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Integrated Risk Management Strategies for Research Centers

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ABSTRACT

This paper describes how risk management strategies have been incorporated into Research Centers and illustrates the specific role of Research Centers as a bridge between academia, industry and government. In this study, based on a review of the evolution of the practiceof risk management in Research Centers as facing practitioners, itproposes a robust framework that is adapted to Research Centerson the basis of an analysis of the evolution of their practicesto deal with multidisciplinary environment. The three core strategies it proposes include precautionary, risk informed, and discursive approaches that it elaborates upon through secondary data analysis, historic insight, and throughout. The paper also discusses how advanced risk management practices can be integrated to address problems resulting from deep uncertainties with the motive to enhance resilience within possible disruptions. These strategies are used in conjunction by Research Centers to enable their combination of innovation and risk mitigation for sustainable growth in line with the societal and scientific objects. The problem with this is that such complexity of research challenges needs a systematic, comprehensive and flexible framework for the management of such risk itself and this study brings out that this is significant.

1. INTRODUCTION

Organisations from any sector (corporate, government, education) use risk management as a structured and strategic process for the guidance through uncertainties of their operations. Risk management practice dates back to ancient times and as early as 2,400 years ago, the Athenians used systemics thinking to measure risk and to bring it into strategic decisions (Haimes, 1991, Bernstein, 1996 and Rabkin, 2009). It has also recognized the long outstanding importance of the need for risk management for governance and decision process. The evidence for this is signals over the past few decades in the emergence of dedicated academic journals, international risk management conferences, and that active scholarly debate surrounding a formal scientific discipline known as risk management. This evolution has not simply been the work of thought leaders and researchers upon overtime to refine these principles for application to challenges of 21st century, which are becoming increasingly complex; this work led this evolution. This continuous discussion provides new learning as it moves the field and in so doing to ensure its pertinence to the modern field of contemporary strategic organizational practice.

As sectors converge within dynamic and complex fields, traditional risk management practices often fail to address the layered risks of modern operations. For instance, in fields like transportation, where numerous variables interact and risks can have far-reaching consequences, traditional approaches are insufficient. Enterprise Risk Management (ERM), originally developed for the business sector, has successfully transitioned into other domains, including transportation (Kepchar, 2023). We demonstrate that ERM's ability to securitize risk management illustrates its versatility and its importance in the strategic adaptations of organizations, not as a stand-alone practice, but as an integrated part of the organization. Berry and Phillips (1998) suggest permanence of risk management strategy (ERM) to the continuity of strategic planning and optimal allocation and utilization of resources.Unlike traditional approaches, which often focus on isolated projects, ERM adopts a holistic perspective, embedding risk management into the core operations of an organization. This view is a contemporary approach to robust, thorough risk governance frameworks(van Staveren, 2014), because risk is woven into the very core of organizational operations. It enables entities to be more resilient and agile by enabling the ability of entities to respond to new and existing risks at all levels of an entity's operation.

The methods of risk management for the field of transportation have become more differentiated and involve both qualitative and quantitative estimations which satisfy the needs of the sector'sdynamic area. More advanced techniques, such as Delphi panels, SWOT analysis and scenario planning systematically unearth potential technological, financial and operational risks, assess their impacts and improve their manageability (Weber, 1990; Smith, Merna, & Jobling, 2006). Development of strategic responses to reduce an organization's vulnerability and increase its resilience and ability to adapt requires proactive identification and management of such risks(Schäffer, 2020; Weis & Klarner, 2022).

In addition, there are important roles for proactive risk communication and participation of diverse stakeholders in the use of risk management. Effective risk management framework requires the involvement of parties from the academia, industry and government that gives a holistic, comprehensive and inclusive strategy(Hansson & Aven, 2014; Hollnagel, 2014; Motarjemi & Moy, 2014 and Satô et al., 2020) . Such broad-based engagement ensures that risk management frameworks are robust, transparent, and aligned with the goals of all stakeholders. Conversely, a lack of inclusivity or transparency can undermine the integrity of these frameworks. When done correctly, stakeholder engagement strengthens the viability of risk management approaches and enhances their alignment with the objectives of all parties involved.

The growing interest in risk management as both an academic and practice discipline is accompanied by significant theoretical and methodological advancements. The objective of this paper is to examine how these highly sophisticated risk management techniques can be used in the context of Research Centers.University Transportation Centers (UTCs) act as potent enablers toward supporting advancements in transportation systems and policies based on research, innovation, and resulting improvements. Research Centers occupy a unique position at the interface of academia, industry, and government, facingdistinctiverisks that require tailored management strategies.

Using Secondary data, this study explores risk management strategies unique to UTCs, incorporating historical perspectives with contemporary practice to frame an overarching framework. This robust framework servesas the foundation for examining and discussing targeted risk management strategies in subsequent sections of the paper.

2. REVIEW OF LITERATURE

This paper reviews the literature and evaluates how integrated risk management strategies are needed within the research centers. Because of increasing complexity of challenges that research centers stand before (ethical, technological, financial, regulatory and other), the risk management is an essential prerequisite to the success of research projects and, what is the most important, their continuation. Research centers need a Holistic framework through which they systematically will have to identify, assess and mitigate risks in all the dimensions of their operations. This serves as reasoning to this fact that, according to Norwich (2025) for its resilient project management in research environments, conventional methods should be changed (with the provision of flexibility, adaptability and perpetual program in risk strategies). This integrated approach provides considerable progress in advancing the business cases and research, which helps to protect against the unanticipated and stay focused on the alignment between the objectives of research and strategic goals.

One of the reasons that Abbey et al (2023) suggest that they have captured the risk management strategies was that most standards use the component but few make explicit that effective communication of risk management strategies is part of this framework to attract the funding the center seeks. Such a framework is needed for technical intricacies of research project that would need transparent communication to foster trust and a clarity among stakeholders to plough through.

Believe as noted by Ou-Yang and Chen (2017), Alavi et al., (2016) the risk management practices in research center are supposed to secure funding. However, lately it seems as if, by adding these practices to communication strategies, transparency becomes even more transparent, and trust in funders even stronger. Between these dual approaches a more nuanced engagement is developed with opportunity investors who have become much more demanding of risk management strategies that are much more complex and bore more detailed presentations.

The risk management process in research centers as indicated by Machireddy et al (2021) invariably involves the use of a systematic approach in dealing with technological uncertainties, financial viability and operational efficiency. However, the limited human and financial resources due to most research centres making the development of financially and risk management strategy robust even more critical (Ashta& Herrmann, 2021; McKendry, Whitfield & Duffy, 2022).

We have added another layer of complexity because what is important is how you are able to conform to what is called regulatory compliance and ethical considerations especially in areas like healthcare. Proposals coming forth from research centers must not only show that they are thorough in the risk assessment and mitigation procedures, but also that they present these procedures in a way favorable to the strategic interests of different funding bodies including Governmental, Private, and Academic (Omowole et al., 2024).

According to Ike et al. (2021) and Ilebode& Mukherjee (2019), proposals which specifically portray how the research will be capable of accomplishing the funders' goals and managing risks are more likely to secure funding. Such proposals seem viable and also strategically sound to the eyes of the potential investors which increase their confidence. While it is generally recognized that good integrated risk management and communication strategies are important, relatively few such studies have been able to integrate the two in an all encompassing framework. While Bratasanu (2018), Hassan &Mhmood (2021)

etc have explained the significance of processes of adequate risk management, some researchers like Ashta& Herrmann (2021) centre on communication strategies without addressing the operational and technical risks inherent in most research projects.

Balancing the detailed presentation of technical risks with the need to present information to stakeholders that is accessible to them but reassuring without being overwhelming, constitutes the pros and cons of the proposed approach. Sometimes a project, while striving to take high risk mitigation, overplays it from the innovative aspects of a project, or emphasizing too technical details which put off potential funders (Ige, Kupa, &Ilori, 2024).

By recently blending risk management and communication strategies, there is potential for greater stakeholder engagement and improved outcomes to grant acquisition. Though, most of these models are sector specific and not widely applicable (Bayerstadler et al., 2021). A flexible and holistic strategy that links these factors increased chances of trusted funders and securing high value investments Bello, IgeAmyaw, 2024).

To address these challenges Ahmed et al (2007) reviewed the various risk management techniques and pointed out some best practices to integrate this risk management into project framework. Additionally, Hopkin (2018) discusses an organized approach to risk management, essential for research centers to capture such opportunities while preserving the initiatives.

Additionally, compatible with the Government of Canada's Integrated Risk Management Framework (2001) and the Edith Cowan University (2013 Gagno) guidelines, a significant increase in operational continuity and accountability arises from, among other things, increasing cross agency collaboration and embedding risk management into strategic decision making.

Finally, as the research centers undergo the difficulties of raising funds and executing on technical projects, integration of risk management and sound communication strategy is not only beneficial but critical. Future research should build on these integrated approaches by refining them into comprehensive frameworks to tackle the many challenges that arise from the commission of technical research programs, and thereby promote resilience and sustainable progress of research in different sectors.

INTEGRATED RISK MANAGEMENT

The research center has to go about its multifaceted risks that amount to operational, strategic, with informational, and Integrated Risk Management (IRM) is the cogent frame work that the research center need to adopt in order to address the threats. The holistic risk management approach of IRM combines the risk management activities in all research operations domains i.e. strategy, processes, systems and personnel. Robustness in decisions and risks governed within this coordinated framework are informed in support of these principles (Institute of Risk Management, 2019).

Structural silos, cultural resistance and integration issues are common challenges in the process of implementing an IRM framework in research centers due to these centers' operations in inter-disciplinary and dynamic objectives environments, which makes integration complex. Over these barriers, it is necessary to have leadership commitment and an active stakeholder engagement. For example, in order to mitigate such obstacles, it takes strategic planning, transparency and a phased approach of implementation stated by PwC (PwC, 2019). Getting to IRM, nevertheless, requires first establishing a thorough risk assessment of the first step, that is, the identifying of vulnerabilities and uncertainties of RLC. This should include internal factors such as increased technology availability and external factors as a new societal need (ISO, 2018). This allows Research Centers to systematically evaluate risk profile by examining it on a global best practices using such approved frameworks such as COSO ERM (COSO, 2017).

Consequently, a Research Center developing IRM should establish such governance structure, policies and procedures that augments its operational needs. The governance involves defining roles and responsibilities, setting risk appetite and tolerance thresholds and metric for monitoring and reporting risks (Deloitte, 2019) whilst governance mechanism is in line with international standards as anchored on ISO 31000, which gives out various guideline on how to have a well organized and functioning risk management system (ISO, 2018) . These standards make the risk management practices reliable, consistent, and adaptable.

Leadership commitment and role in fostering a risk aware organizational culture are crucial for success of IRM. The aligned institutional goals are essential to the engagement leadership roles in risk governance frameworks. Structured communication and joint decision making are supported through proactive leadership which facilitates the use of heterogeneous expertise in a risk management process. It further strengthens the process by adding stakeholder engagement where the different disciplines and sectors' perspectives are incorporated into risk management strategies.

Through IRM, Research Centers can build conditions enabling the creation of a resilient operational environment to respond to uncertainties and sustain the processes of innovation. IRM holistic approach provides research institutions with a framework to navigate through complex risk landscapes with compliance, safety and alignment with strategic objectives. As IRM principles are integrated into operations, research centers are better equipped to achieve desirable outcomes such as high-impact publications and sustained innovation—while avoiding potential disruptions.

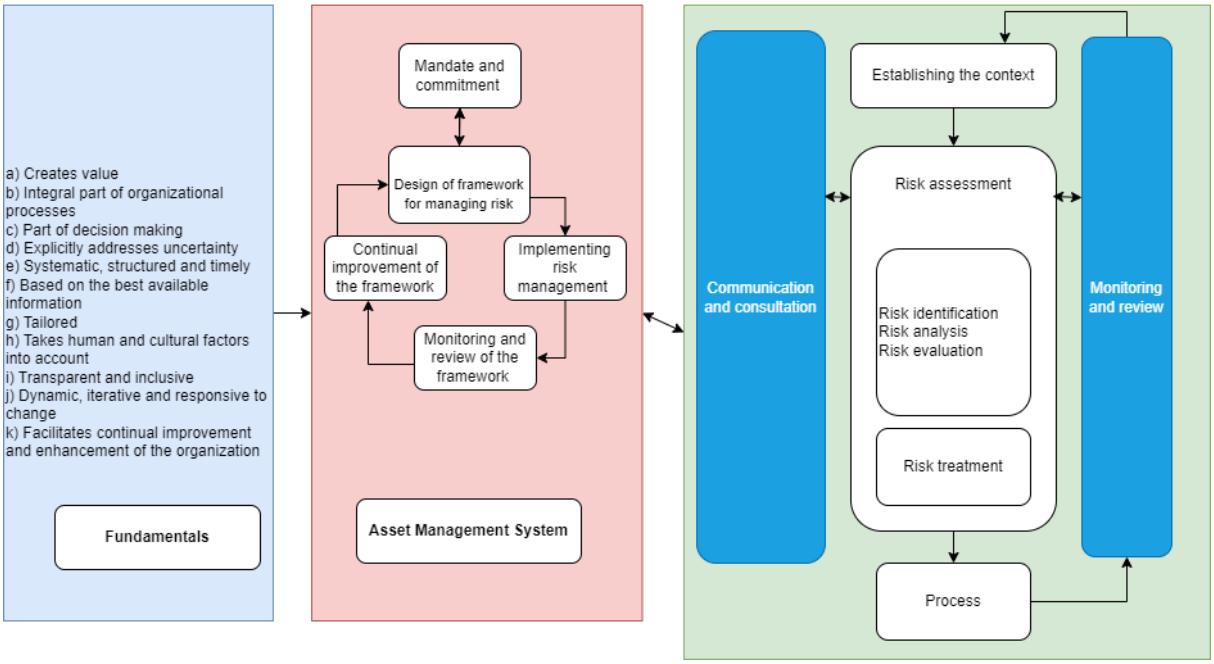

Figure 1: Relationships between the risk management principles, framework, and process ((ISO, 2018)

An ever-evolving framework (system) for risk management is mandated by the concepts underlying the ISO Risk Management standard, as shown in Figure 1. The procedures to be followed while managing risk, which constitute the operational part of risk management, are outlined in the Risk Management Process. A risk assessment consists of many steps, the most important of which are context setting, communication and consultation, monitoring and review, and evaluation. They form an iterative method for risk management when used together.

After initial stages of building an Integrated Risk Management (IRM) framework, research centers must focus on key steps, including developing and implementing targeted risk mitigation strategies, monitoring their effectiveness, and regularly reviewing the organization's risk profile. According to NIST (2018), effective risk management relies on the use of both organizational and technological controls to address anticipated and emerging risks.

The dynamic and interdisciplinary nature of research center combines to make them well placed to utilize modern tools and technologies to optimize implementation of IRM. According to (Gartner, 2021), risk management competencies are expanded through automation, data analytics, technological advancements. With the tools such as risk heat maps and dashboards, Research Centers can be monitoring potential risks in real time and can make data driven decision and take proactive action.

Moreover, emergence of technologies like artificial intelligence (AI), blockchain in research environment can also revolutionize IRM practices. Predictive risk analytics exist that allows research centers articulate risks more accurately given their own specific needs, demands on funded projects and funding priorities of the future. In contrast, blockchain technology affords a secure and immutable way of managing risk transactions and decisions pertaining to transactions and decision that are collaborative and involve more stakeholders where trust and transparency is of prime importance.

Because research environments are complex, the staged and adaptive approach to the effective implementation and evolution of IRM in research centers is necessary. In the fundamental steps, including risk assessment, IRM refinement and development of tailored mitigation strategies are conducted. Again applying the general challenges with overall risk management, the continual challenge of IRM is in continuous monitoring and continuous improvement. It is a cyclical process, requiring a huge amount of committed leadership, active stakeholder interaction and continued commitment to the initiative.

Finally, IRM provides an important paradigm which is to be taken as a guide to navigate through cacophonic, chaotic, and confusing risk environments by Research Centers. Organizational controls, the latest technologies and continuous inputs by means of continuous improvement can be integrated by Research Centers chances are better for improving its risk management and offer better research results. The strategic leadership and staff involvement in adoption of IRM allows Research centers to be resilient and adaptive to achieve the strategic goals(Protiviti, 2018).

Figure 2: Integrated Risk Management domains (Riskonnect, 2023)

3. IMPLEMENTING CORE RISK MANAGEMENT STRATEGIES IN RESEARCH CENTERS

When academia joins forces with industry, the same diversity of environments offers a host of complex risks for Research Centers. The effective way to navigate such challenges requires a triple of strategic fundamental resources, encompassing precautionary, discursive, and risk informed principles, based on frameworks as proposed by (Renn (2008)) or in Society for Risk Analysis (Society for Risk Analysis (2015a and 2015b)). These approaches provide tall order for managing the details of high stakes, interdisciplinary environments.

Risk Informed Strategy: Risk informed strategy is the key of effective risk management. Detailed risk assessments are made about whether to avoid, reduce, transfer, or retain risks, an act of risk treatment. Under this strategy, a high degree of understanding of portfolio risk is a key consideration, in volition to risks that have not only absolute implications but also relative importances in the case when research results can reshape public policies and business practices. Research centers can actively manage the risks surrounding the development of emerging research technology as well as the integration of research across government and private sector boundaries to ensure that the newly researched developments are safe and effective.

Particularly, the precautionary strategy is more appropriate because of its often high stakes nature of research and of public health or safety. The approach consists of the development of safe materials for safe substitutes of hazardous materials commonly used in the semiconductor data facility, and redundancy and flexibility in the critical systems, and flexibility in emergencies. These measures increase the resilience of research centers to avoid unexpected disruptions and achieve maximum operations in different scenarios as well as protect personnel and research integrity.

Discursive Strategy:

An emphasis is given in the discursive strategy on transparency and stakeholder engagement. Research centers that encourage inclusive deliberation and good communication contribute to enhancing the credibility and faith of research centers with different stakeholders such as researchers, industry partners, government agencies, and the public. By implementing this approach, risks and ambiguities are voiced together with the stakeholders and the research initiatives are qualified to societal values and expectations, thus entailing collaborative risk management.

In order to integrate these strategies, research centers can adapt systematic methods recommended by ISO 31000, for example. Such evaluation includes determining and assessing the potential events that could impact on objectives, analysis of the cause and effect of such events, and use of fault tree analysis, Bayesian networks, or similar approaches for a comprehensive risk assessment. Such a structured approach cuts guesswork, and supports the rationale behind risk occurrences and the corresponding impacts.

A risk management framework with a good structure alleviates risks, improves resilience and adaptability, ensuring that

research centers continue to be at the leading edge of research while at the same time safeguarding safety, costs and strategic alignment.

3.1: The Precautionary Principle in Research Centers

It is the basis of the precautionary principle in the management of risks and constitutes in particular the cornerstone in Research Center where scientific uncertainties may lead to high impact. Moreover, this principle has been argued over extensively by, among others, (Renn,2008), (Aven, 2011a) and Cox,2011). It works on two prevalent interpretations.

1. **Precautionary Measures:** If scientific uncertainty about potential consequences of a research activity is significant and these consequences are potentially severe, precautionary measures (e.g., the suspension of that activity) or other means (e.g., consideration of modifying the activity or getting advice from advisers in the field) may be taken to fill the gap until more knowledge becomes available. And in research environments where there might be very significant public health or environmental safety implications for outcomes.

2. **Regulatory actions:** these are undertaken where research may release potentially hazardous agents into the environment or risk human health but no definitive data is available. It ensures that there is no need to be taken by dangerous locations and keeping to the safe and sustainable approach.

The idea is in the precautionary principle that decision makers can act without data or even uncertain data. It does not specify the criteria used for application, but demands an assessment of relative risks with benefits for inclusion. For instance, in high risk, oil and gas, even if risks are well known, there is a need for very strong safety measures to mitigate known risks, like fires.

The precautionary principle operates in research centers to balance the concern of risks without an appropriate protective measure justified by the policy, taking into account the potential threat, on the one hand and the social benefits of scientific advances, on the other. The creation of such a foundation of prudence ensures long term safety and integrity of public trust while encouraging responsible innovation to flourish.

Research centers can incorporate the precautionary principle and further the fields of knowledge and innovation without harming safety or public trust if they incorporate the precautionary principle in their risk management frameworks. Based on this principle, risk informed and discursive strategies constitute fundamental bases for research center's work in high stakes, interdisciplinary environments. Research centers can continue operating resiliently by structured and adaptive approaches and adhere to strategic objectives as well as societal expectations in the stakeholder confidence.

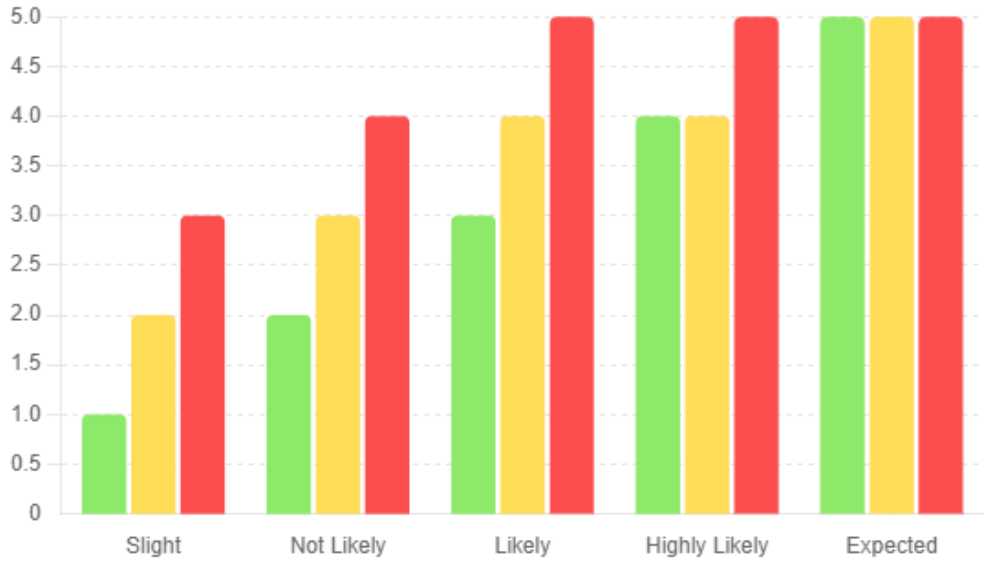

Figure 3: Risk Matrix: Likelihood vs. Impact (Risk management: The precautionary principle)

This picture figure 3 exhibits the precautionary principle on risk management how the interrelationship between likelihood and impact levels. It classifies the risks as low, medium and high according to the risk severity and the degree of risk probability. This visual also shows how Research Centers can quickly rank risks and perform protective action for loss of safety and public confidence.

3.2: Robustness in Risk Management for Research Centers

Resarch centers are inherently situated in uncertain and highly dynamic environments and as such the risk management frameworks of research centres inherently prefer robustness as a first class effort. Making an advocate for this strategy means

strengthening research centers to deal with unexpected pyres without compromising their operability yet meeting their purpose.

Research effort has been devoted to enhancing robustness for the contexts that are linked to research and development (e.g., Baker, Schubert, & Faber, 2008; Hites et al., 2006; Roy, 2010). These studies emphasize the value of robustness, the capacity ofamodels in mitigating risks and ensuring safe,operational research processes in the face of"approximations" and "ignorance." For instance, robust optimization has been applied to the development of performance preserving strategies which operate across a spectrum of uncertain scenarios(Gabrel, Murat and Thiele, 2014).

In practice, for example, it may involve building up a research centres' infrastructure that can take partial diversions or robust supply chain practices to keep research centres running when disturbed or short (Klibi, Martel, & Guitouni, 2010; Joshi & Lambert, 2011). Particularly important for centers whose access to commercial facilities requires uninterrupted access to specialized materials and technologies. Resistance to adversity is just the first part of robustness; robustness also has the ability to adapt graciously to changing risks and recover quickly from disruptions. For example, Topics (Roy,2010) stress the need for robust solution which satisfy feasibility and performance under the worst of all circumstances. Since the results of experiments or technologies in the research environment may turn out more unpredictable and external factors including regulatory or marketing changes can disturb the direction of a technology, such robustness is indispensable.

It is a challenge in robust risk management to strike a balance between over preparation and under preparation. They (Gabrel, Murat & Thiele, 2014) point out that determining an acceptable degree of robustness, which avoids too constricting the engagement with innovation while being ready to cope with the worst cases and to adjust to the less extreme but more likely situations, is essential. This balance holds essential in the process of making decisions on an uncertain environment.

In practice, robustness in research centers is implemented by use of decision support tools, which facilitate scenario analysis and sensitivity testing. By its use, one can identify the most critical risks and can assess how different possible mitigation strategies will affect them (Joshi & Lambert, 2011). Then such analyses must be supported by managerial reviews and adaptive strategies based on continued risk assessments and external developments.

As such, research centers have a strategic, as well as a technical, imperative to be robust. It supports the sustainability and continuity of research work and allows centers, even in the presence of major uncertainties, to pursue their prime goals.

Figure 4: Robustness in Risk Management(https://www.bizzbuzz.news)

Figure 4: Five key elements of building a strong risk management framework. It is assumed that the design is congruent with the professional and adaptable themes of research centers.

3.3: Implementing Resilience in Research Centers

The concept of resilience must be adopted by risk management in research centers because the challenges in balancing innovation and safety compliance in research centers are important to address. In general, resilience means the organization's

ability to react to, withstand and adapt to uncertainties, surprises or risks (what are called 'shocks') which jeopardize the integrity and/or exercising their basic requirements and performance.

Intractable problems of inherent uncertainty and high stakes are commonly encountered by research centers. Resilience is advantageous for these centers, which are part of complex projects involving multiple stakeholders, and becomes essential in many cases. In terms of safety management, (Hollnagel et al.,2006) propose a resilience concept that includes: the capacity to adaptively treat the normal and irregular threats; the capacity for continuous monitoring of operational performance; the capacity to predict the potential risks; and the capacity to learn from previous experience. Scholarship (Lundberg & Johansson, (2015 and Weick & Sutcliffe, 2007) : past research has well documented the importance of resilience in the management of unpredicted challenges and high reliability in operations. In all of these studies, there is an argument made for a culture of 'collective mindfulness' or constant vigilance, not oversimplifications and so forth and such that learning and adaptation should become an intrinsic part of operational practices. Scholars such as (Righi et al., 2015 and Conway et al., 2010) help research center develop resilience engineering as critical framework. Resilience engineering differs from the standard technique for risk assessment, which makes use of static and historical models of failure. Today, the dynamic and complex research environment requires sophisticated tools for understanding and actions to unexpected events - Functional Resonance Analysis Method (FRAM) and System-Theoretic Accident Model and Processes (STAMP) are just two such tools. Unlike resilience for failure prevention, resilience for research centers is about thriving in the competitive and uncertain environment. What it means is to be able to cultivate adaptability, flexibility, and robustness to accommodate and make the best of the research challenges that will be encountered and the opportunities that arise. Integration of resilience in risk management strategies ensures that research center not only survive but thrive in a dynamic rapidly changing research landscape.

In addition, resilience fits the wider scope of socio-technical systems risk management frameworks, which give research centers the opportunity to be prepared for expected and unexpected scenarios. Such proactive approach allows research centers to be ready when the unexpected happens while still being nimble enough to take advantage of the unexpected opportunity to lead innovation and excellence as part of a research ecosystem.

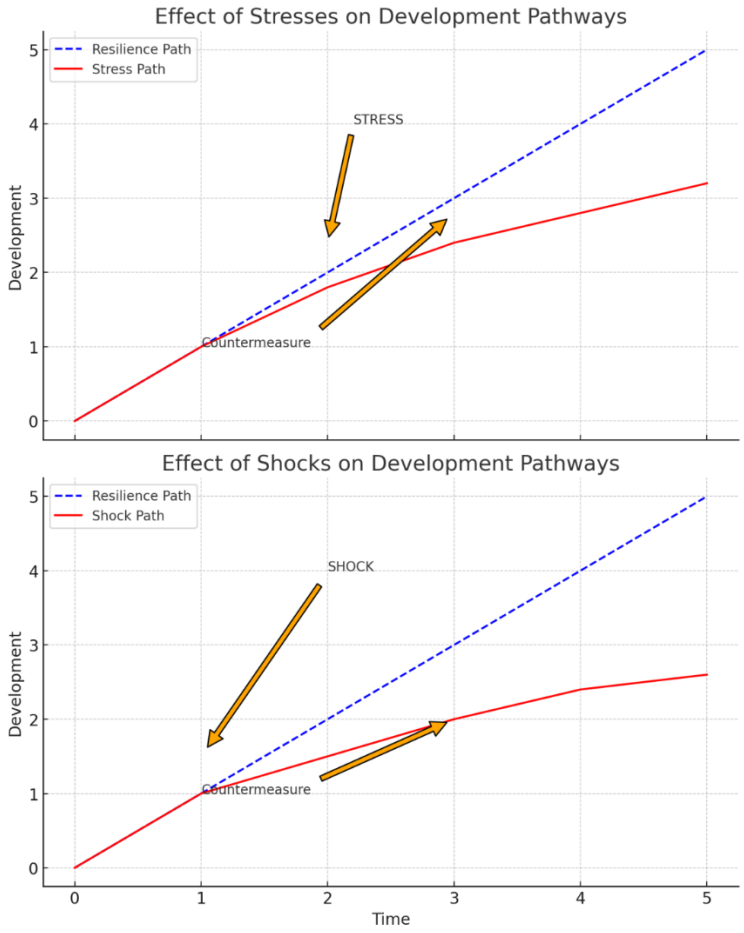

Figure 5: Shocks and stresses and their effect on development pathways according to different levels of resilience (Conway et al., 2010)

In Figure 5 the impacts of stresses and shocks on different development pathways, and as such, how resilience can be utilized

to manage regular and irregular threats are demonstrated. The stresses of the first graph diverge gradually from resilience pathways but are mitigable with countermeasures, as shown in the figure. The second graph shows rapid deviation caused by a shock that has to be robust against countermeasures to recover development.

3.4: Navigating Large/Deep Uncertainties in Research Centers

For example, in the realm of research centers, capacity to manage shallowness and largeness of deep and scale uncertainties is critical to tackling the complex and evolving phenomena caused by climate change and emerging diseases. Given rapid change or novelty of the risks, traditional risk management methods, which typically rely on historical data or established models (often with assumptions about the capital industry), may not apply or are limited by the lack of these resources in creating an estimate of risk.

As argued by (Cox, 2012), robust and adaptive methods are, overall, superior ways for dealing with deep uncertainties. The approaches include a suite of tools to help make decisions when classical models fail to perform. This is, for instance, robust optimization, Bayesian model averaging, and adaptive boosting, which let the decision makers not only to build strategies that will behave on average well in an entire range of future scenarios, but at the same time link these generally quite simple descriptive strategies to these actual scenarios via some weighting factor.

Adaptive management is particularly appropriate for systems where research centers are operating under deep uncertainty. This uses an iterative process of decision making in which the actions are reconsidered and fine tuned in the light of ongoing monitoring and analysis of new data and insights. This type of process is therefore allowed to treat the risks, which are of a qualitative nature and cannot be quantified, while keeping options open for responding to unanticipated events or information gaps.

Both (Aven, 2013a, 2013b), do stress the use of abductive reasoning in order to expand the analytical scope away from those frames that are traditionally used in risk assessment. Through this, you look at what data and models exist currently and are open to how to think about problems in new and innovative ways. Research centers should focus on developing a culture in which uncertainty is seen as an opportunity to innovate and learning, if they are to espouse this mindset.

Following Lambert et al. (2012) , to put the emphasis on how to achieve absolute robustness, the emphasis should be dropped on achieving absolute robustness in decision making rather on identifying and managing the most critical uncertainties. A balance between safety and operational priorities is maintained, while the research centers can perform their resource and effort allocation in a manner that best responds to both safety and operational effectiveness priorities.

Integration of these advanced risk management strategies into the modern scientific challenges mitigates the inherent research challenges. If taken carefully, the part of deep uncertainty can be broken down into manageable components for planning and adaptation. Not only does this make the centers stronger at combating current challenges, but it outfits them with the capacity to lead in the anomalous spaces of science and creativity.

3.5: Addressing Surprises and Black Swans in Research Centers

The concept of Black Swans profoundly influenced risk management by showing the importance of unexpected, high impact event, which said by Nicholas (2008). Taleb's extensivel yan Aven (2015) and Chichilnisky (2013)It is worthly ponders>> of other's contributions, emphasizes the need of organizations, including Research Centers, therby to be prepared to such events that fall out of the prediction model range and are beyond 'normal' expectations.

The Black Swan theory from the vantage point of Research Centers that are active at the forefront of the field of technology and knowledge stresses the significance of resilience and adaptability. These institutions should not only know risks that have been quantified through a historical data but should also be aware of risks beyond traditional expectations (Aven,2015). Aven's key arguments about how to manage risk effectively in these centers focus on the need to avoid having 'Mediocristan' — predicting based on standard distributions and known probabilities. On the other hand, "Extremistan" risks are vastly variable and distinct from one another as they are with different orders of magnitudes of scale and impact.

According to Aven (2015), Research Centers need to adopt risk management approaches in which they shield the knowledge dimension and integrate the knowledge, as well as tapping into the unfeasible knowledge that is out of the reach of materials like traditional statistical techniques. However, these practices are crucial to adaption risk management strategy as it continues to adapt to unforeseeable events [Cox, 2012].

Furthermore, Research Centers' strategic planning should include the concept of antifragility(Taleb, 2012). Antifragile is the ability to create systems and processes that not only survive them, but thrive through them to generate more novelty than could be found anywhere else. The Research Centers, together, will have to work from a global perspective to risk management by doing qualitative and quantitative reviews and preparing for a complete spectrum of options.

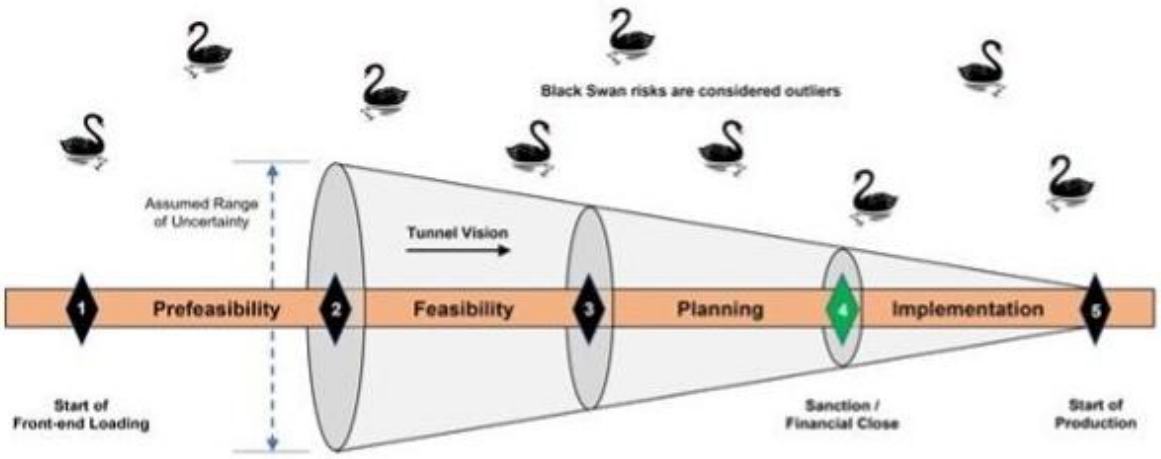

Figure 6: Tunnel vision and Black Swan risks (Rodrigues et al., 2014)

Stages of development through which risk management is applied to Research Centers are placed and descriptions of the limitations of the process of risk identification, mainly caused by tunnel vision is presented. Figure 6 illustrates this, in the fact that complete consideration has to be given for recognizing Black Swans as outliers amongst the full range of uncertainty. The figure portrays a vital progression of phases developing from prefeasibility, through feasibility exploration, planning, and last advancement stages, and accordingly proposes that adaptable hazard administration strategies should address unpredictable, high effect occasions to achieve viable answers.

3.6: Risk Criteria in Research Centers

The use of risk criteria in balanced decision making process in research centers where innovation, safety, profitability, and reputation intersect is important. These criteria simply reduce complex judgments to discussions of acceptable thresholds of risk and begin the process of making tradeoffs. Risk criteria, as per (Rodrigues et al., 2014) , are tolerability levels and acceptance thresholds for decision making processes, without losing track of safety and excellence in research.

However, these are the criteria needed to tackle those issues pertinent to research centers. For example, laboratory operational decisions must balance safety measures for the protection of personnel with new, important experimentation. At the same time, this challenge is similar to many other businesses and the Norwegian petroleum industry in particular where risk acceptance criterias for major accidents and environmental protection are strictly defined (Vanem, E. (2012). Abrahamsen and Aven (2012) point out though that defining such criteria can sometimes fail to reflect the typical understanding of fairness and inclusion and that in these cases the accountability can only be guarded through external oversight or validation.

A main problem with probabilistic risk criteria is that it may overlook the uncertainties in estimations of risks (Aven, 2015). Probabilities are useful, but may not tell the whole story about the risks embedded in novel and untried technologies that are critical to many research center initiatives. To do this decisions should adopt a risk aware approach that takes quantified metrics of the uncertainties and qualitative insights into the uncertainty.

ALARP principle is a flexible framework that allows applying to risk measures in research centers. Gross disproportionality, which provides the basis for applying ALARP, is grounded in both risk informed and precautionary thinking, and it assures ALARP not to provide disproportionate neglect of safety for ALARP cost (Ale et al. 2015). It is of great importance that research centers integrate statistical rigor, managerial judgment, and stakeholder engagement in its risk evaluation framework. These institutions should follow robust, adaptable criteria to move for a safer, more innovative research environment and prove social and environmental responsibility.

3.7: Integrative Perspectives in Research Center Risk Management

Risk management in research centers is presented from an integrative perspective as being a complex and inevitably interconnected form of managing risks. I develop a robust approach that integrates the traditional risk management, resilience and antifragility ideas into designing robust and adaptive risk management strategies. Such integration is able to ensure that research centers go beyond just mitigating risks; that they innovate and keep refining.

For example, (Renn,2008) show how risk governance is multidimensional. Renn creates a method that not only blends scientific evidence with economic, social and ethical considerations, as the research center does in linking technology and social impact, but also fits into the idea of a research center bringing technology and societal impact together. Likewise, as Aven and Krohn emphasize development and sharing of knowledge, use of experience, and interdisciplinary insights—important for any institution that has to deal with emerging risks and uncertainties—institutions such as Campvast are

outlined in their framework.

These integrative framework's are dependent on collective mindfulness and important especially within organizations that are considered High Reliability Organizations (HROs). HRO principles which are adherence to preoccupation with failure, reluctance to simplify, sensitivity to operations, and commitment to resilience and deference to expertise (Weick & Sutcliffe, 2007) are followed in research centers. Such approach helps in preventing the risk, acting adaptively in response to emerging new challenges, and keeping an environment conducive for continuous learning.

The concept of antifractionalality is the importance of thriving under uncertainty and change (Taleb, 2012). This means not only recompense from the disruptions but developing them as growth and innovation opportunities for research centers. By embracing uncertainty, these institutions will be able to strengthen their capacity for innovation by preserving a firm risk management framework. In a nutshell, integrative perspectives offer a balanced and multidimensional approach to risk management, enabling the research centres to deal with the complexities while taking up the responsibility of safety and societal progress.

3.8: Integrating Innovation Risk Management Practices in Research Centers

3.8.1 Tailoring the Integrated Model for Research Centers

Integrated risk management model has to be adopted in research centers working in multidisciplinary interdisciplinary and high stake environments. The stage-gate innovation process (Keizer et al, 2008) is a suitable formalization for researching iteratively and explorative.

3.8.2 Building Capacity for Risk Management

Training programs that provide more practical use of both qualitative and quantitative risk assessment methods could develop institutional capability. Moreover, (Dewett,2004) emphasizes high-level management's attitude with regard to fostering a favourable surround to chance informed decision making. Regardless of their approach, Leaders in Research Centers must engage in either actively championing for innovation or adopting a balanced risk management to assure that the initiative risks are managed properly.

3.8.3 Adapting Risk Management across the Innovation Lifecycle

Therefore, differential risk management strategies to enhance innovation and still secure safety and feasibility are required. On the other hand, for idea generation, and concept development, draft and simple tools, such as brainstorming, and risk assessment can be used with minimal constraints.

However, risk management becomes more and more critical as projects go through the process from initial concepts to experimental validation and implementation. And the issues of uncertainty must be addressed in complex research activities and advanced techniques such as probabilistic risk assessments and scenario planning are inescapable. It provides a means by which Research Centers can effectively compete technology innovation with risk reduction, something (Tidd et al., 2015)'s model advances.

3.8.4 Embedding Organizational Learning

According to (Jantunen, 2005), one critical limitation in most of the research centers is a lack of systematic organizational learning. Often, individual successes are not translated into institutional knowledge because of lacking documentation and knowledge sharing practice.

This gap should be addressed by establishing central, robust repository of risk assessment and project outcome for the research centers. These repositories serve as repositories for collecting both qualitative and quantitative insights towards continuous improvement of future risk management practices. For example, past failures can be documented in experimental stages and those responsible for a failure can be identified in order for future risk of the same to be mitigated proactively.

3.8.5 Customizing Risk Management Systems for Research Centers

However, due to the operational diversity of Research Centers instances would require risk management systems that are context related. Therefore, these systems must be able to consider aspects such as regulatory regulations, research focus and funding gestations. In fact, for example, as a demand side driven center of technology, it may emphasize more on the market dynamics and intellectual property issues while biomedical research may be ruled by strict moral and safety codes.

(Tidd et al., 2015)'s combined risk innovation framework being a flexible model which is customable for the purpose of guiding this customization to ensure that risk management practices are kept relevant and effective. In parallel, collaboration with these stakeholders, the academic institutions, the industry, as well as the government agencies, becomes critical. The roles and responsibility that should be clearly defined in a structured agreement, the accountability, and trust are higher.

3.8.6 Enhancing Research Outcomes through Integrated Risk Management

Incorporating practices of innovation risk management in the research environment can help Research Centers to address the complexities of the modern research environment better. This method offers a rich, adaptive one in which risks can be hedged

and new ground can be broken for big discoveries. Research centers can with success accomplish its mission by focusing on safety, creativity, and societal progresses.

4. CONCLUSION

Sophisticated and agile risk management approaches via Research Centers are key to aid moving academic innovation onto industry and government priorities. To fail to recognize the inadequacy of traditional risk management practices to the dynamic, multifaceted, and complex risks in the research environment would be a failure of this study. Integration of risk-informed, precautionary and discursive approaches provides Research Centers to better cope with uncertainties and to stimulate innovation.

This points to the necessity to differentially use risk management techniques from the ideation to the staged implementation of research. Additionally, the study also discusses the importance of encouraging organizational learning and creating cooperative engagements in order to increase risk resilience. Addressing deep uncertainties that leave us vulnerable to occasional high impact events, like Black Swans, provides the strength which makes operational frameworks of Research Centers so powerful.

Research Centers, in adopting tailored and a synthesized risk management models, not only guarantee their persistence but also be able to innovate and adapt to broader societal and scientific objectives. In these institutions, risk mitigation is largely a responsibility, and they are instead positioned as today's pioneers in building up resilient, impactful and forward-thinking research landscapes.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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