Risk Management and Risk Aversion, from Benefit to Impediment

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Abstract:

Risk management is a critical tool for improving the probability of project success by identifying, assessing, prioritizing, and attempting to control threats to project realization. For industries that require high operational reliability due to the potential consequences of off-normal events, such as the nuclear, aerospace, and chemical sectors, a major focus of risk management is the preservation of process safety. Due to the nature of the processes or systems under consideration, the associated process safety analyses (such as risk and safety assessments) and safety features can require significant resources. These costs are typically tolerated either due to the need to satisfy regulatory requirements or based on the assumption that they generally decrease the occurrence of unwanted events and therefore improve the probability of project success. However, as the level of acceptable or tolerable risk from unwanted events decreases, the required resources necessary for ensuring and demonstrating satisfaction of these criteria can grow and in turn can become one of the dominant impediments to project success.

This paper outlines a high-level theoretical framework for the consideration of dominant project risks, which includes potential project failure from both the occurrence of high consequence off-normal events and the inability to achieve project completion due to the resource needs and innovation losses associated with extreme risk aversion. Utilizing such an integrated approach permits an attempt to optimize the probability of successful project realization while also providing valuable insight into the proper level of acceptable risk. The work is presented as a first step, in hopes of spurring additional discussion and analysis regarding appropriate levels of risk tolerance and the balance of project benefits.

1. INTRODUCTION

Risk management, as a holistic approach, seeks to bring value to organizations by directing and controlling risk. These risks can arise due to various factors, such as financial, market, or operational aspects. For certain industries, like the nuclear, oil/gas, and aerospace sectors, the potential consequences of off-normal events are sufficiently severe such that the preservation of operational safety becomes a major focus of the risk management process. This includes both the consideration of regulatory acceptability and the direct effects on operations due to such events.

The purpose of this paper is to explore how a growing aversion to risk can impact the probability of operational success for organizations, within the context of risk management programs. Specifically, this work examines how the acceptable level of risk regarding off-normal events factors into this framework and can impact the likelihood of project success. The purpose of this study is not to determine an "acceptable" level of risk or a delineation of "safe enough," but instead to identify potential negative consequences of extreme risk aversion in terms of both resource allocation and organizational effects. The hope is that the identification and formalization of these topics will be a step to further study and understanding, which can aid in determining the proper balance of operational safety risk and project risk management.

This paper begins in Section 2 with a review of project risk management, in the framework of ISO 31000 [1] and those unique considerations of industries requiring high reliability. This is followed in Section 3 by a discussion of both the tangible and intangible effects of extreme risk aversion. Section 4 explores the impact of these effects on the likelihood of project success, while Section 5 summarizes key findings, next steps, and limitations.

2. BACKGROUND

2.1. Risk Management

One of the most widely used standards for the assessment of project risk is ISO 31000:2018 *Risk Management – Guideline*s and its associated guidance. As defined in ISO 31000, the risk management process seeks to effectively and efficiently allocate resources to address risks, with the goal of creating and protecting value. Risk management should also improve performance, encourage innovation, and of course support the achievement of the organization's objectives.

For a large industrial project, there are many potential risks to the successful completion of the project and the resulting creation of value. Central to these is economic or financial risk, although there are many contributors to this category. For example, the solvency of the organization, the market demand for the product, or the financial repercussions of errors or accidents (discussed in the following subsection) are only a sample of the potential risks to the going concern.

In general, the resources allocated to risk management, and any resulting actions, are believed to increase the likelihood of project success. At a conceptual level, this follows the plot shown in Figure 1. Here, it is assumed that if no resources are assigned to project risk management, there is some (albeit potentially small) likelihood of project success, whether due to the nature of the project or pure luck. However, as the magnitude of resources dedicated to risk management increase, the likelihood of project success increases at some rate. The rate of increase is likely largest at the start, when major or dominant risks are addressed, then slows with diminishing risk reduction returns at greater levels of resource allocation (discussed further in Section 3.1.1.). The curve asymptotically approaches one, as project success can never be guaranteed. While the general assumption is that continued resource allocation will lead to a further increase in the probability of project success, Section 4 of this paper explores how certain actions or attitudes toward risk may impact this assumption and those underlying the shape of the curve.

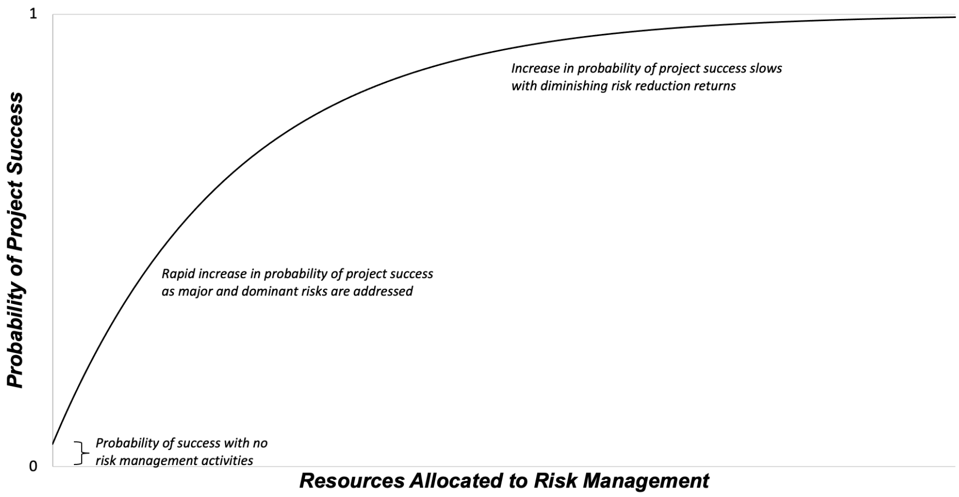

Figure 1: Generally Assumed Probability of Project Success versus Resources Allocated to Risk Management

2.2. Risk Management for High Reliability Industries

For certain industries, the potential negative consequences of off-normal events or accidents are of sufficient severity such that their possible occurrence is an appreciable threat to the success of the project or survival of the organization. Some examples are well known, such as the nuclear power sector, the petroleum and chemical sectors, aviation, and the budding space business. There are other industries that also must account for potential negative outcomes, such as patient safety for the healthcare sector, pharmaceutical testing and safety, and also the military. While different terminology is used for these organizations, it is generally appreciated that they require high reliability of their associated processes.

The specific threat to project success from high consequence off-normal events can vary or be a combination of several factors. For example, the direct financial consequences of an event, such as restitution and penalties, may be so severe as to result in insolvency, including for those organizations that self-insure. Similarly, the resulting publicity from an event may also impact future product demand or threaten the enterprise risk of the organization. The risk may also derive not from the actual event itself but the assessed possibility of its occurrence. For example, a project may fail due to the inability to demonstrate satisfaction of regulatory criteria associated with the likelihood of high consequence off-normal events. In this case, it is not even necessary for the event to take place to threaten project success.

In general, the resources allocated to the assessment and mitigation of the risk associated with high consequence off-normal events is tolerated, for several possible reasons. First, it may be assumed that these designated resources reduce the likelihood of the event occurring and the potential negative project/organizational consequences outlined above. Second, such assessments and actions may be a necessary step to obtain regulatory approval, without which the project would be assured to fail. However, as will be detailed in the following sections, it may be that the converse to these assumptions is true and that the resources allocated to risk reduction become a burden on the overall project and reduce the likelihood of project success, depending on the level of risk aversion selected by the organization (or inherited by the organization from other stakeholders).

3. CONSEQUENCES OF RISK AVERSION

For the high reliability organizations or sectors identified in Section 2, the assessment and mitigation of risk associated with high consequence off-normal events can become a central contributor to the overall risk management strategy. However, as the tolerance for risks from such events is reduced (or the level of risk aversion increases), there are potential negative repercussions on the project or organization overall. This includes both tangible and intangible impacts, which are explored further in this section.

3.1. Tangible Impacts

3.1.1. Cost/Benefit Analysis

The most direct consequence of a decreasing level of risk tolerance is the additional resources necessary to identify, assess, and mitigate the associated risks. It is generally, although not always, true that such actions provide diminishing returns. For example, the most likely and/or severe threats to process operations are identified first and the actions taken to prevent/mitigate such events provide a significant reduction in risk (and the reduction in risk from the off-normal event likely has a directly correlated reduction on the overall project risk). However, as off-normal event risks are prioritized and addressed, the risk reduction for each subsequent treatment also decreases. This generally results in the same curve shown in Figure 1, where the cost/benefit of the initial resources allocated to operational risk have high impact, with diminishing returns as more resources are added[*]. As with Figure 1, the curve approaches but never reaches a probability of unity.

Cost/benefit analyses for off-normal event risk reduction are common practice and are present in both industry guidance [2] and regulation [3]. How far an organization moves to the right on the curve depends on their associated level of risk tolerance for high consequence off-normal events, which may be derived from internal factors, regulator criteria, etc. However, because of diminishing returns, the resources required to achieve additional risk reduction grow, potentially at an increasing rate. The following subsections demonstrate several of the reasons why this is the case.

[*] It may be that new, major risks are discovered and addressed with an increase in risk management resources but that is generally the exception rather than the rule.

3.1.2. Increasing Severity

A decrease in risk tolerance can have a direct impact on the severity of threats requiring consideration and treatment. If it is assumed that initial off-normal event risk mitigation actions were successful, then the potential threat from single-points-of-failure or common internal/external hazards have been reduced or removed. Therefore, further risk reduction requires the consideration of less frequent events that may be the result of multiple failures or more extreme hazards. Addressing such events can become increasingly difficult and costly.

A simple example is the magnitude of resources necessary to address the operational risk posed by natural hazards. At a certain risk tolerance level, a facility considers, assesses, and designs for a seismic event of a particular ground motion magnitude. The repercussions of this analysis propagate throughout the design of the facility, impacting structural design, plant layout, emergency planning, etc. A reduction in the operational risk tolerance for the facility means a consideration of lower frequency seismic events. Given the non-linear behavior of many hazards, a reduction in frequency by a factor of two can lead to the consideration, assessment, and design of seismic hazard now greater than twice the previous level. Similarly, the response of systems and structures may also be non-linear, requiring a significant increase in building costs, etc. to address the new threat level. Lastly, the severity of certain events may reach a level when any further mitigation is simply not possible.

3.1.3. Increasing Uncertainty

An additional consequence of the need to consider and assess potential high consequence off-normal events of decreasing frequency is the growth in their associated uncertainty. This can be a direct factor associated with the available state of knowledge, such as the uncertainty associated with a seismic hazard curve at lower frequencies, or more abstract. As noted above, the potential for multiple-system failure events increases at lower frequencies. However, the system response to such events and the potential timing of failures can grow increasingly uncertain as the scenarios become more complex.

Uncertainty not only makes the analysis of such events more difficult (and therefore costly) and potentially results in increasing levels of conservatism, but it can also make the identification and implementation of actionable items to reduce risk increasingly challenging. If the structural response to a severe seismic event is uncertain, there may be limited options available to address its potential failure. In addition, actions that were taken to address off-normal event risks of higher frequency may negatively impact facility response to lower frequency events with high uncertainty. For example, efforts to maintain a simple, passive plant design can reduce the number of alternative success paths for a safety function under low frequency, catastrophic scenarios.

3.2. Intangible Impacts

3.2.1. Organizational Chilling Effect

An increasingly risk averse attitude by an organization or project can manifest in different ways among those participating in the project, potentially causing them to take actions that are detrimental to overall project risk. The “chilling effect” terminology is used in the legal context to describe the reluctance to exercise legal rights due to potential negative repercussions, such as law enforcement investigation or political retribution [4]. For the current work, the chilling effect term has been borrowed to describe the potential consequences due to the shift in organizational culture that occurs as risk aversion grows. As the risk tolerance of project management and upper management changes, the directional shift may not just trickle down through the organization but become amplified by the time it reaches the technical level. As the viewpoint of failures or unplanned events becomes increasingly negative or less tolerated at the organizational level, staff may become increasingly unwilling to take actions with an associated level of risk, even if the actions could be beneficial from a project risk management perspective.

As an example of how such an outcome could occur, a recent study is presented here that examined this phenomenon in the financial sector [5]. The results demonstrated that analysts would forgo investment opportunities with a certain positive expected value, and therefore likely beneficial to the company, due to the fear of how a potential loss would be viewed by a risk averse organization and the impact on their careers. The attitude extended even to decisions where the potential loss was sufficiently small as not to threaten the organization.

While the presented example is not perfectly analogous to employees in high reliability industries, there are similarities. First, such cultural attitudes can create a reluctance to deviate from previously accepted norms or practices, even if a risk/benefit assessment in terms of project success would encourage such actions. This could include the use of previously accepted (by regulator or internal procedures) methodologies or codes, or the standard design of systems and components. Such factors can also impact organizational innovation, discussed in Section 3.2.2.

Second, there may be an additional chilling effect on those conducting research or eventually operating the facility. Recently, there has been an improvement in operational safety by making safety part of the organizational culture and each employee's personal responsibility. It is expected that safety concerns will be identified, brought to the attention of management, and considered seriously. Studies have shown that such programs have a tangible decrease on worker's personal risk tolerance, which is generally viewed as a positive outcome [6, 7]. However, with growing organizational risk aversion, such as the the increasing popularity of programs with goals such as zero operational accidents or reportable events, this can potentially lead employees and managers to become reluctant to report events or conduct activities where such events may occur, whether due to fear of repercussions or from the benefit associated with meeting a related metric. Clear data on the prevalence of such issues is lacking and difficult to obtain given the nature of problem. Studies typically focus on the trends of the tracked metric, such as reported incidents, as an indicator of success rather than assess potential intangible unintended negative consequences.

3.2.2. Innovation Losses

Perhaps the most severe, hidden consequence of increasing risk aversion is the impact on organizational innovation. It has been shown that corporate culture, and specifically the risk tolerance of the organization, is one of the most important factors, if not *the* most important factor, influencing organizational innovation [8]. The reasons for this can vary by industry, but for the type of organizations and projects discussed here, there are several potential explanations. First, as described in the preceding subsections, organizational risk aversion can cause deviations from known processes/methods or the conduct of certain activities to be viewed by the employee or manager as risky within their personal context. The decision not to pursue innovative ideas or actions may come as a result of the risk assessment made at the personal level and ignore the potential benefits to the organization or project. The fear of having a reportable event or pursuing a design option that contains certain unknown-unknowns may be too great at the worker level.

Organizational risk aversion may also impact innovation in other ways. It has become popular to point to companies such as SpaceX and their willingness to fail fast, often, and publicly, as beacons of innovation. However, it is also informative to view organizations on the opposite end of the spectrum. For example, the development of the Space Launch System (SLS) headed by NASA and its associated contractors has encountered repeated delays and cost over-runs in the billions [9]. While political factors abound, the hesitancy for rapid development and spectacular testing failures in the SLS program (compared to say Starship development by SpaceX) due to public and political pressures are no doubt a factor. The level of risk aversion driven by publicity results in a general avoidance of even developmental negative events, such as testing failures or changes to design[†]. However, these actions also result in a loss of any potential lessons learned or improvements derived from this experience.

[†] Note that ref [8] finds the willingness to change course or cannibalize existing projects as another central factor to organizational innovation, in addition to organizational risk tolerance.

Beyond direct budget and schedule impacts, the view that innovation is stifled at such organizations has caused a shift of talent to those organizations with higher risk tolerance[‡]. While the particular lesson regarding an acceptance of testing failures may not be applicable to all industries, the general attitude to permit a greater level of risk to foster innovation may be a differentiator for certain companies.

4. RESULTING IMPACT ON PROBABILITY OF PROJECT SUCCESS

As outlined in Section 3, a growing aversion to the risk from high consequence off-normal operational events can have both tangible and intangible consequences, which have a subsequent impact on the potential success of the overall project. Such effects may reshape the curve shown in Figure 1, which attempted to capture, at a high-level, the likelihood of project success given the magnitude of resources allocated to risk management. The potential error in the development of this curve is that additional resources are assumed to result in an increased probability of success, even if there are diminishing returns. Such an assumption may be valid when looking only at the risk associated with high consequence off-normal events, as the metric being considered is solely the likelihood of a severe off-normal event. The potential negative impact of those attributes described in Section 3 appears only when looking at the probability of overall project success.

An attempt to correct Figure 1 to include the attributes from Section 3 is presented in Figure 2. Here, it is assumed that at a certain level of risk aversion to off-normal events, the magnitude of resources necessary to reduce the risk of such events any further actually becomes a burden on the overall likelihood of project success. This may be the result of a direct cost factor, where the additional analyses or risk mitigation systems become so costly as to jeopardize the solvency of the project. This is likely the case when the risk tolerance to off-normal events is at a level where the potential occurrence of such events poses no realistic threat to project success[§]. However, the decrease in the likelihood of project success may also be a result of intangible aspects, where a lack of innovation or a fear of deviating from currently accepted practices hampers project development. In actual project risk management, it is often possible to put a quantitative cost estimate on the design changes or analyses necessary to reduce facility risk, but the intangible aspects are hidden.

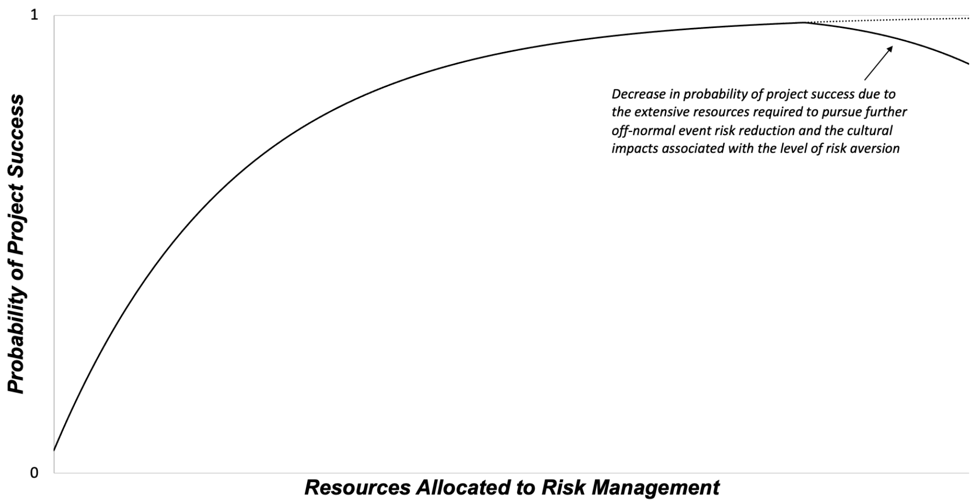

Figure 2: Probability of Project Success versus Resources Allocated to Risk Management when Accounting for Detrimental Effects

It is also important to highlight how those factors reviewed in Section 3 conflict with the principles and guidance of ISO 31000. As outlined by the standard, the process of risk management should effectively

[‡] SpaceX now ranks as the most attractive employer to new engineering graduates, ahead of SLS participants such as NASA and Boeing [10].

[§] For example, if a project timeline is in on the order of decades but the estimated likelihood of severe off-normal events is on the order of hundreds of thousands or millions of operational years.

and efficiently address risks to the project. If the process of risk management advances to a point where it becomes detrimental to the probability of project success, then it would surely violate these principles. Similarly, a risk management process should foster innovation, not serve as a potential barrier to its flourishing.

5. CONCLUSIONS

5.1. Summary

In this paper, an attempt was made to formalize potential issues regarding risk aversion to off-normal events and their potential impact on overall project success. Specifically, the discussion challenges a general assumption that increased resources dedicated to risk management always results in an associated increase in the probability of project success. As the level of risk tolerance for off-normal events decreases, the necessary resources to pursue further risk reduction can grow in a non-linear fashion due to increasing severity of events and their associated uncertainty. The number of resources dedicated to this task can not only outweigh the benefit in the reduced risk of off-normal events, but also *negatively* impact the probability of overall project success. Outside of the direct costs, intangible factors, such as the chilling effect on the risk tolerance of project employees and the stifling of innovation, can have a hidden detrimental impact on the likelihood of project success.

5.2. Next Steps

The current work attempted to form a preliminary framework to assess the potential issues that could arise from a severe risk aversion to off-normal events. The hope is that by identifying and understanding the problems that could arise, either solutions can be developed, or a proper balancing of risk aversion and project benefit can be obtained. This is a topic that will likely continue to be encountered in the future as more and more industries seek to achieve high reliability and the tolerance for severe industry accidents further declines. Without an understanding of the potential negative consequences of extreme risk aversion, there is little motivation to pause further efforts to reduce risk.

5.3. Study Limitations

It is important to note the limitations of the study presented here. For the industries discussed, the potential consequences of off-normal events can be defined and bound. For example, the maximum potential consequences of a nuclear reactor accident (regardless of physical possibility of such an event) can be postulated by assuming a complete, energetic release of the entire quantity of radioactive material contained within. Depending on the facility, the consequences of such an event can have health and economic consequences for some geographic area. Similar assessments can be performed for other industries, such as the petrochemical or aviation sectors[**].

In contrast, there are certain matters whose potential consequences are not easily bound or exhibit the properties of fat-tailed distributions. For example, the impact of a new virus on the human population can vary from a seasonal flu, to a global pandemic killing millions, to a plague that threatens the existence of our species. While analyses can help inform the likelihood associated with each outcome, the possibility of such extreme outcomes exists and therefore can significantly influence the actions selected to address the risk. Actions involving significant resource allocation or other measures are potentially justified if an outcome such as global extinction is within the tails of the output distribution.

[**] Certain industrial events may begin to approach the "boundless" consequence threshold, such as a major deepwater oil well blowout.

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