Part 1

Does Relying on Criticality Put Your Organization at Risk?

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Gaussian

This article is Part 1 of a two-part series focusing on risk as an enabler for asset management. It argues the case for moving away from criticality to an ISO31000 risk-based approach. Part 2 will address how to effectively model asset risk in complex systems.

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The role of asset management (AM) as a strategic enabler contributing to the current competitive business landscape is rapidly evolving. The emergence of the AM professional has transitioned the maintenance engineer from a role whose primary responsibility is repair to that of a strategic value enhancer. This means AM professionals are now tasked with delivering strategic asset value contributions in alignment with their organization's overall business objectives.

On a weekly basis, these AM professionals are confronted with complex questions that require swift decision-making, followed by appropriate action.

Typical issues include:

- Will this asset or system last until the next scheduled shutdown?
- Should the asset/system be replaced in this budgetary cycle or the next?
- How should priorities change if the budget suddenly gets reduced by 10 percent?
- Which assets/systems are most critical to achieving business objectives?
- Which assets/systems are putting the achievement of business objectives at risk?
- Which assets/systems are most deserving of attention and limited resources?

These are all real-life issues that carry both strategic and tactical implications. Unfortunately, it is still prevalent today to see AM professionals devoid of any decision-making methodology that is aligned to asset value contribution and the achievement of organizational objectives. In other words, they do not have a standardized approach or framework from which to make effective AM decisions that will address these complex issues.

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The goal of AM is to provide a clear set of principles that will guide the decision-making of AM professionals and organizations toward the achievement of their organizational objectives. ISO55000[1], the international standard for AM, recognizes risk as a cornerstone in creating an approach or framework to address AM related issues. It states that: *"AM translates the organization's objectives into asset-related decisions, plans and activities using a risk-based approach."*

In this regard, a more incisive understanding of risk, as opposed to traditional criticality, and the application of a risk-based approach advocated by ISO55000 are key enablers for AM professionals to make more effective AM decisions.

Criticality is a non-normalized approach and often a vaguely defined concept that can mean different things to different AM professionals and organizations. Traditionally, it is a process that has been applied within the maintenance and engineering departments in isolation from organizational risk management frameworks. Criticality usually serves the function of maintenance prioritization, but is often ill-suited for providing the decision-making input to operational and strategic challenges where significant asset value can be unlocked.

Instead, an asset risk approach can be used by AM professionals to make more effective AM decisions. This approach is aligned to ISO31000[2], the international standard for risk management, and ISO55000. It contains the current best thinking around the topic of risk management and can assist AM professionals to better structure their operational and strategic AM decision-making efforts.

Effective risk management is a clear value enhancer for asset intensive organizations. This has been demonstrated by multiple published research articles by the Aberdeen Group[3]. Table 1 provides a summary of three of its research findings, demonstrating the clear value benefits of risk management programs at asset intensive organizations.

Table 1: Value Benefit of Top Risk Performers

Definition of Maturity Class	Mean Class Performance
Best in Class: Top 20% of aggregate performance scores	**1.5%** Unscheduled Asset Downtime **92%** Overall Equipment Effectiveness (OEE) **99%** Production Compliance **3%** of Revenue in Financial Loss in Past 12 Months
Industry Average: Middle 50% of aggregate performance scores	**6.6%** Unscheduled Asset Downtime **83%** Overall Equipment Effectiveness (OEE) **97%** Production Compliance **12%** of Revenue in Financial Loss in Past 12 Months
Laggard: Bottom 30% of aggregate performance scores	**14.8%** Unscheduled Asset Downtime **74%** Overall Equipment Effectiveness (OEE) **85%** Production Compliance **18%** of Revenue in Financial Loss in Past 12 Months

Combined from Shah & Littlefield[4], Hatch & Jutras[5] and Aberdeen Group

Moving Away from Criticality

It needs to be stated up-front that traditional criticality is not inherently bad or incorrect. Nor is its intentions flawed or completely misguided. Like most new ideas or schools of thought, traditional criticality experienced a few growing pains. Its synonymous growth with the field of AM has led to numerous individuals and institutions creating their own versions of criticality. Reviewing the published literature reveals several terms, such as risk-based criticality analysis[6], multi-state component criticality analysis[7], analytic hierarchy process-based criticality analysis[8], etc. This is not a negative issue as it shows the necessary thinking, development and refinement that has gone into criticality in recent years.

Similarly, prior to 2014, literature often referred to AM as physical asset management[9], engineering asset management[10], etc. The release of the ISO55000 suite of AM standards in 2014 has helped streamline the thinking behind AM. No longer do AM professionals fret over their version of the name, but rather focus on making AM a legitimate profession backed by a less disjointed and fractured body of knowledge (BOK). One glaring issue in the current AM BOK, however, is the use and continued misuse of criticality.

Literature on criticality is plentiful, diverse and oftentimes confusing. However, a particularly good read is "Criticality Analysis Made Simple" by Tacoma Zach[11]. Here, criticality is defined as: *"a measure of the relative importance of something, usually a tangible system or asset, to the corporate mission, objectives and values of your organization."* The criticality of a system or an asset is determined by a criticality analysis, which is defined as: *"a way to determine which systems and assets are most essential in order to set priorities for further reliability initiatives and deeper analysis."* These two definitions are clear with regard to the aspirations of criticality in general and what constitutes a criticality analysis. However, these definitions also unintentionally cause significant confusion for AM practitioners in the field and during robust online discussions.[12]

With criticality, confusion and common misconceptions rear their ugly heads on several issues. Most of these issues are adequately addressed in Zach's book. For example, it is made clear that an asset or system in critical condition (i.e., poor condition) does not correlate with its criticality to the function or mission of the system. However, the biggest source of confusion remains in the interchangeable use of the word criticality (or asset criticality) and other terms, such as risk and consequences. This is encountered habitually when speaking to AM practitioners in the field and is widespread throughout literature.

Figure 1: The Effective Asset Management Delivery Model (EAMDM)

Take, for example, critical assets. A typical definition would be: *"those assets with a high consequence of failure."*[13] Here, the emphasis on what constitutes a critical asset is the magnitude of adverse effects that would proceed asset failure.

This makes logical sense, however, the issue arises when one looks at the majority of criticality equations found in literature. Most sources mathematically express criticality as follows:

Criticality = Likelihood × Impact, or

Criticality = Probability × Consequences

Here, the criticality of an asset or system is simply the product of its probability of failure (PoF) and the consequences of failure (CoF). A highly critical asset or system, therefore, is one with a high PoF and high CoF, and vice versa, of course. The confusion, however, comes when one looks at established risk literature. Take, for example, ISO31000. Here, risk is expressed as: *"a combination of the consequences of an event and the associated likelihood of occurrence."* In other words, according to ISO31000, risk is also mathematically expressed as:

Risk = Probability × Consequences

The inference here is that criticality and risk are the same thing, however, this is incorrect. A highly critical asset or system does not necessarily mean it is also a high-risk item, and vice versa. High voltage transformers are a popular example used to explain this point. Nowadays, most organizations rely on electricity to function, hence, the transformer providing the electricity is critical to that organization and the achievement of its objectives. However, transformers are generally very reliable, so they are not a major risk to the functioning of the organization and the achievement of its objectives.

It is this confusion with the word criticality, which is often glossed over or swept under the rug in AM literature, that necessitates the adoption of a risk-based approach that aligns to contemporary literature and the best thinking surrounding risk and risk management.

Adopting a Risk-Based AM Approach

Adopting a risk-based AM approach requires AM professionals and organizations to clearly understand the complexities of risk and its appropriate vocabulary. Furthermore, the difference between *asset risk* and *business risk* needs to be clearly defined and how asset risk supports AM needs to be crystallized. Finally, the adopted approach must align to ISO31000 and its structured risk management system.

Understanding the language of risk

All disciplines have their own vocabulary, so it is important for AM professionals to be conversant with the language of risk. This will facilitate cross functional understanding, discussions, learning and knowledge transfer between various departments internal to the organization, as well as with similar and different departments in other organizations.

> **ISO31000 defines risk as *"the effect of uncertainty on objectives."***

ISO31000 defines risk as "the effect of uncertainty on objectives." Unpacking this broad definition reveals three essential words that need further clarification.

The first word is *effect*, which, from a risk sense, means a deviation from what one is expecting. It can be positive or negative. For example, a safety risk is almost always negative, whereas a financial risk may be positive when an asset operates long past its predicted end of life. Defining risk clearly is foundational to an organization's strategic criteria. This helps create an aligned risk framework from which risk-based decisions can be made in line with the organization's risk appetite. Once the framework is defined, both the positive and negative effects can be modeled.

The second word is *uncertainty*. In the real world, everyone lives with risk since the myriad of actions they participate in are bounded by uncertainty. It is brought about by the lack of information or knowledge concerning an event, its consequences and/or its likelihood of happening. With available knowledge or resources, any risk framework can clearly define the bounds of uncertainty and review actions that narrow these bounds in order to provide improved certainty in targeted areas.

Finally, organizations have both formal and informal objectives. Risk management aligns with and supports the achievement of these organizational objectives. This takes one from the operational to the strategic domain and is much larger than a maintenance priority listing. It is imperative to align the risk framework to these organizational objectives. The risk framework then can be applied to decision-making at a strategic, transactional, or project-based level, with clear transparency as to how those decisions are made.

What is asset risk and how does it support AM?

For asset intensive organizations, risk can be broadly categorized as either business risk or asset risk. Maintenance engineering expert Keith Mobley provides a good description of the differences between these two risk categories. In short, business risks refer to political shocks, market losses, business continuity, etc. On the other hand, asset risks refer to those surrounding the installed asset base or asset portfolio of the organization.[14] The focus of this article is on the latter risk category.

Risk forms an integral part of AM. The ISO55000 suite of AM standards contains many references as to why risk and a risk-based approach are important and necessary. This is exemplified in Section 6.1: Actions to address risks and opportunities for the asset management system in both ISO55001[15] and ISO55002[16], which are dedicated to the topic of risk.

The importance of risk in the field of AM is reinforced by the Effective Asset Management Delivery Model (EAMDM)[17], as shown in Figure 1. The EAMDM shows that risk is strategic and delivery focused, as well as foundational. This means the delivery of effective risk management activities needs to be guided by the organization's objectives in order to facilitate the achievement of these strategic goals. At the same time, foundational enablers, such as good quality asset data configuration and information management, are pivotal in enabling a sound basis from which to make evidence-based, risk-driven decision-making. Lastly, risk is delivery focused, which means it should be thought about and executed daily as risk is dynamic and can rapidly turn for the worse.

ISO31000 risk management system

The relationship between the principles for managing risk, the framework in which it occurs and the risk management process described in ISO31000 are shown in Figure 2.

Here, the principles provide the foundation and describe the qualities for effective risk management within an organization. They guide the creation of the risk management framework. In turn, this framework defines and manages the overall risk management process and its full integration into the organization. Lastly, the process for managing risk focuses on individual groups of risks, their identification, analysis, evaluation and treatment. The performance of the process is monitored and fed back into the framework, making the process a continuously improving and iterative cycle.

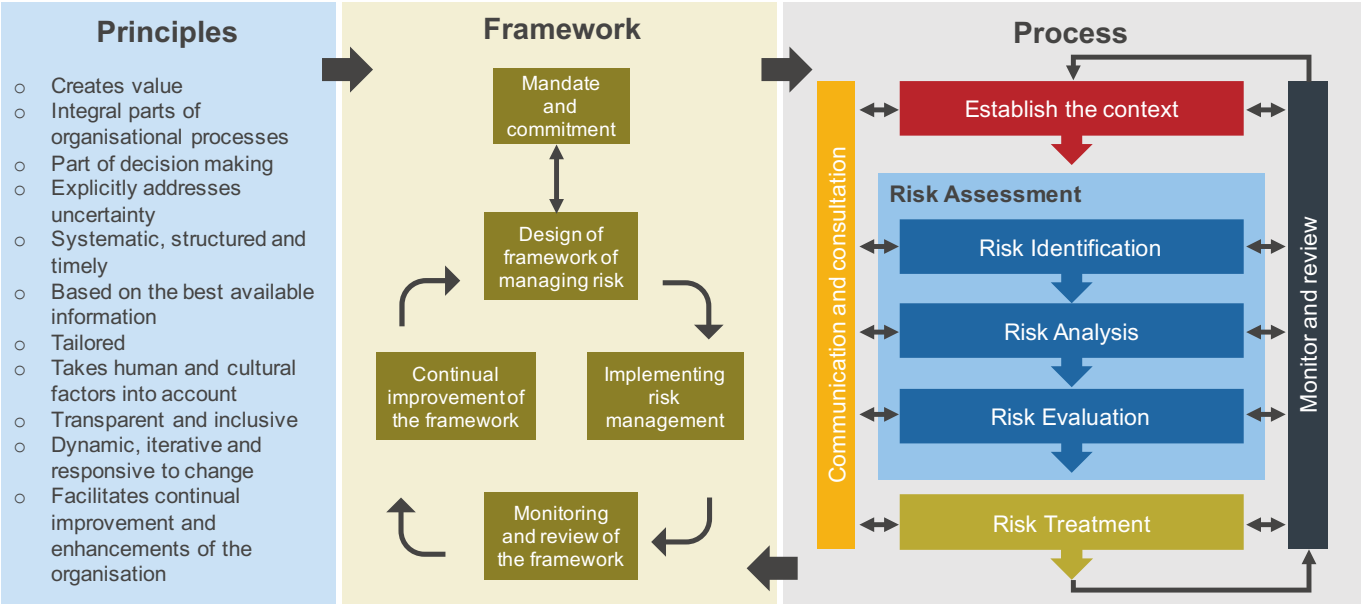

Figure 2: ISO31000 risk management system

Key Takeaways for AM Professionals from Part 1

The discipline of AM has evolved rapidly in the last few years. Unfortunately, some areas of the AM BOK have not kept up with this frenetic pace of change. A notable example is criticality and its continued use and misuse throughout literature. The confusion surrounding criticality is largely due to its synonymous use with risk, as well as the fact that both terms have an identical mathematical expression.

This part of the article, Part 1, highlighted the confusion and called for AM Professionals to move away from criticality and to rather adopt a risk-based approach. Moreover, it established the importance of asset risk and how asset risk supports effective AM.

This point was emphasised by two international AM standards, namely ISO55001 and ISO55002, who both have a section dedicated to the topic of risk. To avoid any unnecessary confusion with criticality and to align with the international standard for risk management, ISO31000, a risk-based approach to asset risk was proposed as solution.

Part 2 of this article will describe an approach to asset risk, which can help AM professionals and asset intensive organisations make better risk-based AM decisions.

Part 2

This article is Part 2 of a two-part series focusing on risk as an enabler for asset management. Part 1 argued the case for moving away from criticality to an ISO31000 risk-based approach. This part will address how to effectively model asset risk in complex systems.

The first part of this article, Part 1, started with a discussion on how rapidly the field of AM has evolved in recent years. It also brought attention to the fact that certain sections of the AM body of knowledge (BOK) have not manage to keep up with this pace of change. A notable example is criticality, which keeps being used and misused throughout literature causing significant confusion among AM Professionals. The confusion surrounding criticality stems largely from its synonymous use with risk, as well as the fact that both terms have an identical mathematical expression. Part 1 highlighted this confusion and subsequently called for AM Professionals to move away from criticality and to rather adopt a risk-based approach.

Part 2, this part of the of the article, will describe a risk-based approach to asset risk. It will show how this approach aligns to the ISO31000 risk management process (Figure 2) and how it can help AM professional and asset intensive organisations make better risk-based AM decisions.

A Different Approach to Asset Risk

Risk managed performance (RMP) is an asset risk approach that aligns fully to the ISO31000 risk management system shown in Figure 2. The approach aims to provide organizations with an effective decision-making mechanism in order to strike the appropriate balance between asset performance and asset risk control, as illustrated in Figure 3 with the zone of risk managed performance.

The goal is to first help organizations reach the RMP zone and then make incremental asset performance improvements over time. Within the RMP zone, the organization's asset portfolio operates within its asset risk appetite. This means the organization is neither guilty of destroying asset performance due to insufficient asset risk control nor destroying possible value creation by excessively controlling its asset risk.

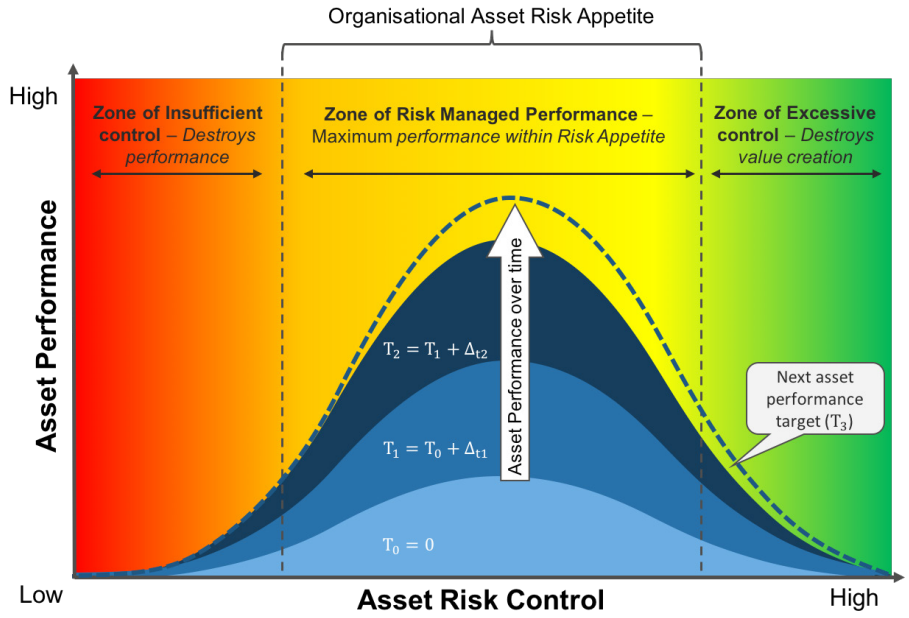

Figure 3: The risk managed performance approach

Asset risk level and organizational asset risk attitude

The appropriate response for organizations to take with regard to their asset risk depends on the asset risk level, as well as the organization's asset risk attitude. The mathematical expression for asset risk level is given in Figure 4. This expression does not violate the ISO31000 definition of risk since asset condition does not mathematically alter the equation. Rather, it is an optional input parameter during the asset risk analysis process (see Figure 2) that can provide additional decision-making insight. The benefit of including asset condition will become more apparent later in this article.

An organization's asset risk attitude depends on a number of factors, such as the nature of operation, overall risk culture, aversion toward risk (i.e., risk appetite and tolerance levels) and how proactively it chooses to manage risk. The three asset risk matrices in Figure 5 are examples to explain some of these points. Assets X, Y and Z are situated on the exact same position on all three asset risk matrices. This means the corresponding asset on each matrix has the same asset risk level. However, from left to right, the asset risk matrices are increasingly risk averse. One would expect the matrix on the left in Figure 5 to be used at a low-risk operation, whereas the matrix on the right would be commonplace at a high-risk operation, such as a nuclear power plant. Even though the corresponding asset may have the same asset risk level, the responses from each organization will differ in accordance to its aversion to risk. Take Asset Y in Figure 5 as an example. It is considered a low-risk item on the left matrix, a medium-to-high risk item on the middle matrix and a medium-to-high risk item on the right matrix. Moving from left to right, one can expect the effort and resources to be spent on asset risk mitigation to intensify as the risk aversion increases.

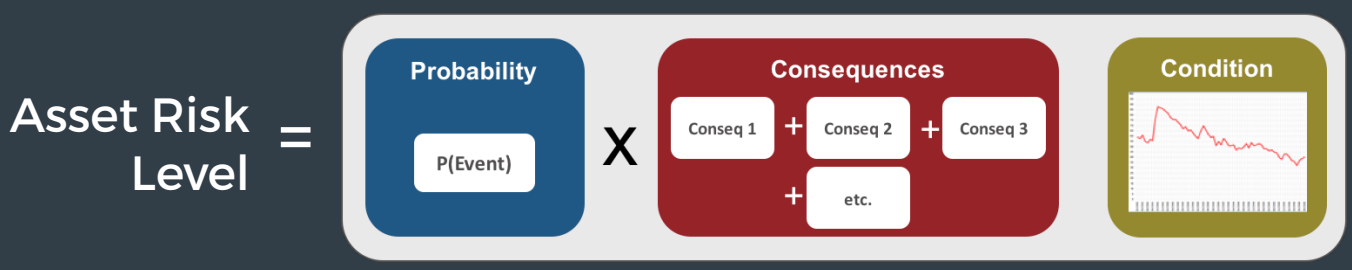

Figure 4: Mathematical expression for asset risk

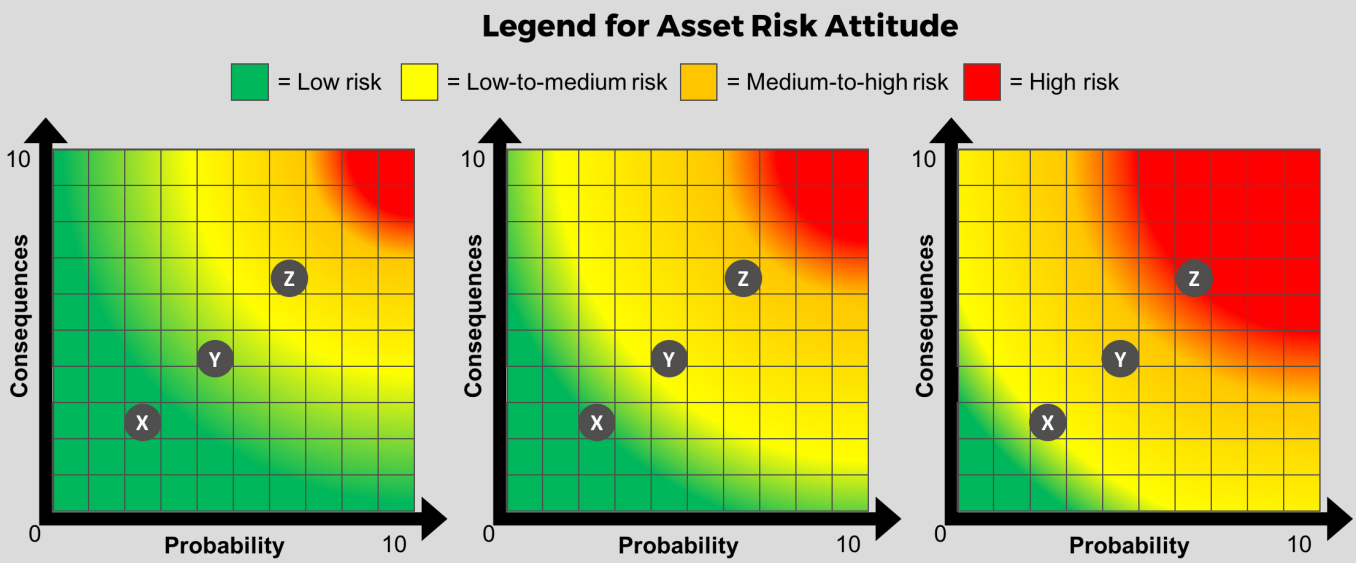

Figure 5: Asset risk attitude examples, left: low aversion to asset risk; middle: medium aversion to asset risk; and right: high aversion to asset risk

Asset risk Pareto analysis

A Pareto analysis can be extremely useful when it comes to representing asset risk. It follows the Pareto principle, which is commonly known as the 80/20 rule. In essence, it alerts AM professionals to those assets in which they should invest 20 percent of their time and effort in order to generate 80 percent of the benefit they would have attained by attending to the entire asset portfolio.

Figure 6 shows an example of an asset risk Pareto analysis. The figure contains a wealth of insight and shows the 20 percent of assets that contain 80 percent of the asset portfolio risk. Moreover, the inherent and residual risks of each asset illustrate the effectiveness of the organization's asset mitigating plans. At the same time, Figure 6 shows whether these mitigating plans are sufficient in reducing asset risk to within the organization's acceptable asset risk appetite levels. This is all shown as the backdrop of the organization's specific risk aversion, illustrated using conventional risk colors, ranging from red, indicating high risk, to green, indicating low risk.

Asset risk matrix

Introduced in Figure 5, a risk matrix is arguably the most popular way of representing risk. Figure 7 shows two examples of asset risk matrices. Both break down the asset risk level, shown in Figure 6 as a single value out of 100, into its constituents, namely probability and consequences. These two-dimensional risk matrices also show the same risk aversion in the backdrop and the organization's asset risk appetite. The difference between the two risk matrices is the size of the bubbles on them, which represent the condition of the assets.

In order to verify the asset register in preparation for an asset risk assessment (see Figure 2), proxy asset conditions are assigned to the assets by means of visual inspections during a plant walk down or from other sources, such as condition monitoring data. This does not have to be a full asset condition assessment. Using an asset condition proxy can give additional insight into the health of the assets. It might be discovered that some high-risk assets are in good condition, whereas some low-risk assets are in poor condition. This might contradict the traditional notion of the asset risk Pareto analysis, in which high-risk assets are attended to immediately, thus adding new insight and consideration to AM professionals' decision-making process.

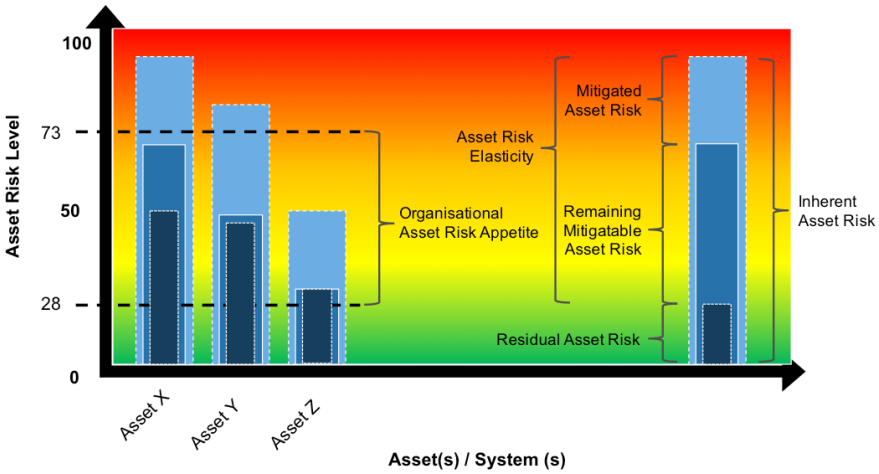

Figure 6: Asset risk Pareto analysis example

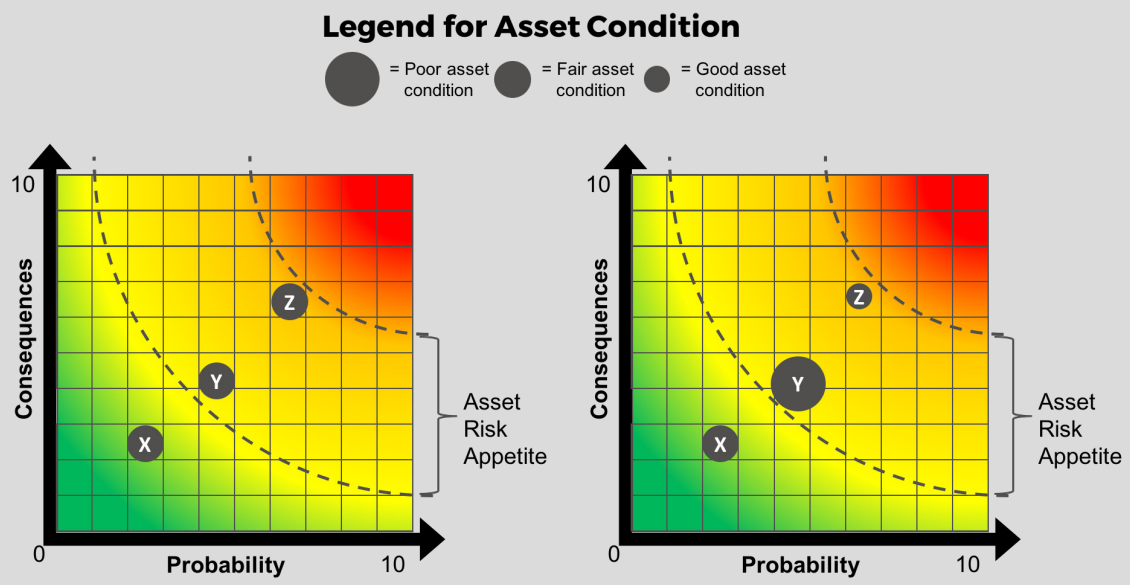

Figure 7: Asset risk matrix examples, left, excluding asset condition and right, including asset condition

Figure 8 plots the asset risk matrix on the right-hand side of Figure 7 in terms of the level of asset risk versus the condition of the asset. It is typically seen in practise that the majority of high-risk assets are known and numerous risk mitigating plans are in place to ensure these assets stay in a healthy condition. However, by overcommitting time and resources to high-risk assets, organizations often overlook their low-to-medium risk assets. This lack of attention can quickly lead to deterioration, resulting in an unexpected asset failure. Since the asset conditions of lower risk assets are not in the decision-making framework, failure of these assets often comes as a shock and without the appropriate level of preparedness.

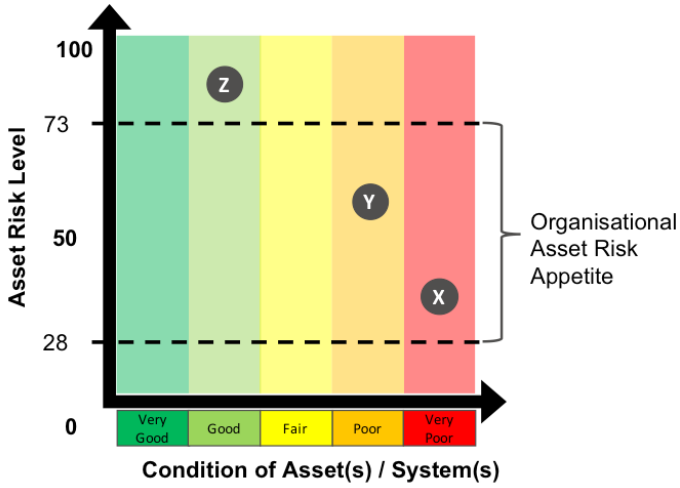

Figure 8: Asset risk level vs. asset condition example

This attention paid to proxy asset condition is unlike most criticality analyses. Typically, a criticality analysis aims to provide insight on where to focus effort in terms of conducting asset condition assessments. However, this may be too late, as one can see the invaluable insight gained between the two risk matrices in Figure 7, as well as Figure 8. Getting a proxy for asset condition does not take significantly more effort and forms part of the risk assessment preparation process, during which the plant is walked down to verify the contents of the asset register.

Risk-based asset hierarchy

Organizations are often challenged with choosing the most appropriate method of asset hierarchy construction. However, constructing asset hierarchies on the basis of asset risk can provide enormous practical advantages. For example, as alluded to in the asset risk Pareto analysis, the majority of asset risk may be limited to only a few assets or systems in the whole asset portfolio. Figure 9 shows an example of a risk-based asset hierarchy and how it can assist organizations to be more effective during their asset risk analysis process (see Figure 2).

Starting at the highest practical analysis level, which in Figure 9 is the section or system level, conducting the asset risk analysis will reveal the section/system with the highest risk. If the section/system risk level falls above the organization's asset risk appetite, the analysis can go one level deeper and analyze asset risk at the equipment level. This process continues until the organization is comfortable in reaching the appropriate level at which to mitigate the risk below its asset risk appetite. The process is termed "chasing asset risk" and is a very useful tool to visually illustrate asset risk since the color of each asset bubble indicates where the asset sits on the asset risk Pareto analysis (Figure 6) graph and the asset risk matrix (Figure 7).

As noted in the beginning of this article, effective risk management is a clear performance enhancer. With that in mind, constructing a risk-based asset hierarchy facilitates a direct foundation to risk-based decision-making and management.

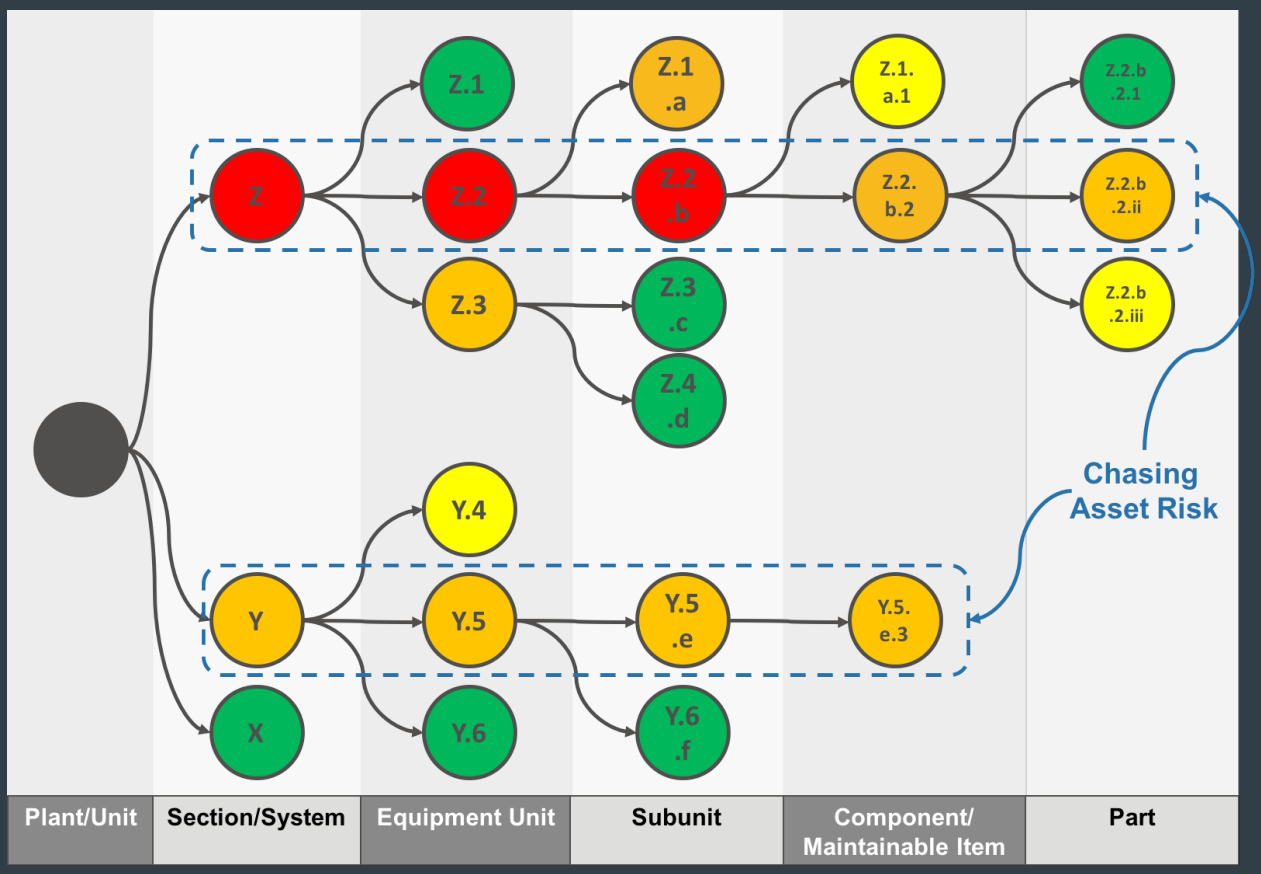

Figure 9: Risk-based asset hierarchy example

Thinking Like a Risk Manager

Risk management theory and practice is a well-trodden path and AM professionals can save time, effort, resources and confusion by aligning to the ISO31000 methodology and vocabulary. ISO31000 promotes seven options to managing risk, which are summarized in Table 2. Keep in mind that these risk treatment options are not necessarily mutually exclusive or appropriate in all circumstances.

By understanding the appropriate risk treatment options available, AM professionals can set forth a path to completion that consists of actions that can achieve their desired outcomes. For example, if one changes the probability of asset failure, it effects the frequency at which the failure may occur and, as such, may allow for a completely different tactical approach to managing the asset. This may be more cost and resource effective, thereby providing an amplified advantage.

Table 2: ISO 31000 Risk Treatment Options

Risk Option	Description of Risk Option
Avoid the risk	Discontinue the activity that provides the origin of the risk
Take on more risk	Use a calculated understanding of risk to exploit risk opportunities
Address risk source	Remove or modify the risk initiator to operate at a lower risk level
Change the probability	Through the combination of understanding the primary functions and failure modes, apply the appropriate range of reliability engineering tools and processes
Alter the consequences	Change the outcome of the event should a risk occur
Share the risk	Distribute risk or insure against risk outcome with another party or parties
Retain the risk	Accept the fact that in the real world, some risks will remain, but understand fully the retained risk that is in place

Key Takeaways for AM Professionals from Parts 1 & 2

Risk management as a professional discipline is mature in its thinking and proven in its application. The ISO31000 process applied by risk managers is shown in Figure 2. There is no need or benefit for AM professionals to reinvent or modify this proven process, but rather to understand and align to it. Adopting this process bridges the divide between asset management and risk management principles and has a number of tangible advantages, which can be summarized as follows:

- It creates a consistent and unambiguous use of language based on international standards.
- It provides a coherent vocabulary for all organizations, their departments and other professionals, such as lawyers, regulators, insurers, etc.
- Using the terms, principles and guidelines in both ISO31000 and ISO55000 means organizations do not have to spend time and effort creating their own. This time can be spent on effectively managing actual risks.
- AM aligns with established risk literature and standards (e.g., ISO31000 and ISO Guide 7318) and, therefore, brings greater credibility to the field of AM.
- Executive managers and board members are tasked with managing enterprise risk. They are conversant with risk concepts and the contemporary language of risk. For AM professionals, conversing with these professionals with the appropriate risk vocabulary will make communication more effective and credible.

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Who are Gaussian?

Gaussian are management consultants focusing on physical asset management and reliability. Through our agile approach we make organisations more effective and efficient. Organisations with the right DNA in place will be effective. Our purpose is to work with individuals and teams to establish the supporting culture and DNA building blocks to be effective.

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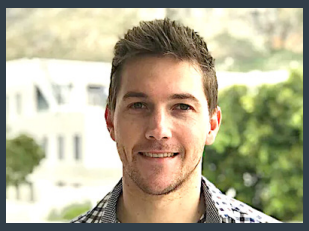
Grahame is an internationally recognised expert in Asset Management. He has over 35 years' experience ranging from Power Generation, through Mining and into Heavy Manufacturing and Pharmaceuticals. He has published widely in books and journals on Asset Management and is a prominent voice at conferences. Grahame's expert focus is on Asset contribution management and how to unlock measurable value within enterprises. He has worked on a global stage and demonstrated value in the most challenging of circumstances.

Outside of Gaussian, Grahame is a keen cyclist, mountaineer and has a deep interest in the world we live in and leaving a legacy for the next generation.

He is a member of the IAM UK, SAAMA and a board member of the Association of Maintenance Professionals (AMP). Grahame is an endorsed IAM PAS 55 Assessor.



PETRUS SWART

Consultant

Petrus holds a Mechanical Engineering degree and a Masters in Engineering Management, both from Stellenbosch University. His focus is on Asset Management and more specifically on linking Asset Management objectives with organizational financial objectives, thus creating a clear "line of sight" within organizations. Other areas of interest include risk management, financial management, strategy development and human asset management.

He has consulting experience in the Southern African mining sector, as well as the international food packaging and diamond processing industries.

Interests outside of work include traveling, meeting and engaging with people from different walks of life, playing and watching sport (cricket, football & rugby) and hiking up Table Mountain whenever possible.