PINNACLE EXECUTIVE BRIEF

Quantitative Reliability Optimization (QRO)

We're introducing the next evolution of reliability - Quantitative Reliability Optimization. Join us as we transform how the world approaches reliability.

TABLE OF CONTENTS

02 Introduction: The Next Evolution of Data-Driven Reliability

02 The Economics at Stake

03 How We Got Here

03 The Current Challenges to How We Ensure Reliability

05 QRO Simplifies Reliability Modeling and Unlocks the Next Level of Reliability Performance

08 Join Us on This Journey to Make the World More Reliable

Introduction: The Next Evolution of Data-Driven Reliability

When it comes to the basic needs of modern living—commodities—we expect them to be available when required and sold at reasonable prices. For this to happen, complex industrial facilities must be reliable. Over the years, the definition of reliability has varied based on the context and people applying the term. When talking at a facility, business, or industry level, *reliable* has meant something different than when talking about a specific asset or piece of equipment within the facility. Pinnacle defines *reliability* as the ability to operate when desired.

As the world's largest industries place an even bigger emphasis on lowering costs while sustaining operations, companies strive to ensure that reliability and maintenance investments are in the right places and result in increased performance. To achieve the optimal balance between maximizing the time a facility is able to operate and the investment needed to achieve that ideal run time, facilities should use a new approach to reliability called Quantitative Reliability Optimization (QRO). QRO represents the next leap forward in reliability modeling and will help ensure industrial facilities maximize their investments while improving their reliability.

In the following executive brief, Pinnacle will describe the economics of reliability that are at stake, how we got to the current state of reliability, today's challenges, and how QRO will address those challenges.

Pinnacle defines reliability as the ability to operate when desired.

The Economics at Stake

In the fourth quarter of 2020, Pinnacle published the first issue of *The Economics of Reliability*, a quarterly report that quantifies the impact of reliability on various industries. The first report focused on the refining industry and provided an example of the financial impact that optimized reliability programs can have on global industries.

In the report, Pinnacle found that complex operating companies around the world spend roughly $500 billion annually on reliability, $50 billion of which is spent by refiners. The analysis showed that a 10% improvement in optimized reliability spending for global refiners is easily attainable and would translate to a savings of $5 billion across the industry.

While this report focused on refining, this analysis can be applied to other complex processing industries such as chemicals, mining, and water and wastewater treatment. When the estimated savings from the refining industry are translated to other industries, there's an opportunity for industrial facilities to collectively save hundreds of billions of dollars annually through optimized reliability programs. To realize this savings, we must improve our approach to managing reliability.

How We Got Here

Fifty years ago, the industrial age gave way to the age of lean manufacturing. Mining operations, power generation facilities, chemical plants, refineries and other large, complex processing facilities began shifting their focus towards reducing downtime while optimizing associated reliability spend. During those decades, dozens of programs were created and standardized to drive towards improved reliability. Reliability Centered Maintenance (RCM), Mechanical Integrity (MI), Risk-Based Inspection (RBI), Spare Parts Optimization, Failure Modes and Effects Analysis (FMEA), Root Cause Analysis (RCA), Turnaround Optimization, Process Hazards Analysis (PHA), and Advanced Condition Monitoring were all models launched during this era. In refining, for example, the reliability (operating when desired) across the segment increased by nearly 15% from 1980 to 2010. While each of these models added notable value, the impacts of their application have taken years to realize.

In refining, for example, the reliability across the segment increased by nearly 15% from 1980 to 2010. While each of these models added notable value, the impacts of their application have taken years to realize.

The Current Challenges to How We Ensure Reliability

Nearly half a century of analyzing assets and making improvements in reliability has propelled some companies to the top of their industry. However, the improvements seen from the models listed above have leveled off over the past decade and companies are beginning to invest billions of dollars in initiatives that will help them achieve the next level of reliability. Many of these investments are focused on better utilization of standardized large-scale programs and advanced data analytics. The goal of these new reliability initiatives is to provide more quantitative insights so that facility leaders and reliability professionals can make objective decisions about how to invest and improve facility performance.
To successfully apply data-driven models, we must recognize that there are gaps in traditional models that are preventing our ability to recognize a return on investment.

These gaps fall into three categories:

1. Analyses focused on individual assets are failing to optimize the system.

Most traditional models and analyses assess the reliability or risk of individual pieces of equipment, specific functions of that equipment, or specific damage modes. While this insight is helpful when evaluating the reliability of a single asset, these analyses often produce limited, subjective information, making it more difficult for facility leaders to quantify how changes in the performance of one asset affects the reliability of their entire facility. Additionally, facility leaders struggle to compare the results of their investments because they only have basic rules of thumb to quantify their impact on the system. As a result, facilities often waste money on initiatives that do not actually improve the reliability of their system, and in some cases, increase the number of failures.

2. Hyper-conservative risk models increase costs without improving performance.

Traditional models have been highly dependent on empirical formulas, industry standards, and user inputs. While these have formed a solid foundation for analysis, these approaches are highly simplified. This oversimplification has introduced substantial uncertainty and therefore inherent risk. To account for this, models and approaches have been designed to be conservative, which has resulted in projected failure rates and quantified risk levels that are often an order of magnitude higher than actual. While this does drive action to reduce risk, it precludes comparison of risk across a system, risks in various assets, and investment versus return. It also results in overspending to address overestimated issues.

3. Static, siloed models fail to leverage existing data.

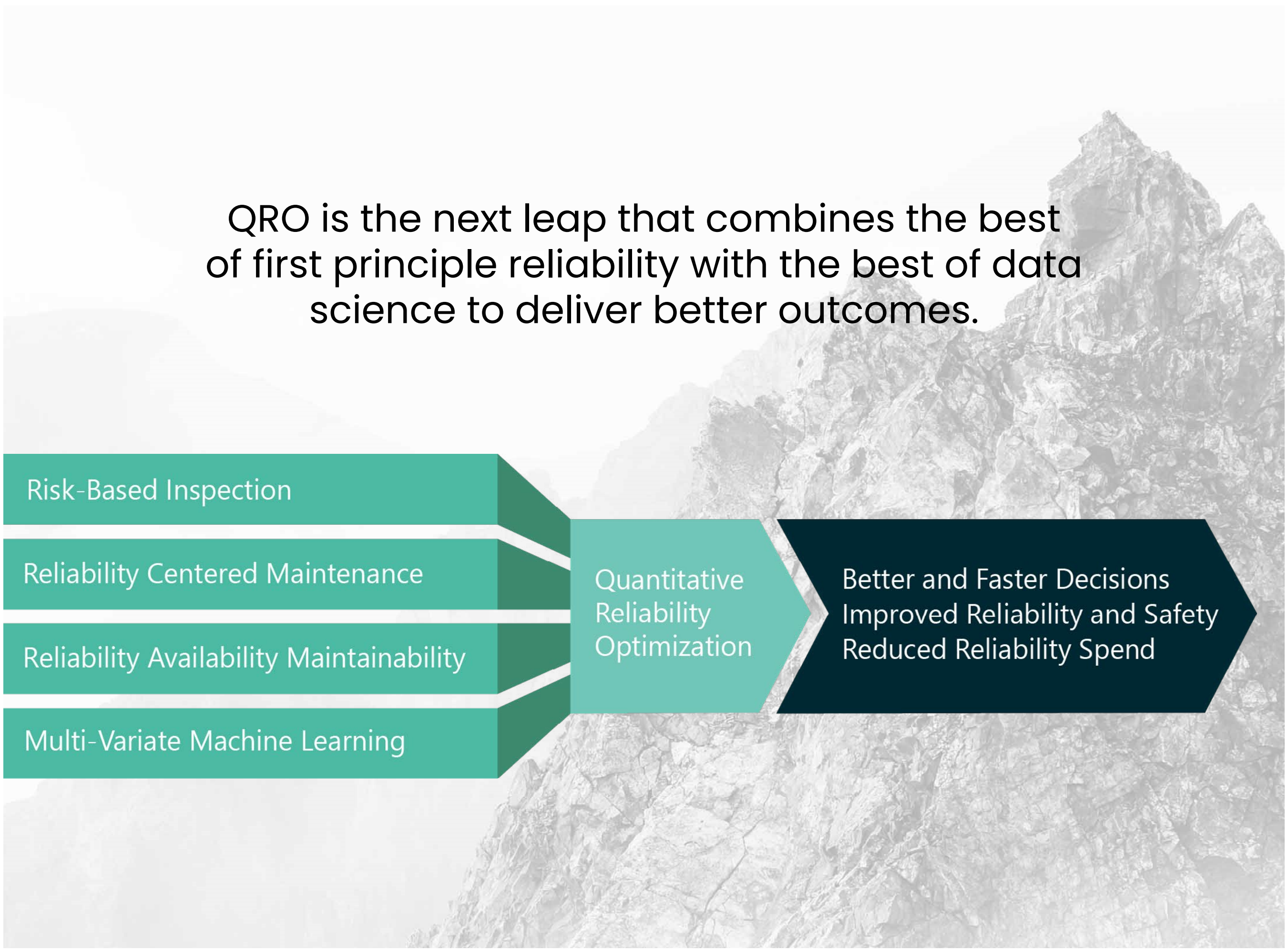
To varying degrees, all traditional models are developed using a snapshot of data and records and are used to build a plan for a specified period of time. The common practice is to implement one program using one model - for example, risk-based inspection (RBI) for fixed assets - then separately implement another program with another model - for example, reliability centered maintenance (RCM) for non-fixed assets. Each of these programs drives specific activities and is not formally linked to another program or live data inputs. As a result, these programs and models miss the insights associated with other programs and models, and the ways in which data changes over time is qualitative at best. The result is both overspending on overlapping programmatic recommendations and increased downtime to address issues that could have been captured with better quantification of data sensitivity.

Many facilities are hoping that new machine learning and artificial intelligence advancements may address these gaps, however, in isolation, that is not likely. In the context of reliability, machine learning can be applied to specific assets or problems that can be solved by identifying aberrations or repeat patterns. However, machine learning is limited when it comes to advanced simulation of complex systems. It can be time consuming to deploy and maintain programs at a scale large enough to be impactful. In addition, the most accurate machine learning algorithms prefer large sample sizes, repeat incidents, and excellent data quality and complex processing facilities rarely exhibit any of these. Therefore, many reliability leaders feel that they are left with expert opinion and traditional programs to inform their decisions. Unfortunately, while reliability leaders are regularly making improvements through their decisions, the human mind cannot take into account millions of inputs and weigh hundreds of possibilities, resulting either in overspending or unrealized reliability. However, by applying advanced data science principles to traditional algorithms and strategies, we can leverage the best of both: minimizing our spend while maximizing our reliability through quantitative decision making.

Together, we need to address these three gaps to realize both improved facility-wide reliability and optimized spend in a compressed timeframe.

QRO Simplifies Reliability Modeling and Unlocks the Next Level of Reliability Performance

Quantitative Reliability Optimization (QRO) is a new approach to reliability modeling that solves the current challenges of reliability previously listed and enables reliability and operations leaders to improve and simplify complex reliability decision making. Just as Reliability Centered Maintenance (RCM) and Risk-Based Inspection (RBI) represented leaps forward in the reliability community in past decades, QRO is the next leap that combines the best of first principle reliability with the best of data science to deliver better outcomes.



QRO was developed by synthesizing and expanding upon the best elements of each of the current reliability methods while introducing new data science and analytical concepts to close the gaps in current programs. By expanding upon the best elements of current models, QRO enables reliability leaders to make data-driven decisions in a way never before possible, providing for improved production levels, safety, and spending performance with statistically backed confidence.

Reliability Model Comparison

Capabilities:	Failure Modes and Effects	Reliability Centered Maintenance	Risk-Based Inspection	Multi-Variate Machine Learning	Process Hazard Analysis	Reliability Availability Maintainability	Quantitative Reliability Optimization
Loss of Containment Relative Risk Mitigation	✗	✗	✓	✗	✓	✗	✓
Functional Failure Relative Risk Mitigation	✓	✓	✗	✗	✗	✗	✓
Critical Equipment Early Failure Detection	✗	✗	✗	✓	✗	✗	✓
Quantitative Approach	✗	✗	✓	✓	✗	✓	✓
Reliability-Based Design	✓	✓	✗	✗	✗	✓	✓
Facility-Wide Optimization of Spend Versus Impact	✗	✗	✗	✗	✗	✗	✓
Complex Reliability Simulations Based on Data	✗	✗	✗	✗	✗	✓	✓

QRO enables reliability leaders to make data-driven decisions in a way never before possible, providing for improved production levels, safety, and spending performance with statistically-backed confidence.

QRO delivers an optimized reliability plan to facility leaders in three ways:

1. QRO links every failure and data point to the overall system.

To optimize a system, an analysis must cover that system. Rather than isolating models on individual assets or specific failure modes, QRO statistically relates all of the components of a system into one analysis. QRO's analysis can cover thousands of assets for a particular facility or many more if modeling an entire fleet or supply chain. This statistical relationship of all the assets enables us to understand how critical data and specific failure points relate to the overall production or reliability impact of the system.

2. QRO leverages data science and subject matter experts to predict failure.

QRO performs a data-driven analysis on each failure point in the system so that each asset is quantitatively modeled for its unique probability of failure looking forward in time. Instead of only providing a single probability number, QRO applies an advanced model called the Lifetime Variability Curve (LVC). The LVC forecasts the distribution of failure probabilities given the level of knowns and unknowns today. As a result, any failure of the system – whether it's a bearing failure on a pump or a leak in the wall of a pipe – can be accurately modeled given the anticipated point of failure and the uncertainty associated to that point on the failure curve.

3. QRO provides for a dynamic reliability model for the entire facility.

The QRO model is continually updated by relevant data sources so that key changes in those data points, whether in process, operations, maintenance, inspection, or economics, update the LVC for each failure point. As a result, facility leadership can then see how changes to their data affect the reliability of their system as a whole. In addition, the recommended data gathering tasks from initial studies like inspections and operator walkdowns provide additional information used to fine-tune the model's predictions. These dynamic updates and the ability to see how they impact the reliability of the system improves the overall confidence of facility leaders that they are making the best reliability decisions for their facility.

Combining all equipment, failure points, and critical data into one analysis engine provides new insights into facility-wide availability. This drives better strategic investment decisions and tactical data-driven reliability planning. Organizationally, plant management and its supporting maintenance, inspection, operations, and reliability departments will be able to see exactly how, when, and where previously siloed spending resulted in increased performance and increased measurable confidence in forecasting.

With QRO, a facility leader or reliability expert can:

- Drive optimization of all maintenance spending based on strategic reliability targets, in near real-time, including the implications of moving a turnaround, feedstock changes, various capital projects, and operating excursions.
- Dynamically plan and schedule tasks, maximizing resources based on how much value they provide in driving total availability performance.
- Understand the economic value of every piece of data that is currently being gathered or possibly gathered in the future, especially from inspection or maintenance activities.

Join Us on This Journey to Make the World More Reliable

QRO is the next step in our collective journey to make facilities reliable. QRO synthesizes and expands upon the best elements of current reliability methods and models while introducing new concepts to drive improved availability, process safety, and spending performance. As a result, facilities will have greater insight into how to drive better performance across their system.

At Pinnacle, we are explorers. We understand that transformation will not come easily, but we also know that transformation is an inevitable part of our journey to make the world reliable. We invite you to join us on our journey through QRO as we establish its capability to fundamentally transform how we approach reliability. In the coming months we will be releasing additional insights into QRO in multiple ways:

- Ideation
  Thought leadership papers that expand upon the concepts of what QRO is, how it embodies a novel approach, and how it improves upon existing reliability models.

- Experimentation
  Studies to prove the accuracy and credibility of QRO's calculations and results, implemented across a variety of both theoretical situations and real-life case studies.

- Demonstration
  We will showcase our toolset for making QRO a reality.

Our vision for success is for you to see the power of QRO and then leverage it within your facility. Join us on our journey to help make the world more reliable with our Research and Development Roadmap.