that these models will be integrated, using common data sources and will feed each other information. For, example outputs from tactical models will be aggregated and fed into the Source to Sea model to determine the impact on the whole business.

Figure 4: Developing model landscape using advanced predictive and prescriptive analytics at Yorkshire Water



Strategic planning and risk management: Source to Sea Strategic Model

Yorkshire Water developed a 'Source to Sea' strategic model with a single holistic representation of the business. This model will allow investment planning and risk analysis that bridges organisational and knowledge silos, and captures the complicated relationships within and between processes and networked assets. This model will add capability to quantify the benefit of strategic investments, identify and quantify systemic risks and develop optimal solutions to those risks. For example the model could be used to quantify the impact of increased flooding due to climate change and identify the most vulnerable and critical assets. It could also be used to consider whether to invest in technologies to reduce customer consumption of potable water or sustainable urban drainage to reduce the volume of waste water entering sewage treatment works.

By representing risk, cost and performance in a single model, it will help ensure that risk (and therefore uncertainty) is integral to strategic decision making. This is critical in strategic decision making where strategies and plans consider long time periods (40 years in the case of Yorkshire Water) and uncertainties are considerable. For example uncertainty around the impacts of climate change, population growth and emergence of new technologies. A notable function of the Source to Sea model is carbon accounting. In addition to quantifying the impact of decisions and scenarios in financial and operational terms, the impact on greenhouse gas emissions is also determined. This is an example of Yorkshire Waters ambition to account for social and environmental impacts in their decision making and planning processes.

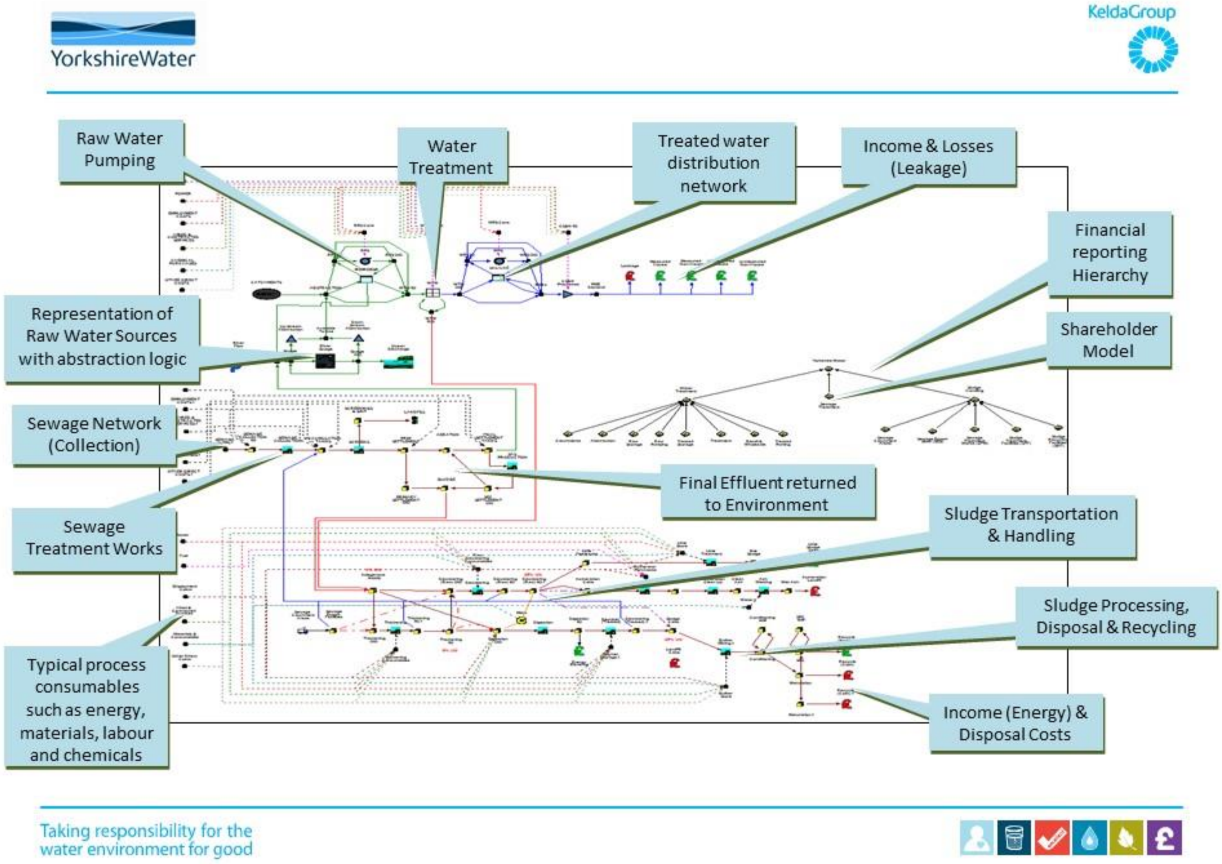
Strategic model scope:

- Water Processes
  - All raw & treated Water Processes represented
  - Representation of customers (*circa* 5 million) down to production management zone level (*circa* 45000 customers)

- Representation of water network connectivity and water flow
- All water treatment works represented individually

- Sewerage
  - Representation of customers down to a sewage treatment works catchment area
- Sewage Treatment
  - All sewage treatment works represented
  - Surface water and infiltration represented
- Sludge
  - All sludge processes represented, including sludge tankering
  - All sludge import sites individually represented
  - Sludge treatment variations by site represented
- Financial
  - Operational accounts for Raw Water, Treated Water, Sewage and Sludge
  - Wholesale/retail accounting separation represented
  - Regulatory accounting (including Regulatory Capital Value)
  - Quantification of financial risk (Value at Risk)
- Time
  - 40 years represented in annual time steps

Figure 5: Source-to-Sea model schematic



The strategic model will be directly used by group risk and assurance, group strategy and strategic investment planning through the following applications. The Kelda Executive Board and Audit Committee will also be key customers of the model outcomes (Table 1).

Table 1: User applications

User group	Use
Executive Board and Audit Committee	The model will be used (via interactive risk dashboards) to provide Board and Audit Committee with enhanced oversight of current and future strategic risks.
Group risk and assurance	Identify and quantify strategic risk and multi risk event scenarios. Enable better reporting to Board, and support/challenge risk owners across the business.
Group strategy	Stress test group strategy, for example, under different population growth and climate change scenarios (raw water resource).
Strategic investment planning	Optimise strategic investment decisions in the context of the operation, maintenance, growth (development) and decommissioning of the asset base, set within a changing environmental, social, regulatory and economic context, forecasting how costs and risks will change over the long term (40 years).

Tactical sludge process model

Operationally Yorkshire Water has built a tactical model for the end-to-end sludge process within each five year AMP period. This model represents the full sludge process throughout all Yorkshire Water assets from wastewater treatment works that export sludge through to recycling or disposal of sludge. Interdependencies between all of the assets involved in sludge production, treatment and recycling or disposal are represented. The model then integrates real time and near-real time data on the volumes of sludge entering the process, environmental factors (temperature), up-to-date asset availability, capacity and unit costs of sludge processing assets, and the availability and cost of options to dispose of sludge (for example routes to dispose of sludge to land are seasonal) to provide weekly production plans. This model also provides support for sludge business planning, production planning, and to understanding of the impact of potential deregulation.

The Sludge Operational Model is run weekly to produce a production plan for each asset. The model can produces plans that run up to 12 months ahead. Because the model represents the entire sludge process from end-to-end it considers all knock-on effects and trade-offs to produce productions plans that are optimised for a system as a whole. A core functionality of the model is that the cost of treatment and value of the energy available in sludge is considered at all stages of transport and production. This is a significant departure from the previous approach where production plans were optimised on an asset by asset and cost by cost basis. The intrinsic link between assets and finances means that this model has also begun to support the annual internal business planning process.

The model produces a unit rate for sludge in exactly the same way you would expect from a production plant. This is further broken down into specific financial and process data such as energy consumption and generation and polymer consumption at a site level. This provides a target for Yorkshire Water to continually improve upon.

Operational sludge tankering model

The Tankering Model is run daily and provides a schedule for each of the 27 tankers that are operated by Yorkshire Water to collect sewage sludge from approximately 400 export sites.

As Figure 6 demonstrates, the organisation can make up to 220 deliveries of sewage sludge each day. With this number of sites and vehicles there are 10 million potential scenarios for tanker movements that exist every day. Creating an optimal plan for movements with this many potential scenarios becomes increasingly complex when the availability of assets and vehicles is dynamic.

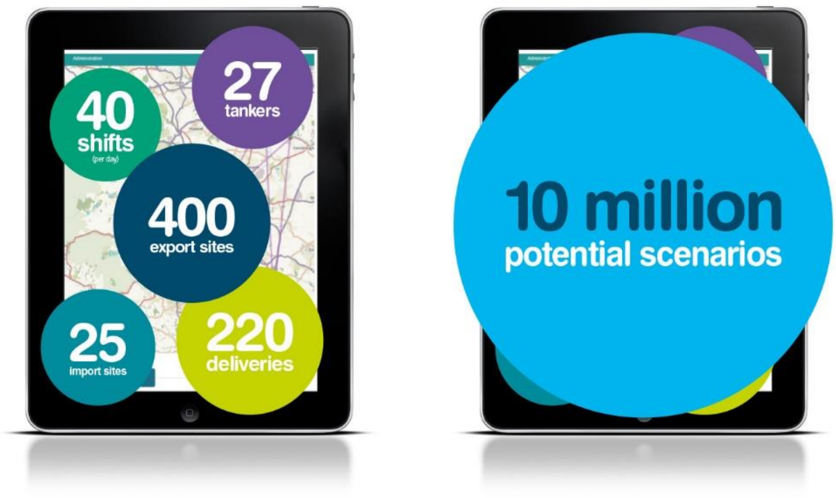


Figure 6: The complexity of sludge tankering operations for Yorkshire Water

The model takes into account factors such as mileage, sludge demand, driver, vehicle and plant availability and the cost to treat sludge at each site. The Sludge Tankering Model is designed to provide Yorkshire Water with a daily logistics plan, in this instance optimised for lowest operational expenditure.

Unlike traditional routing and scheduling tools, the flexibility of EO enables the objective function to be changed and the model could optimise for lowest mileage rather than lowest operational expenditure for example. In addition the model can be used to run scenarios and Yorkshire Water can understand the impact of decisions on fleet efficiency, treatment works compliance and energy generation.

Impact of the new prescriptive analytics technology

The Sludge Operational Model has had a significant impact on Yorkshire Water and sludge operations is now among the most advanced functions within Yorkshire Water in terms of integrated production planning utilizing big data. In addition to providing weekly production plans, by integrating data across the entire sludge process, bottlenecks have been quickly identified by the model, which has also suggested how to resolve these challenges. An early benefit of the model has been improved utilisation of existing assets that has resulted in elimination of the need to hire 3rd party equipment (notably mobile dewatering units) to alleviate local lack of capacity. This has resulted in considerable cost reduction. In addition the model has suggested actions to increase the efficiency of the recycling operation and opportunities to outperform the energy business plan.

Figure 7 shows an example of recent historic performance and future predicted performance for the metrics selected. A wide range of metrics is available on each dashboard.

Figure 7: Example of performance dashboards supporting the production plan approach

Whilst embedding business analytics was the key project, there have been ancillary changes to the culture of sludge management across the organisation. Everyone involved with the sludge process is able to see the impact of their decisions on the overall unit cost for sludge production. The single set of assumptions and single view of the data is an extremely powerful tool to manage business performance.

The Sludge Tankering Model has already been used to review and relocate a number of tankers to more efficient locations, significantly reducing the average miles per tonne of sludge.

While still in the commissioning phase, the strategic 'Source to Sea' model has impacted on Yorkshire Water's strategy, risk and assurance function. Understanding of risks and critical assets has been improved through use of the model to run 'what-if' scenarios. For example a scenario might be run to determine the impact of multiple critical assets being unavailable at a time of unusually high customer demand. This enables maintenance and investment strategies to be focused on the most critical assets.

Running 'what-if' scenarios through the strategic model also supports business continuity planning. Yorkshire Water can model single and multiple events across the entire value chain to test vulnerability and produces an optimised plan recovery plans. This ability to quantify the impact of extreme and rare events for which historical data is limited and provide assurance on how those events would be managed has produced some early tangible benefits, notability reduction in insurance premiums.

Summary and lessons learned

The benefits of the Yorkshire Water approach to using big data and prescriptive analytics modelling approach to managing its value chain outlines in this case study are:

- The ability to manage complexity; understanding which assumptions are most sensitive
- Making visible hidden costs
- Ensuring there is one single set of assumptions
- Increasing the speed of decision making and preventing "analysis paralysis".
- Understanding the bottlenecks within the process.
- Identification of performance relative to business planning
- Ability to constantly stretch performance and outperform the business plan
- Developing a clear understanding of what factors are responsible for delivering performance.

Key lessons learned from the Yorkshire Water case study are:

1. The quality and availability of data were a key enabler in embedding high quality business analytics into Yorkshire Water. However, where sufficient data were not available this was not a blocker and indeed benefit was derived by the modelling driving improvements to data capture and management.

2. Equally important to data were the cultural and process changes that enabled analytics to form part of business-as-usual processes.

3. Combining asset and financial data in a single view at any level, strategic through to operational, created a step change in the way Yorkshire Water managed their operations. Yorkshire Water is becoming centered around analytics rather than applications.

4. Centering the sludge processes around analytics has supported the 'production plant' approach and enabled sludge to be managed as a product along the full process chain. Yorkshire Water colleagues have engaged with the business change and through visualisation of data will be able to see the impact they have on the unit rate for sludge each day.

5. Business analytics can successfully be implemented into a large water utility to support a full spectrum of modelling horizons with a single view of the financial impact of all decisions.

6. Yorkshire Water's business analytics capability is providing the ability to not only understand but to predict the impact of industry changes and challenges from AMP6 and beyond. As the project fully delivers Yorkshire Water will be able to model, predict and improve their decision-making to meet the challenges of the future.

7. Yorkshire Water see this modelling capability as a step towards a fully integrated risk, cost and performance management system across the business, supported by modelling and analytics. While further progress needs to be made in integrating this modelling approach with key business functions, Yorkshire Water are confident that they will achieve their vision. The ultimate prize is that all decision makers understand our systemic risk profile, understand the

relationships between strategic and operational risks, understand the impact of uncertainty on our business plans and strategies, and bring that all together to optimise decision making and thus maximise our social, environmental and economic capital.

"For Yorkshire Water, the transition from experiential decisions to data driven decisions is underway. We are at the start of a journey but the benefits delivered thus far reinforce the need to continue on our path. The process of organisational knowledge revealed through projects of this nature is essential to realising sustainable benefits, underpinned by accurate data and a more systemic approach"

Stephen Herdlhofer in Institute of Water issue 185 (Spring 2015)

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