Integrity Budget Optimization Through Financial Quantification of Risk Results

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Abstract

The aging infrastructure and increasing regulatory requirements have heightened the need for substantial investment in maintaining pipeline system integrity. Consequently, integrity budgets must compete with other financial demands, including growth, expansion, innovation, and strategic acquisitions. It is essential to demonstrate that the integrity investment request is justified and optimized.

This paper presents a financial investment methodology that leverages risk-based likelihood and consequence values, converting them into financial metrics to assist in capital allocation and decision-making. This approach evaluates the economic viability of investments by comparing the costs of preventative measures against potential future failure costs in present-day terms. Additionally, it identifies the year when remediation or preventative investments become economically viable.

We illustrate this methodology through a case study for an operator, evaluating whether it is more cost-effective to repair an existing pipeline to support production growth or to construct a new pipeline section at a significant expense. The study involved simulating various operating scenarios and inputs related to revenue, operating costs, maintenance, and repair costs to calculate net cash flow and internal rate of return. By considering the net present value of all investments and benefits, the study determines the economic viability of different scenarios and provides a final recommendation on the repair versus replacement decision.

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Introduction

Pipeline integrity budget planning prioritizes public safety. Additionally, these budgets must demonstrate optimization for maximum effectiveness and proper fund allocation because they compete for capital against other investment priorities. They must demonstrate that they have been optimized to ensure both appropriate fund allocation and maximum effectiveness, balancing the maintenance of operability with profitability. Spending justifications in integrity budgets often include technical reasons based on best practices and regulations. However, they may fall short in proving the economic viability of the investments.

The In-Line Inspection (ILI) tools are progressively improving the ability to collect accurate information on pipeline threats, making it possible to estimate the risk to pipelines using quantitative methodologies commonly known as Quantitative Risk Assessment (QRA) or Probabilistic Risk Assessment (PRA).

While QRA and PRA are excellent tools for estimating the likelihood and consequences of pipeline failures, translating these risk assessment results into financial metrics is challenging for integrity professionals. The lack of financial metrics in the integrity budgets makes it difficult for capital allocation decision-makers to evaluate and justify integrity spending demands against competing investment priorities.

The methodology presented in this paper bridges the gap between integrity risk assessments and economic decision-making. It ensures that pipeline integrity investment requests are both effective and economically viable.

Economic Viability of Integrity Investments

All organizations have limited funds available for investment. As a result, and in each capital budget cycle, management is tasked with allocating such funds between individual investments to maximize profitability within the context of appropriate risk as well as ethical and prudent business practices. Accordingly, integrity departments must demonstrate that integrity investments are essential, that funds are allocated efficiently, and that investments will yield long-term financial benefits. Integrity planning must also consider the following factors, the impacts of which are often difficult to quantify from a financial perspective:

- Public Safety: As already discussed, public safety is a priority by ensuring integrity investing prevents or reduces the probability of leaks, ruptures, or explosions.
- Environmental Protection: Pipeline operators believe in sustainability, and therefore, integrity budgets try to ensure the appropriate investment will prevent leaks and spills, safeguard ecosystems, and demonstrate compliance with all environmental regulations.

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- Regulatory Compliance: Regulatory requirements, prescribed in the federal and provincial codes or through best practices incorporated in the regulations, require repairs and remediation of discovered threats.
- Operational Efficiency: Optimal pipeline operation is essential to ensuring the safe and timely delivery of committed throughput.

Investment/Spending Prioritization

As noted above, in the capital budgeting process, senior leaders and budget decision-makers must compare disparate investment opportunities to select and prioritize those that will result in the highest profitability within the context of risk, ethics, and prudent business practice. Such investment comparison often utilizes common financial metrics to objectively evaluate and rank investment returns. When investment proposals include only technical justification and exclude financial metrics, budget decision-makers find it very hard to compare them against other investment opportunities. Such proposals risk being rejected or restricted in funding.

Therefore, it is prudent to present integrity budgets in a manner that facilitates the comparison of the budgetary ask with other investment requests through the use of financial metrics. For example, in the absence of appropriate financial metrics, an integrity budget request for $19 million to perform Four EMAT runs (240 km total), Six MFL runs (328 km total), and 41 (expected) digs to address seven high-risk, high-consequence pipelines is difficult to compare against four other investment requests with clear financial metrics such as:

- Growth Project: $50 million; IRR 22%.
- Corporate project; $10 million; savings $2 million/yr.
- Expansion Project; $4 million IRR 6%.
- Acquisition; $250 million; IRR 15%

Unfortunately, the nature of integrity activities, being risk assessment and consequence avoidance, does not lend itself easily to financial evaluation. Accordingly, the presentation of integrity budgetary asks tends to be more qualitative or technical in nature. As a result, a lack of understanding and difficulty in comparing integrity budget requests with other investments can lead to pushbacks, budgetary reduction pressure, or demands for additional justifications. In a worst-case scenario, integrity investment reductions driven by a lack of understanding or comparability could adversely affect an organization.

Financial Quantification of Risk Results

In the context of pipeline integrity, risk could be defined as a compound measure, either qualitative or quantitative, of the frequency and severity of an adverse effect (1) or as a measure of potential loss in terms of both the incident probability (likelihood) of occurrence and the magnitude of the consequences (2). Essentially, risk is the combination of the likelihood of failure and the consequence of failure.

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Risk = Likelihood of Failure × Consequence of Failure

Where,

> Likelihood of Failure: The chance of something happening, whether defined, measured, or determined objectively or subjectively, qualitatively or quantitatively, and described using general terms or mathematically (such as a probability or frequency over a given period).
>
> Consequence of Failure: Impact that a pipeline failure could have on the public, employees, property, the environment, or organizational objectives

The current state-of-the-art risk assessment methodologies, QRA and PRA, quantify the likelihood of failure due to threats and the consequence of a failure event. Additionally, comprehensive risk assessment methodologies allow insights into the risk drivers and help identify the effectiveness of Preventative and Mitigation Measures.

Financial Investment Methodology

The financial investment methodology translates risk assessment results into financial metrics by applying a financial investment methodology approach. The financial quantification of risk results enables financial executives and senior leaders to better understand the implications of risk assessment.

The financial investment methodology has four elements:

1. Investment: Cost of investment required in a project.
2. Expected cash inflows (or avoided cash outflows): How much cash is expected to be gained or cash outflow that will be avoided due to an investment.
3. Timeframe of inflows/outflows: The period over which the investments and cash inflow/outflow will occur, as the value of future money will need to be considered.
4. Investment hurdle rate of return (discount rate) (IRR): This rate is used to discount future cash flows to their present value. It often reflects the cost of capital or the required rate of return, i.e., the return expected from an investment to make it viable.

Net Present Value (NPV)

The NPV value is a financial metric used to evaluate an investment. It compares the net benefit derived from an investment (in current dollars) in the form of the present value of future cash inflows or avoided outflows to the cost of that investment (in current dollars).

- +Ve NPV: Indicates that the investment is expected to generate more value than its cost, making it a potentially profitable investment, i.e., the benefit is greater than the cost

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- -Ve NPV: Indicates that the investment is expected to generate less value than its cost, indicating it may not be a good investment or not an economic investment

The information from the four elements discussed in the financial investment methodology is used to calculate an investment's NPV. Figure 1 illustrates the elements of financial investment methodology.

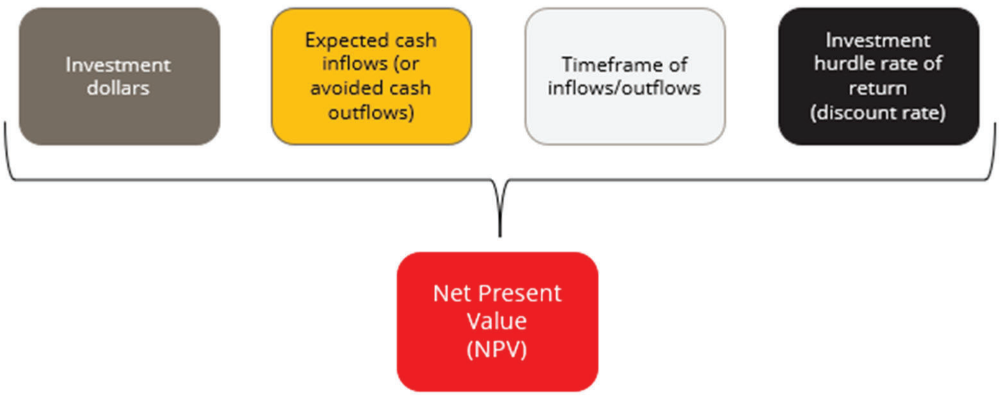

Figure 1. Elements of financial investment methodology

Applying the financial investment methodology in the context of pipeline integrity investing will translate to the following:

1. Investment: What is the cost to prevent a future failure (repair, mitigation, lost revenue due to outage, etc.)?
2. Expected cash inflows (or avoided cash outflows): What is the cost if a failure occurs that would be avoided by the investment (Repair, lost product, spill response)?
3. Timeframe of inflows/outflows: Based on the current state and estimated degradation over time, when will a failure potentially occur?
4. IRR/Discount Rate: In the context of pipelines, the IRR could reflect the acceptable level of risk on a particular pipeline or pipeline network. The IRR could depend on the product type, location of the pipeline, and how critical the optimum throughput from a pipeline is.

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Figure 2 illustrates the application of financial investment methodology to pipeline integrity investing.

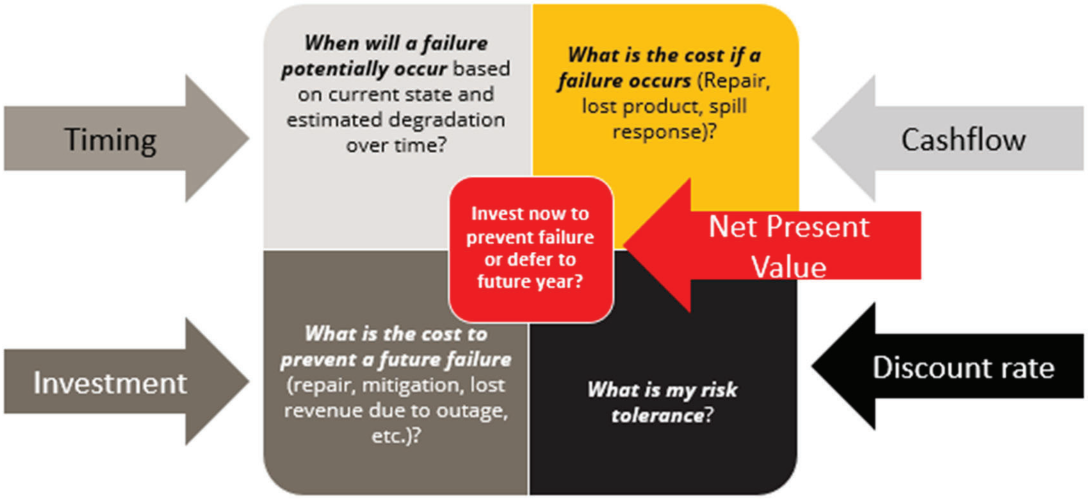

Figure 2. Applied financial investment methodology

Degradation Curves from Risk Results

Calculating the timing of a failure event requires complex calculations that involve assessing the degradation curves, or the probability of failure for each year of operation, using the available threat data. As illustrated in Figure 3, the degradation curve is then used to determine the year in which a failure is more likely than not (50%) or the "mean failure year." This assessment is performed on every segment, and the length of the segment can be varied appropriately.

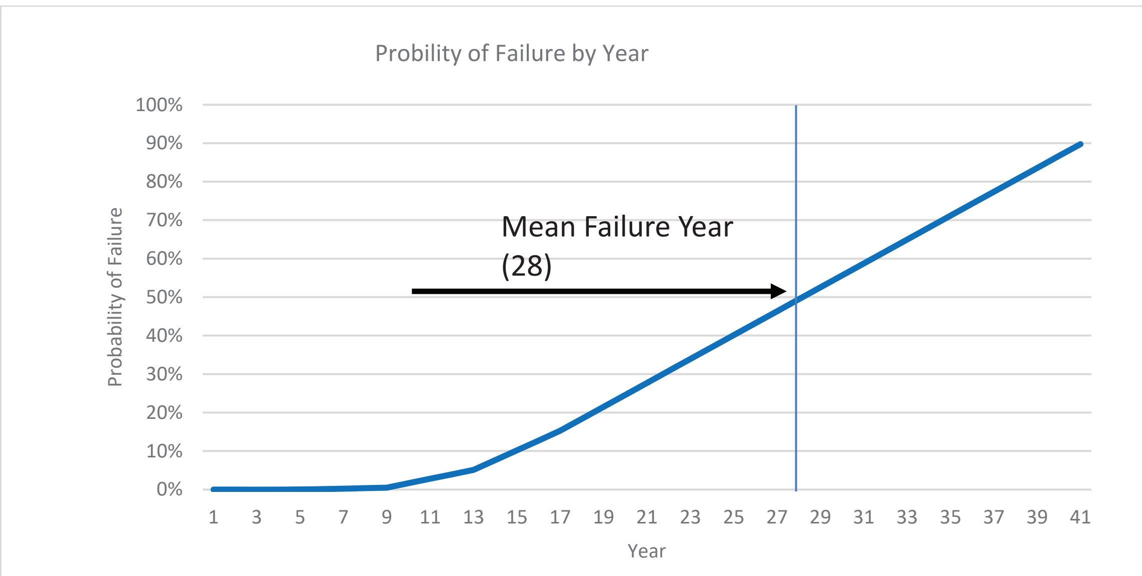

Figure 3. Threat degradation curve

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Quantification of risk results involves assessing the risk (likelihood and consequence values) and applying the financial investment methodology to the risk results to generate financial metrics to support capital allocation and decision-making. The elements in the risk results quantification are:

- Algorithm: Quantitative algorithms for probability of failure; consequence of failure; and Repair and Outage Costs
- Discount Rate/IRR: Appropriate risk threshold (low/medium/high)
- Segment Length: 12m (Ability to aggregate to pipeline level)
- Assumptions: A segment is run to failure without intervention based on Dynamic Risk's quantitative risk algorithms, and each segment failure is mutually exclusive

The mean failure year values from the degradation curves are used to calculate an NPV on every pipeline segment. Figure 4 illustrates the NPV methodology, where an inflation rate is applied to increase the cost of failure (obtained from the risk assessment) to the mean failure year. A discount rate is then applied to the calculated failure cost at the mean failure year to get the present value of the cost of failure. The discount rate used for the segment will depend on whether the section has a low, mid, or high-risk tolerance. The calculations provide the failure cost avoided, which is then compared against the cost of prevention (in current dollars) to obtain the NPV value. A +Ve NPV will mean the avoided cost of failure is higher than the prevention cost; therefore, investing in prevention today is an economically sound investment. A -VE NPV means the cost of prevention is higher than the failure cost, which means no investment is currently viable.

Figure 4. NPV methodology

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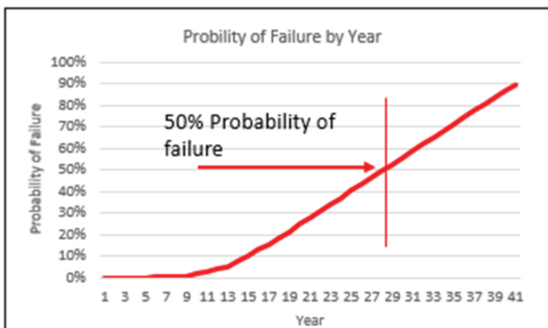
NPV Calculations Example

An example of the NPV calculation is provided to explain the methodology further. Figure 5 illustrates the NPV calculation. The cost of prevention is fixed at $0.988 million. The mean failure for a pipeline segment is 28 years. After increasing by an inflation rate of 3%, the cost of failure in the 28th year increased to $13.853 million. Three calculations are performed with discount rates of 9%, 18%, and 27% to calculate the present value of the future cost of failure. A lower discount rate is used when the risk tolerance is low, whereas a higher discount rate is used when the risk tolerance is high. As illustrated, the present value of the future cost of failure using a discount rate of 9% is $1.252 million. Since the cost of prevention is only $0.988 million, the NPV ($1.252 – $0.988) is positive. Therefore, if a discount rate of 9% is warranted, investing in prevention today is a viable investment. Meanwhile, suppose a discount rate of 18% or 27% is appropriate. In that case, the NPV will be negative, i.e., ($0.137-$0.988) and (0.018-0.988), respectively, meaning that currently, an investment in prevention measures is not an economically sound decision with either an 18% or 27% discount rate.



Key Assumptions	
Inflation	3%
Mean failure year	28
Cost of failure*	$6.1 million
Cost of Prevention*	$0.988 million
** In current dollars*	

Risk tolerance	Discount rate	Future cost of failure (future dollars)	PV of future cost of failure (current dollars)	Cost of Prevention (current dollars)	NPV
Low	9%	13,853	1,252	988	263
Mid	18%	13,853	137	988	(851)
High	27%	13,853	18	988	(970)

Figure 5. NPV Calculations example

The above NPV example can be translated into a budget request: "I want to invest $988k today in prevention for a high-risk, high-consequence segment, which is justified by a Net Present Value of $263k, using a discount rate of 9%”. In the absence of this methodology, this budget request may have been something similar to the following: “I want to invest $988k today to remediate a 38% SCC feature in a high-risk, high-consequence segment, as it shows large POE, resulting in high-risk scores, placing the pipeline in the red portion of the risk matrix (Score > 4)".

For the 27% or 18% discount rate scenario, NPV calculation for a future date can identify the optimal date for investing in preventative measures. Similarly, the Financial Investment Methodology can further be used to develop annual preventative maintenance planning budgets by assessing the year in which the NPV for each affected pipeline segment becomes positive. This is calculated by determining the present value of the future cashflow at every year in the evaluation and comparing it to the cost of prevention in that year, escalated by inflation as shown in Figure 6.

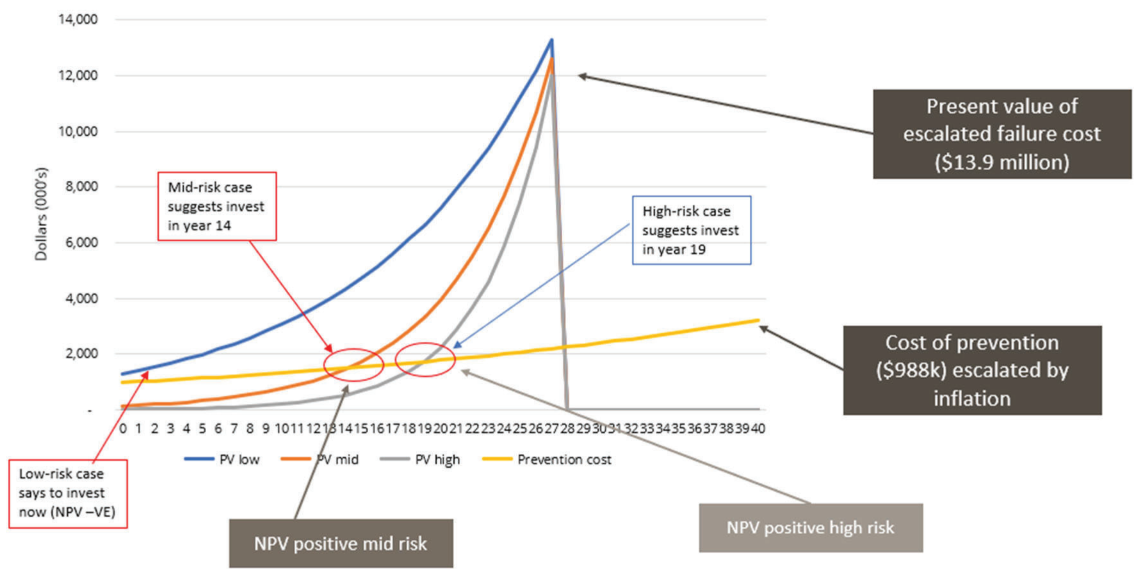


Figure 6. Optimizing integrity budgets

Benefits of Financial Quantification of Risk Results

Using financial quantification of risk results provides an objective methodology for modelling scenarios and optimizing spending on pipeline integrity management. This ensures that resources are directed to the most crucial areas, resulting in cost savings and addressing the most significant risks. Some of the benefits are listed below:

- Optimize: Pigging (re-inspection intervals and tool type) and Digging
- Reevaluate the economic viability of an investment: e.g., Recoat project, Geo-technical mitigation
- Alternate Repair Strategy: e.g., a large number of digs versus lower operating pressure
- Repair versus replace decisions
- Long-term Investment decision: e.g., investment in developing an ILI tool or participating in a joint industry project

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Case Study

A pipeline operator expected a significant increase in throughput demand due to forecasted production growth in regions. Therefore, the following assessment was performed to evaluate whether it is more economical to repair the existing line to allow operation at Maximum Operating Pressure (MOP) to accommodate production growth or to build a new pipeline section at a substantial cost. Some of the attributes for the pipeline are listed below:

- Pipeline Length: >50 km
- Product: Oil pipeline
- Pipeline age: ~50 years
- Currently operating pressure: ~40% of design operating pressure
- Issues:
  - ~10% of the pipe lengths have cracks and/or internal corrosion, impeding the ability to increase pressure without significant repair costs
  - Currently utilizing high-cost drag reduction agent (DRA) to increase overall throughput

Net annual cashflows for the existing and replacement pipelines were developed to facilitate comparison of net present value and internal rates of return calculations. Table 1 lists the major inputs and assumptions used in the repair versus replace assessment:

Table 1. Inputs and Assumptions (Data Categories)

Category	Source
Revenue	Operator provided (Function of inputs such as terrif, throughput, capacity scenario's)
Operating Costs	Operator provided
Maintenance, repair, and inspection costs	Operator provided
Discount rate	12% (Assumed after discussion with the operator and review of risk results)
Inflation	Assumed (per current inflation rates)
DRA requirements and resulting capacity levels at various operating pressures	Operator provided

In addition to the above assumptions, the existing line's net annual cashflows included the cost and timing of preventative maintenance activities using the Financial Investment Methodology described above under three operating pressure scenarios: Maximum Operating Pressure (MOP), 80% MOP, and 40% MOP. The probability of failure curves, repair, and consequence costs were developed on a 12m segment basis at each operating pressure scenario, utilizing locational attributes, the latest

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inspection data, and applying quantitative algorithms. The timing and amount of preventative maintenance for each 12m segment were calculated using the Financial Investment Methodology, with such amounts aggregated to create an annual cash expenditure requirement that was included in the net annual cashflows. Changes in pressure impacted both the probability of failure curves and the amount of DRA required to meet various capacity levels.

The assessment results showed that repairing the existing line is more economical than replacing it under all three pressure scenarios. Sample results from this type of financial assessment are shown in Figure 7.

MOP

Economic output	Existing Line	New Build
Total NPV of cashflow 20 years	80,142,276	(6,680,189)
PV of terminal value	9,329,356	9,609,283
Total value	89,471,633	2,929,094
IRR 20 year	66.3%	10.8%
IRR 40 year	66.3%	12.9%

80% MOP

Economic output	Existing Line	New Build
Total NPV of cashflow 20 years	80,116,280	(6,680,189)
PV of terminal value	9,339,924	9,609,283
Total value	89,456,204	2,929,094
IRR 20 year	66.2%	10.8%
IRR 40 year	66.2%	12.9%

40% MOP

Economic output	Existing Line	New Build
Total NPV of cashflow 20 years	77,739,121	(6,680,189)
PV of terminal value	9,103,255	9,609,283
Total value	86,842,376	2,929,094
IRR 20 year	64.2%	10.8%
IRR 40 year	64.2%	12.9%

Figure 7. Example: repair versus replace assessment results

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Conclusions

Pipeline integrity management programs generate extensive data on the risks and consequences of failure. Yet, they may fail to offer the financial context to compare and make informed capital allocation decisions. This limitation can lead to significant challenges in obtaining the necessary integrity budgets, as these must always compete with other capital expenditure priorities.

Quantifying risk metrics and applying financial investment methodology provides a clear, objective basis for decision-making that resonates with financial executives. As a result, it optimizes short-term and long-term integrity spending and facilitates effective capital planning and allocation across the organization.

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