INFRASTRUCTURE OPTIMIZATION: A STRUCTURED APPROACH TO UNDERSTANDING AND MANAGING RISK

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Each day asset managers face critical decisions about how best to use limited resources to maintain desired levels of service and protect their organizations from risk. When should the water plant be expanded to ensure delivery of sufficient capacity? Is it time to replace or line the 8-inch sewer pipe that may leak into the storm sewer in the oldest section of town? How often should maintenance be performed on back-up pumps at the sewage lift station?

Although Geographic Information Systems (GIS) and work order management systems provide valuable data about asset location, condition, maintenance history and work schedules, they don't answer the critical questions of **where and when** to act:

- **Where and when should a municipality spend money on asset maintenance versus rehabilitation and/or replacement (R&R)?**
- **In what order should maintenance and capital improvement projects be completed?**
- **How should budgetary constraints be balanced to maximize levels of service?**

To effectively prioritize maintenance and capital improvement expenditures, more municipalities are turning to a structured, quantitative approach, known as Infrastructure Optimization (IO). IO empowers asset managers to make the **"where and when"** decisions by evaluating, understanding, and managing risk.

In the context of asset management, risk is defined as an asset's probability of failure (PoF), multiplied by the consequence of failure (CoF), multiplied by a redundancy factor (R). The probability of failure is the likelihood that an asset will fail. The consequence of failure is the financial or health and human safety cost resulting from asset failure. The redundancy factor is a measure of actions taken to mitigate risk. The overall risk calculated by this equation is often used as a measure of criticality, and is referred to in the industry as business risk exposure (BRE). Those assets with the highest probability of failure, the highest consequence of failure, and the least amount of redundancy are those with the most critical BRE.

Probability of Failure (PoF) x Consequence of Failure (CoF) x Redundancy Factor = Business Risk Exposure (BRE)

In the IO Toolset, BRE provides the underlying framework for decision-making. To determine risk or BRE, IO users assign numerical values to a number of factors related to probability of failure, consequence of failure and redundancy. Then, users compare an asset's risks, its estimated remaining life (ERL), and the costs—both current and future—for maintenance and renewal. IO enables users to generate a multitude of "what-if" scenarios and choose the options that best allow them to manage their risks within their budget realities.

Developed by Woolpert, a leader in the infrastructure management industry, IO is a low-cost alternative to other products on the market. As an add-on to Esri® ArcGIS, IO does not require a costly expenditure for additional software, nor does it require hydraulic modeling. IO leverages a municipality's existing GIS data and extends the functionality of its current work and asset management system. It is compatible with Azteca Cityworks® and can be used for all types of assets—utilities, facilities, structures and equipment. It is designed for use by operators, planners and schedulers, maintenance professionals and engineers.

Before developing the IO Toolset, Woolpert's asset management consulting team conducted extensive research into risk management best practices and guidelines created by national and international entities. These included the New Zealand Asset Management Support (NAMS) organization, which develops and maintains the industry's leading International Infrastructure Management Manual (IIMM), and the Institute of Asset Management (IAM), the developers of PAS 55. Other best practices and guidelines incorporated into IO were from the US Environmental Protection Agency (EPA), the National Association of Clean Water Agencies (NACWA), the Water Environment Research Foundation (WERF), the American Water Works Association (AWWA), the American Public Works Association (APWA) and the Water Environment Federation (WEF).

Building on these best practices and guidelines, Woolpert developed an IO Toolset with the following four components:

1. Risk Assessment and Management
2. Baseline (Replacement Costs)
3. Optimized Decision-Making
4. Reporting

1. Risk Assessment and Management

The IO Toolset contains functionality to calculate a PoF score, a CoF score, and an overall BRE score tailored to a municipality's individual assets. This functionality requires the development and configuration of factors that contain unique weights and ratings. The following are example factors:

Probability of Failure (PoF):

- Asset Condition Rating: Excellent, Good, Fair, Poor or Failure Imminent
- Asset Performance Rating: Excellent, Good, Average or Poor
- Asset Reliability Rating: Excellent, Good, Average or Poor
- Maintenance History Rating: Well or Over (0 to 20%), Reasonable (0 to 10%), Average (0 to -5%), Poor; (0 to -20%) or Never Maintained (0 to -30%)

Consequence of Failure (CoF):

- Critical Facilities Rating: Residential, Residential/Light Commercial, Commercial or Hospital/Industrial
- Availability - Return to Service or Replacement Rating : <2 days, 2-5 days, 5-30 days, 1-2 months or >2 months
- Community Impact/Health Implication Rating: None, Low, Medium or High
- Size Rating: <8", 10-12", 15-24" or >24"

Once the PoF and CoF factors are defined by an organization's employees, the IO Toolset leverages data from the existing GIS and maintenance management system to quickly populate the information needed to calculate PoF and CoF values. From these values, the BRE scores are calculated. This information can be utilized in many ways. For quick visual reference, BRE scores can be color coded and mapped. Assets with the highest BRE scores appear in red on the map. Assets with the next highest BRE scores appear in orange, followed by those with lower scores in green and yellow. The mapping functionality as well as other spatial analysis capabilities help engineers and operators quickly evaluate areas of high risk that require attention.

For example, operators responsible for valve exercising programs could use the mapping function to prioritize the areas with the highest consequences of failure. This IO functionality allows them to isolate and exercise those valves that are most critical before addressing those with lower consequences of failure. Also as a result of the mapping function, users may choose to refocus their CCTV maintenance programs to investigate pipe assets that have higher-risk exposure scores, rather than continue their traditional CCTV cycle based on location and other non-risk approaches.

2. Baseline (Replacement Costs and Predicted Replacement Timeline)

With IO, users create a baseline for each asset by calculating its estimated remaining life (ERL). As part of the IO configuration, users identify from industry guidelines or holistic knowledge the Estimated Effective Life (EEL) of asset types. The AWWA provides a detailed discussion of calculating the estimated typical service lives of water pipes (average years of service) in its report, "Buried No Longer: Confronting America's Water Infrastructure Challenge."

IO uses EEL information to calculate the ERL of an asset. IO features three potential methods for calculating ERL: age of an asset, asset condition and the decay curve. The straight-line, aged-based method is a simple approach, using EEL and Date Installed to predict ERL. The condition-based approach is a more sophisticated method, utilizing condition scores along with EEL to more accurately predict ERL. Alternatively, a decay-based approach can be utilized with additional configuration; the user inputs the average decay rates of the selected assets. With the IO Toolset, users choose the method they prefer for determining the ERL.

The Toolset also calculates an asset's annual risk cost of ownership. This cost is defined as the probability of failure multiplied by the dollar consequence of failure during a given time period.

$$\frac{(\textit{PoF Percentage } x \textit{ Replacement Cost})}{\textit{ERL}} = \textit{Annual Risk Cost of Ownership}$$

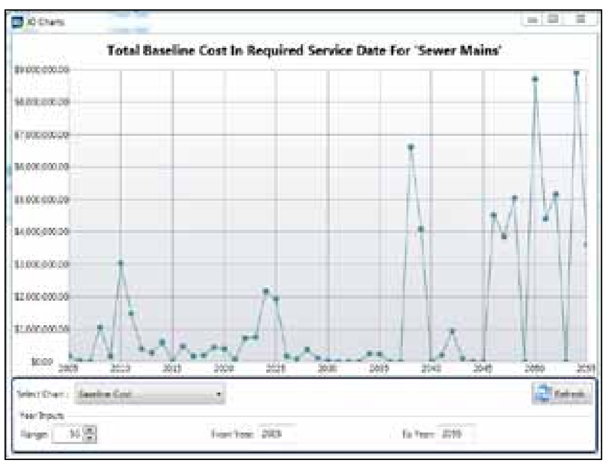
Using this simplistic method, users can generate failure probability into a level per-year risk cost. The Annual Risk Cost calculation allows users to quickly determine if the annual maintenance expenditures for an asset exceed its annual risk, as shown in the following example from the article, "Asset Management: A Risky Business!"

A city has a newer 250-foot, 8-inch sewer pipe between two manholes in a subdivision, and the probability of structural failure has been calculated at about 2% within the next 10 years. If a failure occurs, the direct cost, assuming replacement of the 250-foot segment, will be $30,000 (at $120 per foot). If a spill results from the failure, the "cost" of that category of spill has been calculated at $10,000. Therefore, the annual risk cost of ownership of this pipe segment is at most 2% (probability of failure in one year) times $40,000 (direct and community cost of failure), or $80.

$$(.02 \ x \ \$40{,}000) \div 10 \text{ years} = \$80/\text{year}$$

If the city is inspecting the 250-foot segment each year using CCTV, at a cost of $2 per foot, it will cost a total of $500. That means the city is paying $500 a year to prevent $80 worth of annual risk. Given the probability of failure and the annual risk cost, the CCTV inspections can be conducted every six years at an average cost of $83.33 a year to more cost-effectively manage the annual risk cost of $80.

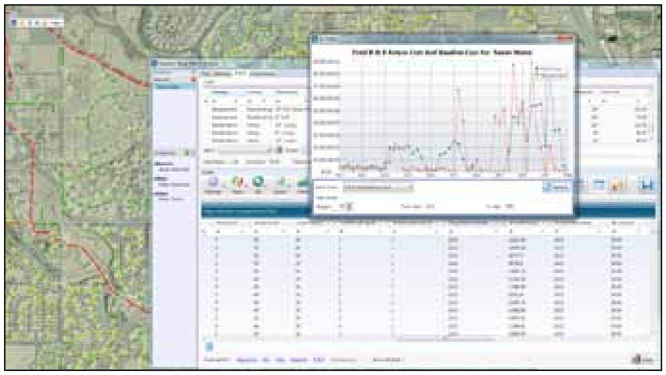
In accordance with guidelines from the IIMM, the IO Toolset includes a framework to populate and calculate standard asset replacement costs. Users can easily update these costs to reflect changes in current pricing, as well as changes anticipated in the future. With IO's graphing functionality, viewers can quickly compare costs over time for actions such as replacement of sewer mains from the year 2012 through 2050. Understanding baseline costs, predicted replacement timelines and annual risk costs is critical in evaluating where and when to maintain or renew assets.



3. Optimized Decision-Making

With risk clearly defined and baseline costs and predicted replacement timelines at hand, the IO Toolset allows users to generate a variety of what-if scenarios to optimize decision-making. During this process, users also consider their organization's defined maintenance and renewal strategies, which vary depending upon an organization's needs.

Using the IO advanced viewer, users pull together all necessary data in one place. Along with information from the risk and baseline components, viewers have the visual capabilities of GIS to explore other sources of data. For example, a user could activate a capital improvement layer from a street management division. The user could also view the work order history of an asset by utilizing the Cityworks toolbar.



The IO Toolset allows comparison of a number of variables. These include costs for asset maintenance, repair and replacement, now and in the future, and the cost impact of using alternative materials for a project. For example, a user may wish to compare the total cost of a wastewater pipe rehabilitation strategy to a pure asset replacement strategy; IO enables cost comparisons for various rehabilitation techniques, such as cured in place or pipe bursting, along with the potential prerequisite maintenance costs that would be incurred prior to performing the techniques. This foundation aids the user who is utilizing advanced asset failure risk and cost distribution models (these capabilities are planned in future IO releases). Users can also create projects and budgets in the Toolset, and track actual costs against those budgets. Again, projects can be mapped for quick visual reference.

4. Reporting

To enhance communications and create executive-level support, the IO reporting component produces content-rich graphs and charts that are exportable to Microsoft® Excel. The reporting functionality includes the following:

- Ad-hoc capabilities enabling a user to filter and group items in order to create reports for viewing or export to Excel
- Charts and graphs for ease of visualization
- Capital improvement project details, including renewal strategies and associated costs of the project
- A project dashboard to quickly navigate to key components of each project, such as cost per year, type and number of assets and residual accounts

Implementation of the IO Toolset

Municipalities that choose the IO Toolset are finding that implementation, in most cases, can be accomplished in fewer than 90 days at a lower cost than other alternatives. Implementation times may vary, depending upon the amount of time needed by the user to define risks and input risk ratings and baseline cost data. System requirements for the IO Toolset are Esri ArcGIS software 9.x or 10.0 and Microsoft .NET framework 4.0. Once a municipality selects the IO Toolset, Woolpert installs the product and provides training; knowledge transfer is provided throughout the project. Woolpert also works with the client to select asset types for a pilot project and helps determine the risk factors to be used for those assets. Additionally, Woolpert provides an IO support website for users and telephone support, if needed.

Summary

A growing number of cities are turning to Woolpert's IO Toolset for a structured approach to optimizing infrastructure asset management. The reasons are compelling.

- Helps asset managers make cost-effective decisions quickly and efficiently, and make better use of resources by understanding and managing risks.
- Makes use of existing GIS data and software, and allows cities to do more with the data they already have.
- Allows asset information to be easily viewed in one place—the IO viewer; asset managers no longer have to pull data from multiple sources.
- Is a low-cost, rapidly-deployed solution that allows a municipality to take complete ownership of inputting and updating data.

Perhaps most importantly, the IO Toolset is specifically configured to a community's assets. Municipal employees identify and define the risk factors, based on their knowledge of the city's assets, which allows for the most accurate assessment and management of risk.

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[1] Cityworks is a registered trademark of Azteca Systems, Inc.

[2] PAS 55:2008 standards comprise three areas: 1. definition of asset management terms; 2. requirements specification for good practice; and 3. guidance for the implementation of good practice.

[3] The American Water Works Association. "Buried No Longer: Confronting America's Water Infrastructure Challenge." http://www.awwa.org/Government/content.cfm?ItemNumber=1062

[4] Harlow, Ken, and Young, Kevin. "Asset Management: A Risky Business!" http://www.bcwaternews.com/assetmgt/AM13_Risk.pdf