

Case Studies: OPEX Savings Through Quantitative Risk-Based Inspection Optimization
David Joyal, Technical Lead – Pipeline Risk Modeling, JANA Corporation
Ken Oliphant, Executive Vice President and Chief Technology Officer, JANA Corporation

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David A. Joyal, M.A.Sc.
JANA Corporation
Aurora, Ontario, Canada

Ken E. Oliphant, Ph.D., P.Eng.
JANA Corporation
Aurora, Ontario, Canada

With sound risk models, risk-based optimization can be applied to integrity management activities to provide optimized strategies for balancing risk and cost. Case studies are presented for leak survey, valve inspection, and legacy cross bore inspection optimization. OPEX savings of 20-40% can be achieved while maintaining the same level of risk

Introduction

Integrity management activities such as inspections and leak surveys present a significant expense for pipeline operators. Operational expenses (OPEX) for typical maintenance and inspection programs can range from tens to upwards of one hundred million dollars for a medium-to-large gas distribution company. The process for inspection planning is often based on historical experience, or taken directly from industry standards. These approaches, while generally providing an acceptable level of confidence in the state of pipeline assets, often leave room for significant improvements in efficiency. A risk-based optimization using fully quantitative risk models presents an opportunity to significantly reduce OPEX spending while maintaining the same level of risk.

Two common approaches to risk-aware inspection planning are index models and fully quantitative risk models. The primary benefit of using fully quantitative risk models is that they provide an absolute dollar value of the risk present in a pipeline network. In contrast to the more common index models, this allows for a direct comparison between the amount spent on inspection activities and the risk benefit these activities offer.

For most assets, the likelihood of failure increases with time between inspections – i.e. the more time between inspections the greater the chance that something will go wrong. On the other hand, the average annual cost to inspect decreases as the time between inspection increases, so that if inspections occur every two years, the average cost is half what it would be if they took place every year. A risk-based optimization provides a way to find the balance between these competing costs to determine the lowest overall combination of risk + OPEX.

Defining Risk

Risk is defined as the Probability of Failure (PoF) multiplied by the Consequence of Failure (CoF) – i.e. how likely an asset is to fail or not work as intended and what are the potential costs if that happens. Many operation and maintenance activities are intended to reduce risk – either by reducing the likelihood of a failure (through maintenance, replacements, inspections, etc.) or the consequences of a failure (using control systems, emergency planning, leak surveying, etc.). Understanding the risk in the system is critical for any operator as it provides a basis for decisions about which activities are worth doing and at what frequency.

Why Fully Quantitative Models?

The benefit of using fully quantitative models to assess risk is that they offer a statistical basis for the calculation rather than relying on more subjective ranking or index models. Fully quantitative models allow

an operator to quantify, in absolute dollar terms, the risk benefit of an inspection. This means that the risk and OPEX spending can be compared directly to determine the dollar benefit (reduction in risk) for each dollar spent on inspection activities. The absolute dollar value of risk also allows for comparisons with other expenses throughout the business.

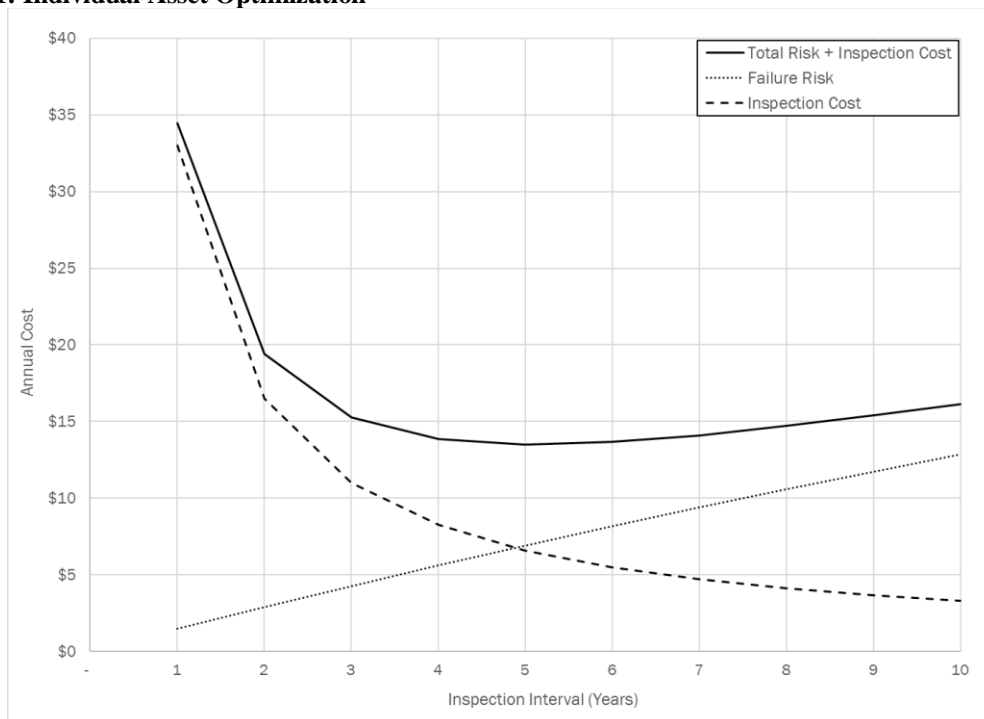
Consider the alternative approach; even if a current index model produces an appropriate ranking of assets by risk, the benefits of the inspections are unknown in absolute terms. Often inspections are planned by first setting a budget and then, based on the ranking, inspecting as many assets as possible within the budget. However, how do we determine if the budget is appropriate or if the inspection is worth conducting? The last \$100 spent may have reduced risk by \$10,000, in which case the spend should probably be higher, or only by \$1, meaning it would be more efficient to reduce OPEX spending. Without an absolute dollar value of risk, this is impossible to determine.

Optimizing Inspections

Given the potential inefficiencies outlined above, the natural next questions are how these inefficiencies can be eliminated and what benefits can be achieved by doing so. An optimization routine provides a method for determining the best possible inspection plan. The opportunity for significant OPEX savings can be found by identifying areas or assets which are currently being over-inspected from a risk perspective.

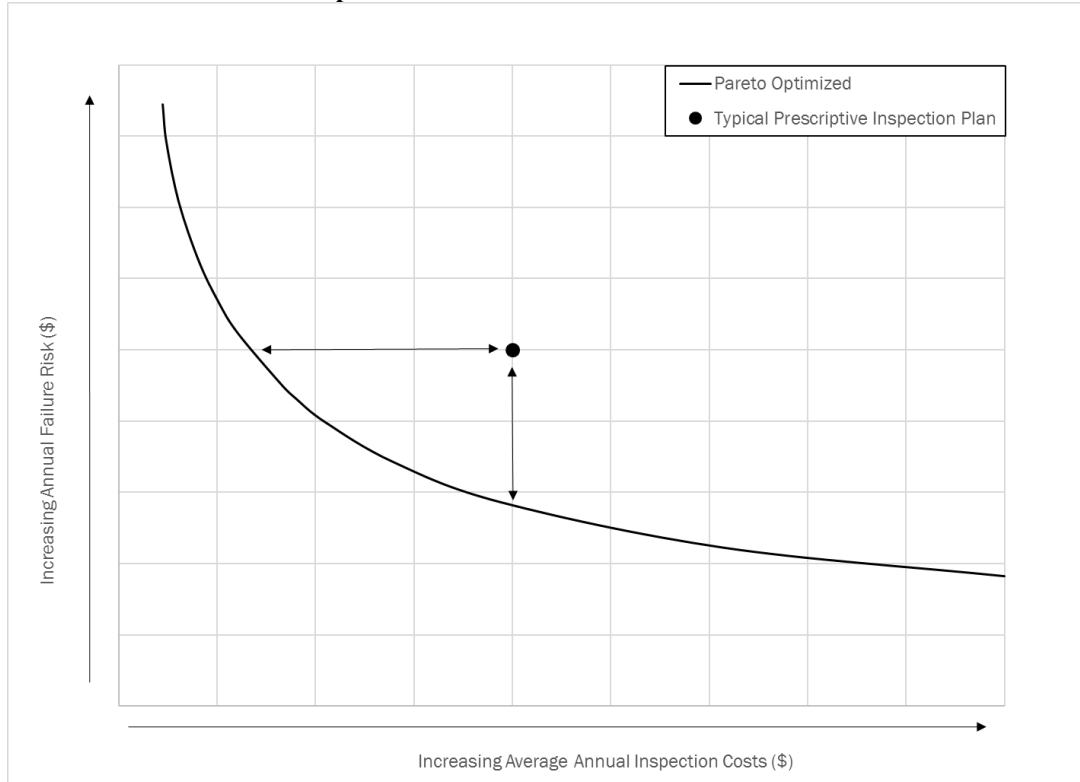
Many potential methods exist for optimizing an inspection program, the most straightforward of which involves minimizing the combination of OPEX spent on inspections and the risk associated with that inspection plan. **Figure 1** shows a sample chart illustrating how the optimal point can be found for an individual asset. As the time between inspections increases, the failure risk rises while the average annual inspection cost declines. The optimal point is where the Total Risk + Inspection Costs is at a minimum, which generally occurs where the annual inspection cost is equal to the annual failure risk – for this example an inspection interval of five years is optimal.

Figure 1: Individual Asset Optimization



By changing the desired balance between risk and inspection cost, a different optimal point can be found. For example, if we increase the weight given to risk, the optimal interval will be smaller as it becomes more important to remove the risk than to save on inspection costs. Whereas **Figure 1** shows the optimal interval for a single asset, the curved line in **Figure 2** represents all of these possible optimal plans, showing the corresponding total risk and cost. Where a plan falls on the chart depends on the weight given to risk relative to OPEX spending. The true optimum is where one dollar spent will reduce risk by one dollar.

Figure 2: Pareto Set of All Possible Optimal Plans



The dot on this chart represents a typical prescriptive inspection plan. These plans tend to be conservative as they group together assets with very different risk characteristics. For example, all valves in a city's downtown may be inspected on the same schedule, even if they are different materials or ages.

This chart shows that for the same inspection spending, risk can be reduced (moving the point down to the optimal line), or alternatively, while maintaining the same level of risk, substantial OPEX savings can be achieved (moving the point left to the optimal line). Overall inspection spending can typically be reduced by 20-40% by optimizing the inspections.

Case Studies

Three cases are provided to illustrate the application and benefit of a risk-based optimization for integrity management activities. Optimization programs are of course not limited to the activities discussed here and can be employed across entire networks of assets.

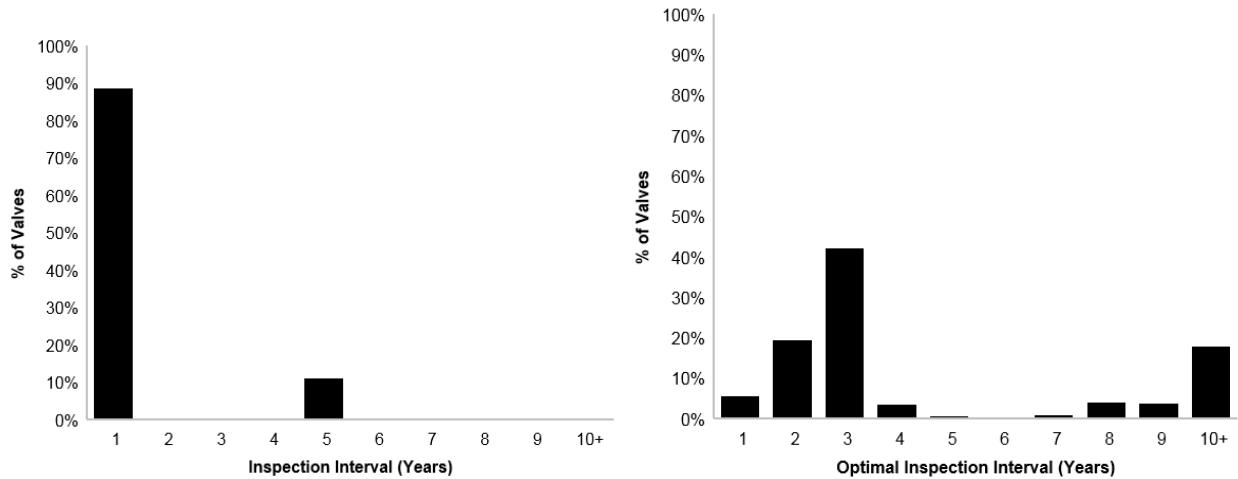
Case 1: Valve Inspection

Valve inspections are important as they help to ensure that the valves are accessible and in working order in case they are needed in emergency situations; they also check for leaks on the valve. Company A originally used a fixed interval for timing between inspections of isolation valves – valves in rural locations were inspected once every five years and all others were inspected every year. Notice that this means location was the only consideration in inspection timing – a 50-year-old steel valve would be inspected just as often as a brand-new plastic valve in the same area. As the risk of these two valves is almost certainly not the same, there is clearly room to improve the efficiency of inspections.

In this particular case, it was discovered that there were significant opportunities to increase the efficiency of the inspection program in place. Company A could keep the same level of risk while reducing their OPEX by over 30%, however at this point there would still be opportunity for further savings as this would result in a plan where risk was given four times the weight of inspection spending. The true optimum would increase the level of risk, but result in OPEX savings of over two thirds (66%) off the current budget.

A risk model was developed incorporating all relevant information about the asset, along with historical inspection data, to predict the risk associated with each valve for a given inspection interval. When combined with inspection costs provided by the operator, the optimal inspection interval was calculated for each valve, along with the corresponding risk. **Figure 3** shows the difference in inspection intervals between the original and the optimized plans.

Figure 3: Prescriptive vs. Optimal Valve Inspection Intervals



Case 2: Leak Survey

A leak survey is conducted to try to find and remove leaks before they can result in significant consequences. Unsurprisingly, the longer a leak is left unrepaired, the higher the chance that it will cause an accident. Therefore, increasing the time between leak surveys increases the risk in the system.

As with the valve inspections, Company B was using pre-determined intervals for conducting leak surveys. These intervals were slightly more sophisticated than a simple location basis, but opportunity still remained to more efficiently set inspection intervals. The optimal list of assets for inspections provided to Company B showed that with the same budget, risk exposure could be reduced by 40% or alternatively, OPEX savings of 40% could be realized with no change in risk.

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The risk model developed for the leak survey looked at the risk benefit of surveying – i.e. how much risk is reduced by completing the survey. By calculating how many leaks the survey was expected to find, along with the potential consequences these leaks could cause if they were not found, an overall risk benefit of the survey was determined.

The optimization seeks to maximize the risk benefit per dollar spend on surveying. For leak surveying there are some regulatory restrictions which limit the amount of time that is allowed between surveys. These constraints, as well as a maximum budget, are considered in the optimization routine. This case shows that even a constrained optimization can produce substantial efficiency improvements.

Case 3: Legacy Cross Bore Inspection Program

Legacy cross bore inspection programs have been initiated by many companies to remove cross bores from their network before they can result in significant consequences. Industry best practices recommend prioritizing these inspections on a risk basis. A risk-based optimization routine was developed for Company C to produce this prioritization.

The results of this project demonstrated the ability of a quantitative approach to deliver a practical risk-based foundation for prioritizing legacy cross bore inspections. Breaking the area down into inspection regions addressed many of the concerns Company C had around data availability and allowed confidence that inspections will be conducted efficiently.

Legacy cross-bore inspections can be optimized on a risk basis using an appropriate quantitative risk model. A risk-based inspection program was developed using the following model, which combines the probability of a cross bore (P_{CB}), the probability that cross bore is punctured (P_{CBP}) and the consequence associated with a puncture (C_P) for each asset:

$$Risk = P_{CB} \cdot P_{CBP} \cdot C_P$$

The probability of a cross bore is driven by asset characteristics such as the installation method, installation date, material etc. The probability of puncture depends on the sewer type and size, call-before-you-clear programs, etc. The consequence is largely based on location, with larger more populated buildings having a higher consequence. Together these form a risk metric used to optimally plan inspections.

In addition to a prioritized list of assets for inspection, assets were pooled into inspection regions which were also prioritized based on risk. Planning inspections by area presents the opportunity to reduce overhead and improve the per-asset inspection cost as all inspections in the area can be done at the same time with the same team. Planning by area also provides a way to deal with assets that are missing the data needed to do a risk assessment – if the asset is in a high-risk area, it will be inspected along with the other high-risk assets.

Additional Savings Opportunities

While optimizing the inspection interval or replacement timing for an individual asset is fairly straightforward, there are also other possible factors which can be included in an optimization to achieve additional OPEX savings when considering a network of assets.

Each of the previous cases focuses on optimizing a single inspection type (Valves, Leak Survey, Cross Bores). The potential also exists to use a risk-based approach to optimize a combination of integrity management activities.

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For example, assume the optimal inspection interval for an asset is currently two years. If the asset is then replaced, the optimal interval may be reduced to eight years as it is new and less likely to have problems. The trade-off between the replacement and inspection costs, as well as the risk implications, can be balanced by using a risk-based approach to determine the optimal timing of the replacements and corresponding changes to inspection intervals.

When combining the optimization of inspection programs, additional OPEX savings may also be realized from opportunistic activities. Nearby valves may be inspected during a main replacement, or a leak survey of the area may be conducted while performing valve inspections, at limited additional cost on top of the original activity expense.

All of these factors can be considered in a sophisticated optimization program.

Conclusion

Risk-based optimization of pipeline integrity management activities presents the opportunity to significantly increase the efficiency of a typical inspection program. A fully quantitative risk model allows an absolute dollar value of risk to be calculated to determine the optimal timing of inspection or surveying activities to maximize the risk reduction benefit for each dollar spent.

The three cases discussed demonstrate the flexibility and broad scope of the risk-based inspection optimization, with each case showing a slightly different approach. In each case, the efficiency of the inspection plan was improved with significant opportunity identified for risk reduction, OPEX savings or both. Based on the cases presented, typical OPEX savings of 20-40% can be realized by implementing a risk-based inspection optimization program.