Technological requirements for water system asset management

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Abstract Asset management is a broad term and a relatively new paradigm to the water industry. This paper is intended to present an overview of the asset management approach that emerges as a managerial and technical framework for a water utility to effectively manage above and below ground assets. Based upon the lessons learned from some limited practices in the developed countries including UK, USA, Australia and New Zealand, the article is focused on elaborating the new concept of asset management and technological requirements to implement it for a water or wastewater organization. Following the brief overview, the elements of asset management are addressed along with the classified essential technology that enables water asset management and the potential cost savings resulting from an effective program. It concludes by looking into the challenges and barriers for adopting this innovative approach.

Keywords Asset management; decision support; lifecycle cost; optimization; sustainable infrastructure; water supply systems

Introduction

Human societies have been managing assets for years. The concept of asset management is widely used in many sectors, for instance, financial service institutions have long used the term to mean ‘getting the best return from their investments’. The best return is certainly the primary goal of profit-driven industry to implement the professional management of physical infrastructure, of data and information, of people, public image, reputation and other types of asset. Oil companies, power and water utilities and other industries have recognized that, despite all their cost-cuttings, reorganizations, new technology, productivity and quality initiatives, the picture is fragmented. Inefficiency and conflicting objectives, lack of coordination and missed opportunities are still plentiful. Thus water industry also turns to the asset management to improve its performance-for-cost.

The United Kingdom, Australia and New Zealand are pioneering such a holistic approach (Foley, 2005; Harlow, 2005; Lumber and Kirby, 2005; Smith, 2005). Industrial and political imperatives have forced a radical rethink on how to get better cost performance. Where the commercial or safety impact of failure is high, it is clearly vital to find the right combination of risk, performance and cost. Therefore, airlines, oil and gas, power and process industries have tended to develop, test and implement the most sophisticated reliability and performance optimization tools. However, an asset management program also needs to be well managed. Like managing any other innovative program, it is all about people: shared understanding, cross-functional collaboration and teamwork, problem-solving instead of repeated fire-fighting.

The relevant asset management disciplines and procedures have generally emerged from the highly structured or regulated industries, initially the armed forces, airlines and nuclear sectors but now rapidly spreading to power, water and other public utility sectors. Supply chain initiatives, quality management, total productive maintenance and reliability...
centered maintenance are examples. Their industrial usage has sometimes suffered from poor adaptation or implementation, but the underlying common sense (in properly managed introductions) is self-evident. More specifically, very limited research has been done for developing systematic asset management methods for water utilities. This is where asset management methods are needed to make sure that the jigsaw puzzle is complete and the bits fit together.

**Water asset management**

Asset management is defined as an integrative program that enables a utility to minimize the life-cycle costs of owning and operating infrastructure assets while maintaining required service levels and sustaining the infrastructure (Allbee, 2005; Causey, 2005). The definition uncovers the elements of technique and managerial requirements for successful implementation of asset management programs.

**Managerial requirements**

First of all, asset management is marked by its highly structured and integrated approach to identifying assets and getting to know them very well. Properly practiced, it involves all parts of an organization and entails a living set of asset performance goals. With a solid program, a plan is established for each asset from the very beginning; the resources used are measured on an asset-by-asset basis; and the results achieved are evaluated against the goal. Therefore, it equips managers with the asset-specific knowledge required to choose exactly the right assets, to optimize maintenance activities, and to refurbish and replace the selected assets at just the right times in a cost-effective manner.

**Technological requirements**

Asset management does require meeting technical requirements as follows.

*Minimize the costs of asset ownership.* Asset ownership accounts for the bulk of all costs including the capital cost, management cost, operational cost, social cost and risk cost over a lifecycle. Any significant reduction in such costs means major savings.

* Maintain required service levels.* While asset management reduces costs, it also improves reliability because it emphasizes detailed attention to assets. And because it emphasizes monitoring the condition of assets and their maintenance costs, resources can be better allocated to where they’re needed, and away from where they are not.

*Sustain the infrastructure.* This is the ultimate goal of asset management. A sound asset management program is both short-term (maintenance-oriented) and long-term (refurbishment and replacement-oriented). Its planning horizon is a long period, typically, 40 years or more. Planning within this time frame will yield the information required for utility governing bodies to understand infrastructure needs and to fund them properly.

**Technological tools**

Asset management about achieving the whole life optimal impact of every asset, which may be contributed to by all areas of the business: maintenance, operations, projects, safety, engineering and compliance, etc. It needs a set of disciplines, methods, procedures and technical tools to optimize the whole life business impact of costs, performance and risk exposure. The tools that pull every one together within an organization are classified into three categories: information management systems, hydraulic and water quality analysis tools, and decision-making support systems. They must be interactively applied to
facilitate the all stages and aspects of asset management from asset registering, condition monitoring, risk assessment, hydraulic and water quality analysis, performance evaluation and asset improvement decision.

**Information management**

The asset information includes its identification system, historical and current condition data. It requires the following information tools for effectively managing asset information.

**Asset register.** This may range from a simple coded equipment list to a fully-fledged technical information database with GIS diagrams, technical specifications and even video clips of the equipment and how it works. However simple or sophisticated, a comprehensive list of what the assets are, where they are and what they do is essential.

**Condition assessment and monitoring.** Core to the improvements of asset management is a shift towards condition-based activity, i.e. only doing work when the assets need it. Inspections, condition assessment and monitoring systems need to drive maintenance, renewals and modification decisions. However, there has been considerable over-selling of on-line condition monitoring. The asset management approach considers the ‘crude but cheap’ options of operator monitoring or visual inspection quite objectively in comparison to the high technology (and high cost) approaches.

**Performance and maintenance history data.** In the past, data gathering has been a weak link in the chain. There is usually no real incentive to provide the data (‘nobody seems to use it’). To break this vicious circle, asset management methods address the decision-making steps first (why do we need the data, and how would we use it?), and then identify what data is needed to support such decisions. Once the usage is clear, we have a much better chance of gathering the right data in the first place and maintaining enthusiasm for its continued collection.

The other modules of asset information management may include:

- **Resource management.** It enables managers to systematically categorize the materials, contractors, tools and facilities used for the business.
- **Safety, risk and environmental management.** It helps to meet the government and institutional compliance, and identify risk potential identification.
- **Project management.** It facilitates project planning, logistics, document management and change control.
- **Financial management.** Assists financial budgeting and reporting.

**Modeling and analysis**

The important part of water asset management is to evaluate the system performance, supply service level and what-if scenarios. This requires systematic analysis of the hydraulic and water quality characteristics. Hydraulic and water quality models have played an essential role in the analysis.

**Hydraulic model.** It serves as computer tool that allows engineers to replicate and predict the hydraulic behavior of a water supply system. The results form the basis for asset improvement decision and further analysis of water quality conditions.

**Water quality model.** It is able to simulate the transport and fate of any constituent throughout a water supply system. With the help of a water quality model, engineers
and decision makers can undertake the analysis of water quality characteristics for current and future conditions. It improves the understanding and insights into the water supply performance.

Although the computer models provide a good tool for systematically analyzing the hydraulic and water quality behavior, construction of accurate hydraulic and water quality model is not a hit-and-run task. It needs profound understanding of the system in the real world, and also the insights into network hydraulics.

Decision-making support system
It is business-based decision making that really makes the difference. There are three key stages as follows:

**Identify problems and opportunities.** The potential deficiency and system abnormality can be uncovered by undertaking the evaluation of key performance indicators, trend analysis, suggestion schemes and quality management activities. This requires effectively performing analysis at system level and linking the results with the information management system, e.g. finding a leakage area and quantifying the unaccounted for water or discovering the shortage of water supply for the planning horizon.

**Define feasible solutions.** Various systematic techniques including failure modes, effects analysis and root cause analysis, are available for investigating problems and identifying feasible solutions or improvements. More importantly, careful analysis current conditions, future demand and supply criteria will better prescribe the alternative solution space, which may often involve many conflict decision objectives.

**Search for tradeoff.** This can include cost, risk, performance evaluation of the possible options, and best optimization of the possible solutions. This brings us back to the starting point: what comprises the best combination of costs, risks and performance, with a whole-life view of the infrastructure? Asset management decision-making is rapidly expanding to include ‘what if?’ analysis, system performance simulators, cost/risk tradeoff optimizers, project lifecycle costing and investment prioritization tools. State-of-the-art decision-making technology is not limiting, but enabling this decision-making support process to take off, understanding and correct implementation that will determine the degree of success that can be achieved.

**Work scheduling.** A systematic and consistent scheduling system as improvement/expansion is vital to make sure that the right investment is made on the right assets at the right time with the right materials. This is the core of a work management system and another ‘must have’ tool.

One of practical examples is illustrated for using the state-of-the-art optimization-based design tools for improving a water system in the USA to meet the growing demand (Wu et al., 2005).

**Case study example**
This study has been conducted for the improvement of growing water system. It is expected to improve the system to meet 30% demand increasing a portion of the system, which is mainly supplied by an elevated tank. The main water sources are 20 wells and a reservoir. The goal is to divert sufficient water from these sources to the tank and to ensure the tank is refilled to an adequate level for the next day supply. It has proven to be a challenge for experienced engineers to identify a sound design solution by evaluating numerous...
scenarios. GA-based optimization design tool (Wu et al., 2002) is applied to assist the engineers to accomplish the improvement decision-making for the water system.

A comprehensive hydraulic analysis has been first undertaken to identify the problem of system supply inadequacy. This allows the optimization model to be established for the originally planned future demand (30% growth rate in 15 years) and also the phased-in future demand growth conditions. Optimization analysis has been conducted to reflect both conditions while meeting all the daily supply requirements. This state-of-the-art optimization modeling technology enables searching for not only the feasible solutions but also the optimal or cost effective solutions for each demand growth scenario. The optimal solutions from all the optimization runs are verified by running extended period simulations, which produce a complete analysis of the solution over a long period of supply to identify the systematic operating circle, and thus sustainable supply is ensured.

Most importantly, the improvement construction or working schedule is also identified by undertaking the optimization modeling analysis of the phased-in demand growth. A cost-effective solution for one phased-in demand growth represents the best priority of the construction of the new pipes to upgrade the system to meet the projected demand growth. With five phased-in demand growths, optimal improvement solutions are obtained for each of five phase-in demands. It enables indication of the priority of new pipe installation in 15 years. The set of the optimized solutions for all the phased-in demand growth represents the schedule of the capital improvement program to enhance the system capacity, in other words, which pipe and what size should be installed first in order to meet the growing demand. This is an important decision for budget allocation over a planning horizon to ensure which asset should be improved at what time.

**Challenges**

True asset management is a new way of managing and running utilities. As with anything new, challenges are expected. Below are some difficulties encountered by the pioneers during the process of implementing asset management.

*Fundamental change.* Asset management is not just another new program. It is a fundamental change in the way a utility operates. It does not have a defined ending point; it is a continual cycle of improvement, a permanent change. If an organization fails to recognize this, asset management is unlikely to achieve long-term success.

*Detailed measurement.* Asset management depends on continuous measurement, feedback, and updating of asset plans. The level of effort involved in allocating costs to specific assets, tracking these costs, assessing asset conditions, and updating asset plans and asset-related activities is far from trivial. Members of an organization may well resist these new activities if the benefits are unclear.

*Increased accountability.* Asset management shines a clear light of accountability on people involved in procurement decisions, IT systems, capital management, and O&M. In the O&M area especially, resource utilization is continuously monitored and areas of inefficiency are spotlighted. It is to be expected that this level of accountability may be resisted.

*Inter-function cooperation.* Asset management requires an unprecedented level of cooperation, on a day-to-day basis, among the major functions of an infrastructure agency. Engineering, planning, finance, O&M, and information systems must work...
closely together. Since many utilities tend to be vertically organized with well-developed 'silos' in some areas, this cooperation may be difficult to foster.

To many utility managers these barriers will sound quite familiar. Because of the depth, breadth, and permanence of a true asset management program, they may appear even more pronounced than when they were encountered in previous initiatives. Clearly, vigorous leadership and a high degree of institutional strength will be required to make asset management work. The benefits, though, are likely to be worth the effort:

- improved regulatory compliance;
- more meaningful financial reporting;
- increased system reliability;
- long-term system integrity;
- eligibility for infrastructure funding;
- significant cost savings.

**Conclusions**

Asset management is to bring the existing best practices together, and fill some of the remaining gaps. It aligns what we do to achieve business goals, and ensures that the component activities operate in harmony. It requires some sophisticated technical solutions but the most important element of all is the human one—shared understanding, motivation, trust and collaboration to find the best combined outcome, rather than local and short-term self-interest. Implementing and executing such an overall change and reformation is not easy. But, no one can afford to overlook it due to the globalized market that requires each of water organizations stay on the competitive edge in getting the best return on the investment while satisfying customer expectation. Some examples of implementing asset management programs are in the developed countries. The technical fundamentals should remain the same for developing countries although the managerial methods and framework may be adapted and customized to a local culture to ensure a successful implementation.

**References**


