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**How risk science can explain the cautionary thinking and risk seeking  
behaviours in society**

Henry Ssekyewa

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## Abstract

In the aftermath of the Covid-19 pandemic, several researchers have accentuated the influence of risk and uncertainty on human behaviour. With perspective to the rippling effects of Covid-19 pandemic, it is the objective of this thesis using a broader set of examples of risk behaviours, to reflect how risk science through its fundamental concepts, principles, theories can explain the individual and societal behaviours in the face of risk and uncertainty.

Overall, the discussion identifies the risk characteristics of the selected examples, and using risk science concepts and theories analyses how individual and societal behaviours could be explained. In the case of vaccination against covid-19 virus, the overall implementations of government policies were grounded on precautionary principle, hence the earlier interpretation of a new vaccine against Covid-19 pandemic being an expression of cautionary behaviour in society, however, when analysed through the anti-precautionary principle, the use of a new vaccine to remedy covid-19 pandemic is an expression of both risk seeking and cautionary behaviours. The study of the case illustrates the overlap of societal values of protection – save lives, and development – find a medication, full reopening of socioeconomic activities. In the case of use of football helmet in American football relative to rugby, we observe that the interaction of social processes and risk over time leads to positive secondary effects as evidenced with innovation in helmets, social advocacy and institutional accountability. In the case of rocket launch sequence, the flight readiness protocols are an exemplification of five principles of high reliability organizations, but also note that human resource is core to the enhancement of safety and performance under uncertainty. In the case for diversification of portfolios, the nature of the increasingly globalized and industrialized society renders it vulnerable to systemic risks as seen with Covid-19 pandemic whose rippling effect could potentially disrupt the financial markets. As such diversification across different sectors may offer respite to market forces. In the case of venture capital financing, the secondary aspects of risk such as familiarity, voluntariness and experience inform the decision making under uncertainty. With participation in extreme sports, the potentially catastrophic consequences and voluntariness to the hazard influence the interaction with risk, but also inform risk avoidance strategies.

In conclusion, the review and study of the examples of risk behaviours in which the society express cautionary thinking, risk seeking behaviour and mix of both, we find that society's experience and interaction with risk often carries auxiliary effects. For example, in some examples, familiarity and voluntariness with risk are associated with risk seeking behaviours, and because of the interaction with the risk, the society is incentivised to reduce uncertainties or mitigate the consequences of the hazard, thus resulting in innovation. Further, we realize that while government policies upon which the vaccination program were based were justified using the precautionary principle, the relatively new idea of anti-precautionary principle may very well explain the government policy.

## Abbreviations

ECDC	European Centre for Disease Prevention and Control
WHO	World Health Organization
SARF	Social amplification/attenuation of risk framework
PPE	Personal protective equipment
NASA	National Aeronautics and Space Administration
VCs	Venture Capital firms
HROs	High Reliability Organizations
NFL	National Football League
IPO	Initial Public Offering
SRA	Society for Risk Analysis
PCR	Polymerase Chain Reaction

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# 1 Introduction

## 1.1 Background

Several authors (Aven & Boudier, 2020; Chan et al., 2020; Kimhi et al., 2020) have highlighted Covid-19 pandemic influence on research with particular focus on human behaviour in the face of risk and uncertainty. They note that in an effort to limit and mitigate the spread of the coronavirus, most countries instituted restrictions and measures. As a result, most individuals and society in general would have had to adjust and adapt their daily routines and activities to government instituted measures and restrictions. However, Aven and Boudier (2020) highlight that in situations as evidenced with coronavirus pandemic where the phenomena underlying the risk is unknown or associated with deep uncertainties, and accompanied by very weak knowledge base, any efforts to develop a strategy to counter the pandemic clearly required a balance between conflicting concerns. Without considerations of the varying societal conflicts and interests, these very measures spurred auxiliary consequences – social, political, economic and health in nature - to the society.

While Kimhi et al. (2020) suggest that Covid-19 pandemic presented a considerable challenge to both researchers and professional practitioners for the fact that no such extensive pandemic had occurred in modern times, as such no available literature on risk and human psychology could definitively have anticipated the individual and societal coping mechanisms in prolonged exposure to risk and uncertainty. Zhang (2021) while acknowledging earlier research by Bavel et al. (2020) emphasizes that because of the novelty of Coronavirus, the lessons from previous virus outbreaks could not directly be applied to Covid-19 pandemic.

It is worth noting that health risks can be characterised by deep uncertainties with potentially catastrophic consequences, which when the consideration of globalized society and systems is taken, health risks can quickly evolve into systemic risk since they are rooted within a broader context of societal, economic, and political risks (Klinke & Renn, 2006). In the case of coronavirus pandemic, the globalized economic, social and transport infrastructure accelerated the spread of coronavirus, while government measures aimed to slow the spread and possibly reduce the associated consequences, these very measures had unintended effects on individual and social behavioural response (see Ammar et al. (2020)). These responses in turn became significant obstacles to the efficacy of the health emergency preparedness and response programs as they worsened the spread of the coronavirus.

This is in line with Abbas and Eltayeb (2022) who point out that the Covid-19 pandemic exposed a weakness within the health care and emergency preparedness infrastructure in that the response systems did not account for human behaviour in situations of prolonged exposure to risk and uncertainty. As such, they argue that understanding individuals' risk perception is

vital insight into their response, behaviour and adoption of preventive measures (Abbas & Eltayeb, 2022). Abbas and Eltayeb (2022) assert that an individual's sense of compliance to health guidelines is influenced by their beliefs, attitudes, and perception. While Aven and Boudier (2020) acknowledge earlier works of Slovic (2010) on risk perception - particularly the effect of amplification of risk and emotions, and the research by Tversky and Kahneman (1973) on availability heuristics and the effect of negative events, to highlight the societal experience of risk and subsequent risk behaviour and decision-making.

## 1.2 Knowledge gap and objective

Despite the considerable research on individual and societal behaviour under risk and uncertainty, the coronavirus pandemic has demonstrated the existence of significant gap between theory and practice. While Aven and Boudier (2020) acknowledge the limited societal impact of risk science, they assert that risk science still exemplifies a crucial knowledge base for guiding the application of principles, concepts and theories for assessing, communicating and managing of risk. Several researchers support this assertion, for example, Kimhi et al. (2020) acknowledge the challenge presented by Covid-19 to the global community and its impact on society's wellbeing and functioning, while pointing out the research opportunity with regard to time variable of risk and effect on individual and societal behaviour. Aven and Boudier (2020) make reference to the earlier work of Lofstedt and Boudier (2017) on the role of uncertainty and knowledge, to assert that risk science ought to provide clarity on the definition and interpretation of fundamental concepts on risk, as the way in which risk is conceptualised and defined can influence the perception of risk and risk behaviour.

With perspective to the rippling effects of Covid-19 pandemic, it is the objective of this thesis using a broader set of examples of risk behaviours, to reflect how risk science through its fundamental concepts, principles, theories can explain the individual and societal behaviours in the face of risk and uncertainty.

## 1.3 Scope and limitation

This thesis seeks to a study example of cautionary, risk seeking and mix of both behaviours while drawing to reference to risk science to identify the structural characteristics of these risky activities that may explain individual or societal response and better predict coping mechanisms in the face of increasing and inevitable natural disasters, health epidemics, environmental hazards, socio-political and economic crises.

For examples of cautionary behaviours, this paper reviews the use of a new vaccine to remedy the consequences of Covid-19 pandemic, and the use of head helmets in American football relative to rugby; for risk seeking behaviours we review venture capital financing, and the

involvement in extreme sports; and the for the mix of cautionary – risk seeking behaviours we review the rocket launch sequence in space exploration, and diversification of portfolio.

The study of risk behaviours will be limited to review of available open-source literature and information.

#### 1.4 Structure of the thesis

The structure of this thesis is such that in chapter 2 we shall reviews the theoretical aspects of risk behaviour, while in Chapter 3, we introduce fundamental concepts from risk science that that we believe can explain the societal experience of risk, in chapter 4, we present a brief review of the selected risk behaviours, while in chapter 5, we present discussion on the applicability of these concepts from risk science on the societal experience of risk using the examples selected risk associated activities and finally in chapter 6, we present a conclusion.

## 2 Theory

In industrialized countries, risk is increasingly a bellwether of social discourse on economic development, and health and environment safety (Kasperson et al., 1988). With Chan et al. (2020) asserting that the very central features of modern global society, i.e., globalisation and urbanisation, make them more vulnerable to the challenge of pandemic diseases and their global implications on social, political and economic infrastructures. While Ramezani and Camarinha-Matos (2020) note that contemporary societies and their organizational structures and systems are increasingly challenged by unexpected disruptive events with extreme effects, while the current engineering and socio-technical systems are designed to operate under stable conditions.

In the face of these systemic risks associated with complex and deep uncertainties with potential to cripple the entire global economic system, many institutions are increasingly seeking management strategies that can enhance the safety and reliability of their operations while avoiding mishaps (Khorsandi & Aven, 2014).

### 2.1 Risk perception

Chan et al. (2020) present an evolutionary point of view to assert that people are risk-inclined but also control-inclined. While alluding to situations of prolonged exposure to risk, Chan et al. (2020) contend that cognitive re-evaluation is a core feature in risk perception as individuals rethink their actions and adjust their behaviour accordingly. They argue that in such prolonged exposure to risk environment whereas perceptual, emotional, and motivational factors remain active, it is rather the strategic, tactical, or operational factors that become dominant predictors of behaviour (Chan et al., 2020). As such Chan et al. (2020) argue that risk-taking is a coping mechanism to environmental changes and uncertainty while control of the environment is necessary for risk reduction and survival (see also Trimpop (1994)). Hintze et al. (2015) assert that risk aversion is a universal behaviour common to both humans and animals, to highlight why psychologists and behavioural economists seek to model risk aversion behaviours in attempt to predict human behaviour. While Paulsen et al. (2012) define risk aversion as the tendency to prefer certain over risky options.

Kasperson et al. (1988) accentuate the multidimensionality of risk as they emphasize the evolution of risk over time and space, while arguing that technical risk assessments generally analyse the impacts of an event or human activity in terms of direct harm only, yet consequences of risk can extend beyond direct harm to include significant indirect impacts. As Renn (1998) contends to the breadth of societal experience of risk, while establishing that it encompasses not only the public perception, but also the appraisal of risk context, non-physical impacts of risk and the historical interactions between the risk and social or cultural artifacts.

While psychological research on risk has demonstrated that the perceived properties of the risk source or the risk situation affect the perception of risks, Renn (1998) elucidates on these qualitative risk characteristics which include personal control, institutional control, familiarity, voluntariness, dread, artificiality of risk source, equitable distribution of risk, blame etc. Chan et al. (2020) assert that risk perceptions are deeply embedded into socio-cultural backgrounds, and as such risk behaviour is the product of an interplay between individuals, actions of others, and the community or social - environment (see also Rhodes (1997), Zinn (2008)).

Renn (1998) affirms that risk perception can be described by way of perceived violations of what humans' value, perceived patterns of occurrence, and social context variables. As such Renn (1998) asserts that to integrate public perception and risk assessment, a clear definition of the term risk and risk management is necessary. Yet Renn (1998) acknowledges that there is no universally accepted definition for the term risk, consequently the concept of risk means different things to different people. Renn (1998) submits that the distinction between reality and possibility is one element common to varying risk concepts and as such defines the term risk as the possibility that human actions or events lead to consequences that have an impact on what humans' value (see also Rosa (1998)).

Renn (1998) accentuates the social scientist's view of risk as a social construct of potential threats that are capable of claiming real losses and thus argues that public perception should govern the selection of risk acceptability and tolerability criteria. Renn (1998) adds that risk concepts from a social science point view hold that the causes and consequences of risks can be mediated through social processes, hence, the focus on personal or social preferences (see also Brehmer (1987); Lopes (1983)).

## 2.2 Social values and Preferences

Renn (1998) highlights the pluralistic nature of our society while alluding to difference in value systems, as such the forementioned researcher argues that risk managers are confronted by a multitude of competing cognitive claims, values and interpretations. The resulting conflict between professional risk assessor and the risk bearer unfortunately impedes the management of risks in accordance with rational criteria of risk reduction and fair burden sharing (Renn, 1998). Consequently, a challenge arises as to what values or preferences should guide collective decision making (Renn, 1998). While Renn (1998) also asserts that risk management entails at least three value judgments including risk acceptability or tolerance criteria, cost- benefit trade-offs criteria, and strategies to cope with uncertainty.

The existential threat of external factors, for example political pressure, economic factors etc, imply that institutional structure of managing and controlling risks are prone to organizational failures and deficits, which may increase the actual risk ( Renn (1998); see also Perrow (1984); Short and Clarke (1992)). As such, Renn (1998) enunciates on the effects of political pressure

in the face of scarce financial resources on risk reduction measures and increased public concern for environmental and health hazards.

Due to the existence of risk and the associated consequences, possible risk reduction remedies will be suggested based upon the risk assessments carried out. This creates a resource allocation challenge as priorities and selection criteria to determine the boundary between tolerable and intolerable risk levels and consequently the question as to who sets the standards (Renn, 1998).

Organizations are continually confounded by resource allocation problem, whilst risk management process is in essence an exercise in resource allocation, necessitating the balancing of conflicting interests inherent in exploration of opportunities on the one hand, and avoiding losses, accidents, and disasters, on the other (Khorsandi & Aven, 2014; Vinnem & Aven, 2007). However, Renn (1998) cautions the use expected values in creating priority list of public concerns as they tend to obscure variance in individual and social group differences towards risk perception and thus unable to capture the effect of group affiliation, social and cultural orientations (see also Aven (2019)).

Renn (1998) argues that risk context is relevant in social discourse as simplistic risk reductionist strategies are not the only society concern, noting that people will bear the harm if it is justified or if it serves as means to other goals, however, Renn (1998) concurs with (Linnerooth-Bayer & Fitzgerald, 1996; MacLean, 1986), that people will reject risk if it is imposed on to them or it is in violation of their attitudes and values. Kasperson et al. (1988) emphasize that the assessment of risks is both a scientific activity as well as an expression of culture. Whilst Renn (1998) advocates for a dual risk management strategy incorporating socio-political concerns and technical risk assessment to better address the dual nature of risk demands. Renn (1998) suggests that public values and social concerns should determine the selection criteria risk tolerance or acceptability whereas technical assessments identify and compare the performance of different options for risk reduction.

### 2.3 Risk attitudes

In real life situations, Renn (1998) postulates that people use contextual information for example their experience and familiarity, as cues to base their individual judgements, however, in the face of new and challenging information, cognitive dissonance may occur in which people defend their previously held beliefs and thus are reluctant to absorb new information and adjust their risk attitude (see also (Festinger, 1957; Heimer, 1988)).

Renn (1998) asserts that individual risk response is shaped by their perception of risk and as such scientific assessment influence the individual response to risk only to the degree that the technical assessments integrate their individual perceptions. While an individual's attitude

embodies their beliefs about the nature, history, consequences and justifiability of a risk cause (see Thomas et al. (1980)), Renn (1998) asserts that the person's perception of risk is part of an attitude that person holds about the cause of the risk.

Chan et al. (2020) affirm that there is a stark difference between how we perceive risk and actual risk which can trigger varying behavioural responses. They add that risk attitude rather than actual risk influence behavioural responses and as such more or less information may induce changes in risk perception (Chan et al., 2020). While Donohew et al. (2000) allude to individual differences in risk-taking in arguing against the general assumptions of rational model of decision-making in which individuals are assumed to carefully weigh possible choices and outcomes as they go through their lives.

Risk-taking attitudes and behaviours are important elements of human behaviour as they determine a range of decision-making strategies in the face of complexities and uncertainties underlying risk situations and environment ((Chan et al., 2020), see also (Rieger et al., 2015; Savage, 2019). Risk attitudes matter as they elicit individuals to make trade-offs that influence their risk behaviour (Chan et al., 2020).

In deference to the work of Weber et al. (2002) on decision research, Paulsen et al. (2012) posit that individual risk preference are situational dependent, for example risk associated with recreational, social, financial or health related activities. As such Paulsen et al. (2012) underscore the need to distinguish between different types of risk-taking contending that the context of varying risky situations is fundamental to how value is assessed and consequently, decision making. Paulsen et al. (2012) extend their argument for the distinction in types of risk-taking in context and situation to assert that an individual can exhibit both risk- seeking and risk averse behaviours.

In the following chapter, we review relevant fundamental concepts, theories and principles that can accentuate the individual and societal risk behaviour including the social amplification/attenuation framework (SARF), antifragility, the concept of collective mindfulness as espoused by high reliability organizations (HROs), the precautionary principle, the prospect theory, the portfolio theory, and anti-precautionary principle.

### 3 Fundamental concepts from risk science

Aven and Bouder (2020) note that risk is a generic term and as such is characterized by fundamental knowledge base that integrates insights from broad scientific disciplines, while translating this knowledge back into various application. However, Kasperson et al. (1988) acknowledge the limitation of risk science, noting the inability of current risk concepts to comprehensively anticipate and explain public risk response. For example, Aven and Bouder (2020) highlight the coronavirus pandemic and its effect on risk studies, while enunciating on the influence of a global pandemic on risk science, risk communication and risk management.

While Khorsandi and Aven (2014) argues that with the increased complexity, interdependencies and interconnectedness of systems, anticipating the risk of future events requires an interdisciplinary effort as there can be many system variables at play that can affect the properties and behaviour of a system. Kasperson et al. (1988) accentuate on the complexity and transdisciplinary nature of risk, while acknowledging earlier research Hoos (1980); Wynne (1984) that noted potential for social processes to influence the propagation of risk effects. Still, Aven and Bouder (2020) assert that risk science provides the most justified knowledge available for assessing, communicating, and handling risk (Aven & Bouder, 2020). Following, we review the set of identified concepts, theories and principles from risk science which are relevant to the examples of individual and societal risk behaviours and can explain their response in the face of risk and uncertainty.

#### 3.1 Social amplification- attenuation of risk framework

Despite the advancement in risk analysis and management strategies in health, environment and safety over the last century, Kasperson et al. (1988) observe that modern society still views itself as less secure. They highlight public concern and social impact of particularly risk events with relative minor physical consequences on conventional risk analysis (Kasperson et al., 1988) . Kasperson et al. (1988) note that risk analysts and societal management of risk in general are confounded by a dilemma in which seemingly minor risk or risk event as assessed by technical experts elicit massive public response, often accompanied by social, political, and economic impacts. For example, the Arab spring that was triggered by a confluence of factors including corruption, economic stagnation and technology in form of social networking platforms.

The narrow and ambiguous focus of risk assessments on probabilities and magnitude of consequences fails to capture other aspects of risk that may shape the public response for example the familiarity with the hazard, voluntariness, personal ability to influence the risk, the catastrophic potential etc., and as such probabilistic risk assessment fail to inform societal choices and response (Kasperson et al. (1988), see also Rayner and Cantor (1987); Renn (1986); Slovic et al. (1982)).



Kasperson et al. (1988) argue that risk only has meaning within a context of the interaction between risk events and social processes, and as such information system and characteristics of public response are essential elements in determining the nature and magnitude of risk (Kasperson et al., 1988). Kasperson et al. (1988) assert that information systems may amplify risk events either by intensifying or weakening signals that are part of the information that individuals and social groups receive about the risk, or by filtering the multitude of signals with respect to the attributes of the risk and their importance. Kasperson et al. (1988) argue that social context may alter the focus and scope of risk assessment while illustrating how the tendency to filter information about hazards may profoundly alter the form and content of the risk information produced.

In effort to address the short falls of technical risk assessments, Kasperson et al. (1988) propose a framework capable of integrating the cultural, social and individual response that shape public experience of risk into technical risk analyses.

Kasperson et al. (1988) introduce the concept of social amplification and attenuation of risk whose central proposition is that risk events interact with psychological, social, and cultural processes in ways that can heighten or attenuate public perceptions of risk and related risk behaviour (Kasperson et al., 1988). Kasperson et al. (1988) define social amplification of risk as "a phenomenon by which information processes, institutional structures, social or group behaviour, and individual responses shape the social experience of risk, thereby contributing to risk consequences." Renn (1998) suggests that the social amplification and attenuation of risk framework as proposed by Kasperson et al. (1988) can better articulate the social experience of risk as it highlights the duality of risk as an objective threat and a social construction.

Kasperson et al. (1988) argue that the concept of social amplification of risk is dynamic in the sense that it entails a continual social learning and interaction with risk. Understanding the different interactions of risk, society and cultures may explain the social response of risk amplification and attenuation, thereby informing risk analysis and management process (Kasperson et al., 1988). Renn (1998) asserts that the social amplification of risk framework reflects the interaction between hazards and the psychological, social, institutional, and cultural processes.

Kasperson et al. (1988) posit that the concept of social amplification of risk can provide guidelines on how to model the complex relationships among risk, risk analysis, social response, and socioeconomic effects. Kasperson et al. (1988) assert that social amplifications of risk shapes behavioural responses, which, in turn, can initiate auxiliary effects whose consequences can act to either amplify the risk itself, for example demand supplementary remedial barriers, changes in risk monitoring and regulation, changes in training - education,

or required qualifications, political and social pressure, social disorder, enduring mental perceptions etc.

Renn (1998) contends that the amplification - attenuation risk framework integrates psychological perception, social influences and cultural preferences to articulate how a risk event can amplify or attenuate individual and social perceptions of risk and shape risk behaviour. Renn (1998) elucidate on the social amplification and attenuation of risk during public perception process pointing to research demonstrating that many people have a fairly accurate representation of expert assessments when ordering risks, but overestimate highly publicized, large-scale health, environmental and technological risks, while underestimating routine risks with low catastrophic potentials. However, in situations where technical risk assessments grossly underestimate overall risk, Kasperson et al. (1988) argues that the society through social amplification provides a corrective mechanism.

Kasperson et al. (1988) raise the case of social attenuation of risk in which the society exhibits comparatively little or no interest at all in risks with demonstratively significant hazards. These forementioned researchers argue that social attenuation of risk is a coping mechanism through which individuals adapt to the multitude of risk and risk events encountered daily (Kasperson et al., 1988).

Kasperson et al. (1988) contend that the foundation upon which social amplification lay can be found in social experience of risk both as a direct personal experience and through indirect experience as information received about risk or risk events. Direct experience of risky events not only accentuates the perception of risk as it increases memorability and imaginability of hazards (Kasperson et al. (1988), see also Slovic (1986)), but it can also enhance and inform risk avoidance strategies by way of feedback on the nature, extent, and manageability of the hazard (Kasperson et al., 1988).

Kasperson et al. (1988) also note that in absence of direct personal experience of risk, information mechanisms of social amplification become principal element in public response, and as such the attributes of information for example the volume, extent of dramatization, symbolic connotations of the information and the level of expert disagreement may influence social amplification. Kasperson et al. (1988) emphasize that the volume of information flow irrespective of the accuracy or content may serve as amplifier as the media coverage may define and shape the issues (see Mazur (1984)) as it directs public attention toward particular risk problem, in doing so, they awaken and enhance latent fears about that particular risk (see Sorensen et al. (1987)).

While cautioning the adverse consequences from underestimation and under response by risk analysts and public, Kasperson et al. (1988) acknowledge the confounding relations of social amplification and attenuation on conventional risk analysis.

## 3.2 Antifragility

Societies around the world are increasingly interconnected through a set infrastructures such finance, transport, communication etc that are susceptible to random and somewhat unexpected disruptive events with catastrophic consequences. Ramezani and Camarinha-Matos (2020) allude to the increasing frequency and impacts of the disruptive in recent times drawing examples from security, health, politics, climate and environment. While these black swan type of events are associated with unpredictability and harm in their effects and consequences, Ramezani and Camarinha-Matos (2020) acknowledge the earlier work of Chroust and Aumayr (2017) who postulated that it is reasonable to assume that future scenarios in which turbulence and instability are no longer episodic crises but, the new normal.

Taleb (2012b) introduced the concept of antifragility as a blueprint for living with rare and random events associated with large consequences and deep uncertainty (Aven, 2015a). Taleb (2012b)'s concept of antifragility acknowledges the nature of these black swan type of events associated with deep uncertainties, while suggesting the embrace of the variability and randomness so as to learn and improve. While Taleb and Douady (2013) find support for antifragility in evolution asserting that the natural selection process is an example of antifragility with adaptability to large deviations and volatile environment increasing the survival rate of robust species.

The notion underlying the fragility and antifragility is the sensitivity for variability and uncertainty of environment or system. Taleb (2012b) defines fragility as an accelerating sensitivity to a harmful stressor which mathematically culminates in more harm than benefit from the effect of random events, while the forementioned researcher suggests antifragility leads to more benefit than harm. Taleb and Douady (2013) assert that fragility is associated with system failure from the variability of its environment beyond its threshold limits whereas antifragility is associated with improvement under variability and uncertainty.

Taleb (2012b) argues that empirical data, history, or statistics are not relevant in the prediction of rare and random events, but rather the assessment as to whether the item is accelerating towards harm or benefit. Contrary to Taleb (2012b) perspective on risk predictability and management of black swan events, Aven (2015a) argues that the objective of risk management is not to accurately estimate the probabilities of rare events, but rather to reveal and assess underlying uncertainties, and make adequate decisions under uncertainty. In situations of limited resources, informative risk descriptions provide decision support necessary to find proper measures to confront potential events from occurring (Aven, 2015a).

Aven (2015a) further posits that judgment of the level of antifragility of the system can be made with reference to historical performance, as well as judgments of the robustness of the system and system's ability to learn and make improvements (Aven, 2015a). Aven (2015a) argues that

there is no objective description of the fragility level, noting that it is strongly dependent on the analysis carried out, the methods used and the analysts involved – further emphasizing that assessments are based on assumptions and simplifications. Aven (2019) advances the notion of potential surprises while alluding to the limitations traditional risk management approaches in complex systems, noting that surprising scenarios will always occur in such systems as risk assessments cannot conclusively provide analysis and solutions to meet the associated risks. While the forementioned researcher notes that the potential for surprises is relative to the current knowledge (Aven, 2019). While Aven (2015a) cautions against the subjectivity (or intersubjectivity) of risk experts' estimates noting that surprising events of black swan type may occur in relation to the expert judgements made, and as such uncertainties and surprises ought to be incorporated into the various risk concepts and measurement.

Aven (2015a) discerns the difference between antifragility concept, and the other risk science concepts of robustness and resilience, pointing out that all the three risk concepts address the stress dimension, however, the antifragility concept extends beyond established functions to linking variation, uncertainties, and risk at the stress level to improved learning and future development.

Taleb (2012b) presents the concept of antifragility as a solution to rare, random, and surprising events where no extreme negative events occur in antifragile systems, only positive ones. As such Taleb (2012b)'s concept of antifragility holds that antifragile is protected from adverse events where the system guarantees no extreme negative consequences (Aven, 2015a). However, Aven (2015a) digresses with that supposition arguing that for any real-life system, we cannot ignore the possibility of a major negative event occurring, while noting that even with continuous improvements, complex systems are only antifragile to an extent.

Aven (2015a) suggests that making incremental system improvements over time will reveal a possible trend towards antifragility, where consequences will typically be minor, with the higher the probability of large positive consequences and the lower the probability of negative consequence. Aven (2015a) contends that the antifragility concept is complex as it incorporates time dimension in risk assessment by embracing randomness, variation and uncertainties, this the forementioned researcher argues will result in improved system performance. Aven (2015a) notes antifragility concept emphasizes the importance of continuous improvement, even with rigid operational design systems, Aven (2015a) contends that there is potential operational and organizational improvements.

The antifragility concept espouses the interdisciplinary nature of risk analysis, with its emphasis on improvements over time especially the understanding of variation and focus on learning drawing parallels to quality management (Aven, 2015a; Aven & Krohn, 2014). With regard to the ability to learn and make improvements, Aven (2015a) accentuates the five principles of the concept of collective mindfulness, linked to high reliability organizations

(HROs) as way to improve the overall understanding of risk by discerning important signals and warnings and acknowledging uncertainties and the importance of knowledge.

Aven (2015a) surmises that antifragility concept's main features are rooted in its embrace of uncertainty and variation of underlying the risk, improved learning, and performance of the system over time.

### 3.3 High Reliability Organizations – Concept of Collective Mindfulness

Today, many of the vital infrastructure is increasingly complex, vast and interconnected, and as a result, the consequences of failure are extreme, catastrophic and systemic while being associated with deep uncertainties and unknowns. Khorsandi and Aven (2014) contend that fundamental to understanding, and consequently managing risk, is the uncertainty component of risk, noting that a proper acknowledgement of uncertainty entails understanding the value as well as the limitation of the underlying knowledge and the available information with respect to the situation. Under the circumstances, several researchers argue that to maintain and even improve system performance in the face of uncertainty requires a perspective on risk which looks beyond conventional risk assessment and management methods (Aven, 2015b; Khorsandi & Aven, 2014; Taleb, 2007, 2012a).

Khorsandi and Aven (2014) assert that risk management efforts are strongly influenced by the risk perspective adopted, arguing that for organizations that are seeking to improve their risk management capabilities and enhance the reliability of their operations, a broader perspective on risk and uncertainty may be critical to the convergence of the concept of reliability with risk management field. Khorsandi and Aven (2014) accentuate the hypothesis that organization's risk perspective can enhance the reliability of their decision, while pointing to earlier research by Roberts and Bea (2001) who suggested that it is organizations that empower their people to recognize and respond to a variety of problems that have fewer accidents, to assert that an organization's attitude towards risk can influence its performance under uncertainty.

While the pursuit of high reliability necessitates finding novel ways to reduce uncertainties, seeking new knowledge and updating existing information while enhancing communication infrastructure within the organization (Khorsandi & Aven, 2014), the forementioned researchers acknowledge the resource constraints for many organizations seeking to achieve and enhance reliability in decision-making.

Under situations of high risk and large uncertainty, several researchers have proposed that the concept of collective mindfulness as a perspective to address risk and uncertainty as it stimulates greater awareness of uncertainties, and how they are interpreted, evaluated, and communicated (Khorsandi & Aven, 2014). The concept of high reliability organizations

(HROs) focus on potential for failure is epitomised by the process of mindfulness attention to the interactions between risk and uncertainty (Khorsandi & Aven, 2014). As such the concept of HROs has come to exemplify the organizations enduring quest for to balance the tension between operating safely and reliably, while maintaining operational efficiency (Khorsandi and Aven (2014), see also Rochlin et al. (1987)).

Sutcliffe (2011) argues that concept of HRO provides insight into adaptive organisational forms for complex environments. Sutcliffe (2011) notes that HROs embrace systems with interdependence, continuously evolving operations environment resulting in variability and uncertainty in situations. Khorsandi and Aven (2014) highlights the increased complexities of systems today while acknowledging the limited understanding of the underlying processes, and thus assert that for organizations seeking to achieve reliability in operations need to create a culture of mindfulness that enables them to think and interact with uncertainty as this would encourage a more informed understanding and appreciation of risks.

While drawing insight to earlier works of Weick et al. (1999); Weick and Sutcliffe (2001), Khorsandi and Aven (2014) contend that HRO theory accentuation of the cognitive processes of mindfulness facilitates organizations' efforts to create and maintain situational awareness of their surroundings and the risks they face while seeking ways to enhance their ability to manage and mitigate such risks. According to Khorsandi and Aven (2014) the course to establishing a culture of mindfulness and the achieving its associated principles and capabilities as risk management strategy is not straightforward at least in part due to varying perspectives on risk and uncertainty.

The existing literature on the concept of HRO is closely linked to organizations operating in complex and hazardous environments while articulating the distinctive traits that enable them to achieve and maintain high reliability and effectiveness in high risk and deep uncertainty environments doing so not only with hindsight and foresight, but also in real time, and in constantly evolving situations (Khorsandi & Aven, 2014). While Sutcliffe (2011) argues that despite the diversity of high reliability organizations, these organizations share a number of similarities including operation in unforgiving social and political environments, operate risky technologies with potential for error, while the scale of possible consequences from errors excludes learning through experimentation, and that these organization deploy complex processes to manage complex technologies ( see also Roberts and Bea (2001); Roberts and Rousseau (1989)).

Sutcliffe (2011) highlights the distinction in HROs attitude towards variation while acknowledging earlier work of Weick et al. (1999) in which HROs attitude is referred to as mindfulness, noting that the organizations purposely organize their resources with the objective of increasing awareness to details such that they can detect the slightest subtle ways in which contexts may vary, thus enabling them to track small failures (preoccupation with failure), resist oversimplification of what they face (reluctance to simplify), remain sensitive to current

operations (sensitivity to operations), maintain capabilities for resilience (commitment to resilience), while taking advantage of shifting locations of expertise (deference to expertise) (Sutcliffe, 2011).

Weick and Sutcliffe (2001) in an effort to identify the ways in which HROs establish mindfulness, point to the organization's preoccupation with failure – where they focus on detecting warning signals or potential threats to system operations and performance. Khorsandi and Aven (2014) emphasize that because of the rarity of events, magnitude, and seriousness of the consequences, HROs cannot afford to learn from trial and error and as such understand that achieving reliability is a function of uncertainty management, where they have to use every opportunity to learn and improve their systems for detecting, reporting, and managing errors, and safety concerns to avoid failures.

With increased complexity and sheer scale of data, organizations are constantly challenged as they seek a broader understanding of their systems and environment in which they operate and on which decisions and action are based upon (Khorsandi & Aven, 2014). Bea et al. (2009) caution on the dangers of simplification as this could limit their ability to identify and respond to potential threats with Weick and Sutcliffe (2001) pointing out the characteristics of HROs reluctance to simplify.

For organizations seeking adequate protection from the spectrum of risks they face especially from rare or surprise events and threats from external factors, risk assessments and uncertainty analyses are important tools for generating transparent representations of uncertainties (Khorsandi & Aven, 2014). However, even with the best of intentions, the analyses are subject to the assessor's knowledge and biases, as such acknowledging the limits of the assessor's ability to accurately capture all aspects of uncertainty is fundamental to HROs maintaining a heightened level of awareness regarding the state of their system and operations (Khorsandi & Aven, 2014). Achieving a greater sensitivity to operations is rooted in the effort to detect and act upon errors or threats to their operations (Khorsandi & Aven, 2014; Weick et al., 1999).

Khorsandi and Aven (2014) suggest that resilience encapsulates the organization's capacity to absorb, manage, and recover from the impact of disturbances and surprises. Resilience embodies the ability to cope with variability and rarity associated with unexpected events, as such resilience entails learning and adapting to changing conditions (Khorsandi & Aven, 2014). Khorsandi and Aven (2014) point to HROs great emphasis on uncertainty, asserting that this leads to an innovative mindset while noting that “the more we know about what they do not know, the greater they can recognize the importance of instituting variety in their actions and contingency options for handling uncertainty.” This embrace of uncertainty as multidimensional variables broadens their representation and interpretation allowing for imagination of the wide range of possible actions to managing risk which is in essence a manifestation of commitment to resilience.

To emphasize commitment to resilience of HROs, Sutcliffe (2011) argues that the characteristic of HROs is not that they are error free but that errors do not disable them. Several researchers have argued that resilience is the inherent ability of an organization to absorb strain and maintain or recover a stable functional phase in spite adversity (Sutcliffe (2011), see also Sutcliffe (2003)). As such HROs invest and build capabilities for resilience enabling them to cope and manage the continuous fluctuations associated effects before their effects escalate (Sutcliffe (2011); see also Schulman (2004); Weick et al. (1999)). Sutcliffe (2011) argues that it is these mechanisms for monitoring and reporting small warning signals before they can spread throughout the system that encapsulate HROs flexibility and capabilities to respond in real time thereby maintain stable functional state.

Khorsandi and Aven (2014) acknowledges the constraints with regard to time, resources and access to available knowledge, as such decisions in high-risk operation necessitate deference of decision making authority to those with the available expertise or knowledge of the situation (Roberts, 1990). As such in hazardous situations that require quick decision-making during operations and where preserving safety is of utmost importance, effective decision making revolves around those with expertise (Khorsandi & Aven, 2014). To emphasize the need for deference to expertise as a characteristic of HROs, Weick and Sutcliffe (2001) alludes to the filtering of information that is received by the higher ups while cautioning the demerits of filtering in the managing unexpected events.

### 3.4 The Precautionary Principle

The health and environment are often associated with highly complex and poorly understood systems, whilst activities within the these fields necessitate a balance of conflicting pressures of economic growth and social and environment protection (Kriebel et al., 2001). For example, the use of fertilizers and pesticides within farming, while they may improve agricultural productivity in the short term, their long-term effects are often unknown, as these chemicals may sink into underground contaminating the water aquifers and wetlands for which many organisms depend, and even more direct effect on human body organs and nervous systems of the farmers applying them is often not disclosed by the manufacturers.

Kriebel et al. (2001) acknowledges the growing understanding that human impacts on ecosystems are multiple and integrated, while advocating for interdisciplinary teams so as to develop a greater understanding of the ecological context of health and advance biodiversity conservation and ecosystem health. As a limitation of conventional scientific methods, Kriebel et al. (2001) allude to difficulty to study interaction effects. They assert that for complex biological systems; such as human physiology, ecosystems or human populations; the cause-effect relationship are non-linear (Kriebel et al., 2001). They raise the issue of complexity and narrow understanding of phenomena for which risks are associated while emphasizing the limitation in knowledge generation noting that at times even informative experiments to study the systems simply cannot be conducted for ethical or logistical reasons (Kriebel et al., 2001).



Kriebel et al. (2001) make reference to the example of endocrine disruption in wildlife to emphasize the relevancy of multidisciplinary research while noting that because of the fragmentation of scientific discipline it is not only difficult to develop coherent hypotheses but also challenging to find new insights from a narrow disciplinary viewpoint. Kriebel et al. (2001) acknowledge that inherent uncertainties in data and theoretical assumptions in risk assessments, while emphasizing the assessor's knowledge limitation, assumptions and professional judgements and biases that require reconciliation by decision makers.

Several researchers have raised the point that science cannot replace decision making process (see Aven (2019)), but emphasize that it is simply a decision support tool to inform risk assessment used by the decision makers (Kriebel et al., 2001). Foster et al. (2000) accentuate the notion that precautionary principle is a concept for decision making under uncertainty whose implementation necessitates assessment of the uncertainties in scientific data associated to the potential hazard. Kriebel et al. (2001) emphasize that the motivation for precautionary principle is rooted in great complexity, scientific uncertainty, and potential for catastrophe in the event of occurrence of a specific hazard.

The precautionary principle provides an overarching framework upon which policies geared towards the protection of human health and the environment in the face of uncertain risks are based, but demands exploration of wide range of preventative alternatives to harmful activities, while shifting the burden proof to the proponents of the activity (Kriebel et al., 2001).

Foster et al. (2000) acknowledge the varying formulations of the precautionary principle noting that this raises possible policy issues with regard to interpretation and consequently implementation. The oft cited variant formulation of the precautionary principle is the Rio Declaration on environment and development that stipulates that:

“the lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation” (Foster et al., 2000).

While Aven (2019) cites the SRA (2015) definition of the precautionary principle which stipulates that:

“If the consequences of an activity could be serious and subject to scientific uncertainties, then precautionary measures should be taken, or the activity should not be carried out.”

While Kriebel et al. (2001) acknowledge earlier research by Jackson (1999) where the precautionary principle defined as such:

“When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause-and-effect relationships are not fully established scientifically.”

However, Kriebel et al. (2001) accentuate the central feature of the precautionary principle in decisions under scientific uncertainty and argue that when there is substantial scientific uncertainty about the risks and benefits of a proposed activity, then policy decision should err on the side of caution with respect to the environment and the health of the public. As such the principle places the onus on those who seek implement the activity for which hazards are associated to provide the evidence to the contrary.

Kriebel et al. (2001) also raise the points of opposition to the precautionary principle among which are that principle stifles innovation, and that as a decision theory, the precautionary principle advocates making decisions without adequate scientific justification. Sandin et al. (2002) also acknowledge the critics of precautionary principle with the view that the principle is in contrast with a scientific approach to risk assessment and risk management. Sandin et al. (2002) acknowledge that the objection to the precautionary principle's lack of specificity poses a problem for the proponents. But Sandin et al. (2002) accentuate the premise of the precautionary principle noting the conditional requirement for actions be taken when there is lack of full scientific certainty, while highlighting that the condition does not mandate that precautionary measures be implemented when there is no particular evidence of the presence of a possible hazard (Sandin et al., 2002).

While recognizing the controversy of the precautionary principle within Risk management as regard to development and trade protection, Foster et al. (2000) acknowledge the widespread political support of the precautionary principle particularly its role within environmental and health protection. Aven (2019) acknowledges continuous society contentions regarding development and protection, white noting that these conflicts are rooted in societal differences in values and priorities, but also the scientific and analytical argumentations. As such, Aven (2019) argues that the cautionary principle, and by extension the precautionary principle, find role in protection of society from potential hazards and threats with serious consequences by giving weight to uncertainties. Aven (2019) further asserts that being cautious is in essence a human behavioural response in the face of uncertainty and risk. From the various definitions of the precautionary principle, the condition for scientific uncertainty and caution are a reflection of risk aversion.

### 3.5 Prospect Theory

Kahneman and Tversky (1979) posit that “people perceive outcomes as gains and losses, rather than as final states of wealth, where the gains and losses are defined relative to a reference point, which usually corresponds to the current asset position.” However, the location of reference point and the coding of outcomes as losses or gains, can be affected by the formulation of the offered prospects and by the expectations of the decision maker (Kahneman & Tversky, 1979). As such Kahneman and Tversky (1979) assert that “the carriers of value or

utility are the changes of wealth, rather than the final asset positions that include current wealth.”

Kahneman and Tversky (1979) contend that this assumption is compatible with the basic principles of perception and judgement as people’s perception are an evaluation of changes or differences relative to reference point rather than an evaluation of absolute magnitudes. Kahneman and Tversky (1979) emphasize the prominent characteristic of attitudes to changes wealth that is the upset that one experiences in losing a sum of money appears to be greater than the pleasure associated with gaining the same amount, as such, the value function of losses is steeper than the value function of gains. They further observed a greater reduction in desirability of the prospect when its characteristics are altered from a sure gain to a probable one, than when both the original and the reduced prospects are uncertain (Kahneman & Tversky, 1979). While Kahneman and Tversky (1979) also point out that the marginal value of both gains and losses decreases with their magnitude. As a result of special circumstances on preferences, Kahneman and Tversky (1979) assert that the derived utility function of an individual does not always reflect their true attitudes to money. Paulsen et al. (2012) suggest that emotional affect and potential for serious consequences are meditating factors in decision making underlying risk behaviours.

Kahneman and Tversky (1979) present the prospect theory as an alternative theory of choice to the expected utility theory for decision making under risk. They find justification for the prospect theory in the inconsistencies of the axioms of the utility theory, as they argue that choices among risky prospects exhibit several pervasive effects including the certainty effect and isolation effect (Kahneman & Tversky, 1979).

Kahneman and Tversky (1979) demonstrate the certainty effect a phenomenon in which people overweight outcomes that are considered certain, relative to outcomes which are merely probable. This they argue contributes to risk aversion in choices involving sure gains and to risk seeking in choices involving sure losses (Kahneman & Tversky, 1979). Kahneman and Tversky (1979) illustrate the certainty effect violation of substitution axiom of the expected utility model demonstrating common attitudes toward risk or chance where most people choose the prospect where winning is more probable, but when the probabilities are small, most people choose the prospect that offers the larger gain.

Kahneman and Tversky (1979) further highlight that in the positive domain, certainty effect contributes to a risk averse behaviour for sure gain over a large gain that is merely probable whereas in negative domain, the certainty effect leads to risk seeking behaviour for a loss that is merely probable over a smaller loss that is certain. As such Kahneman and Tversky (1979) introduce the phenomenon of reflection effect, where the outcomes of prospects are only losses and assert that reflection of prospects around 0 (zero) reverses the preference order. They note that reflection effect implies the prevalence of risk seeking in choices between negative prospects (Kahneman & Tversky, 1979). This is consistent with Chan et al. (2020) assertion

that experience of loss may also influence an individual's attitude to risk, as they note risk-seekers might more willing to take risks following losses and more risk-averse following gains. Paulsen et al. (2012) while acknowledging the works other researchers on the influence of emotional processes on risk and decision context suggest that affective heuristics is responsible the reward overshadowing the losses. As such the reflection effect too, violates the expected utility theory as preferences between the corresponding negative prospects are inconsistent with axioms (Kahneman & Tversky, 1979). They surmise that the overweighting of certainty favours risk aversion in domain of gains and risk seeking in domain of losses (Kahneman & Tversky, 1979).

Kahneman and Tversky (1979) establish that the reflection effect eliminates aversion for uncertainty or variability as an explanation for certainty effect. Contrary to the notion that certainty is generally desirable, Kahneman and Tversky (1979) contend that certainty increases the aversiveness of losses as well as risk seeking behaviour (Kahneman & Tversky, 1979).

Kahneman and Tversky (1979) introduce the isolation effect which occurs when people simplify between alternatives by disregarding the components that the alternatives share, and focus on the components that distinguish them, this they suggest leads to inconsistencies in preferences because a pair of prospects can be decomposed into common and distinctive components in more than one way, and these different decompositions could lead to different preferences (Kahneman & Tversky, 1979). While Chan et al. (2020) emphasizes the role of contextual factors in risk-taking, noting that individuals are generally susceptible to the framing effect as they tend to process information differently depending on how it is presented thereby influencing their willingness to take or avoid risk. In illustrating the reversal of preferences as a result of decomposition of prospects, Kahneman and Tversky (1979) demonstrate the violation of the basic supposition of a decision theoretical analysis, that choices between prospects are determined solely by the probabilities of final states.

Kahneman and Tversky (1979) acknowledges earlier research by Edwards (1962); Fellner (1965) who advocated for the replacement of probabilities with decision weights to explain the aversion for ambiguity.

Decision weights measure the impact of events on the desirability of prospects, and not merely the perceived likelihood of these events, however, the decision weight attached to an event could be influenced by other factors (Kahneman & Tversky, 1979). Whereas Schmidt and Zank (2008) allude to sign dependence utility functions to assert that there exist two separate weighting functions, one for transforming probabilities of gains and one transforming probabilities of losses, which do not need to coincide. However, Kahneman and Tversky (1979) delineate between overweighting and overestimation, where overweighting refers to a property of decision weights whereas overestimation commonly associated with assessment of the probability of rare events, while they acknowledge that in real life situations, both

overweighting and overestimation may operate to increase the impact of rare events (Kahneman & Tversky, 1979).

The prospect theory postulates that decision weights be used to replace the probabilities, with the Kahneman and Tversky (1979) noting that people generally assign lower value to decision weights than the corresponding probabilities, except in the range of low probabilities which they suggest could explain the attractiveness of insurance and gambling as people overweight low probabilities (Kahneman & Tversky, 1979).

### 3.6 Portfolio Theory

Markowitz (1991) contends that if an investor were only interested in the expected value of portfolio, then the investor need only to invest in one security that maximizes the expected return, however, Markowitz (1991) asserts that an investment based solely on expected return would be a violation actual or rational investment behaviour. While Elton and Gruber (1997) assert that both individuals and financial institutions face the challenge of how to allocate wealth among alternative assets. Markowitz (1991) emphasizes that diversification is in fact a common and reasonable investment strategy directed at reducing underlying uncertainty within one's investment portfolio. However, Markowitz (1991) assents to the existence of intrinsic uncertainty within economics, while acknowledging the relevance of uncertainty to the analysis of rational investment behaviour. Markowitz (1991) notes that the theory of rational behaviour under uncertainty provides insights as to optimization problem and adequacy of mean and variance criteria.

Markowitz (1999) asserts that as diversification of uncorrelated returns increases, the portfolio risk should approach zero, however, Markowitz (1999) acknowledges the limitations and efficacy of diversification as risk management strategy in cases of correlated returns, while pointing out that even with unlimited diversification, the risk component can be substantial (Markowitz, 1999). This is in line with Aven (2019) who posits that the rationale for use of expected values can be found in law of average numbers in which expectation will approximate with the average value when considering a large portfolio of projects (see also Aven (2017)), however, Aven (2019) contends that interdependencies among activities could lead to deviations between the average value and the expectation. Markowitz (1999) notes that as of 1952, an adequate theory of investment that addressed the effects of diversification when risks were correlated was lacking, as such it was the goal to develop a theoretical foundation for portfolio analysis as a practical way to approximate the maximized derived utility function of a rational investor.

In an article on Portfolio selection, Markowitz (1952) advanced the portfolio theory in which the forementioned researcher hypothesised that investors by behaviour will seek to maximize the expected return of the portfolio as a whole, as such Markowitz (1952) proposed that the

expected return and variance of the return of the portfolio as criteria for portfolio selection (Markowitz, 1999). The portfolio theory envisages investor or firm behaviour as they seek to optimize their portfolio (Markowitz, 1991). Markowitz (1991) maintains that investors are preoccupied with risk and return, and as such these should be measured for the entire portfolio, where the variance is a measure of risk of the portfolio.

Elton and Gruber (1997) assert that modern portfolio theory embrace of variability as one key contribution to portfolio analysis, noting that the investor could not select the assets based exclusively on the characteristics that were unique to the security, but rather, needed to consider the security interaction with other securities, as accounting for the correlations resulted in an ability to construct a portfolio with the same expected return, but less risk than a portfolio that ignored the co-movements between the securities.

Although Elton and Gruber (1997) acknowledge that the mean return and variance of return of a portfolio is simplification of the distribution of returns of the portfolio, they add that mean variance theory remains the cornerstone of modern portfolio theory. They further note that the mean variance portfolio theory was developed to find the optimum portfolio for mean- variance return distributions over a single period, however, the theory can be extended to multi-period portfolio analysis under the assumption of independence of returns between periods (Elton & Gruber, 1997). Elton and Gruber (1997) also find evidence for mean-variance return relations over time.

### 3.7 Anti-cautionary/ Anti-precautionary principle

Khorsandi and Aven (2014) assert that risk management is inherently about resource allocation, necessitating balancing of conflicting interests while avoiding losses or disasters. This is an affirmation of an earlier assertion of Renn (1998) who posited that difference in value systems impede the management of risks in accordance with rational criteria of risk reduction. Aven (2019) articulated on the dilemma further by asserting that the conflicts surrounding development and protection objectives are rooted in societal differences and priorities, and scientific and analytical argumentation.

Renn (1998) accentuated the notion of risk context within social discourse, as the researcher noted that people will bear risk if it is justified, or it serves as means to other goals. With the forementioned researcher further stating that contextual information such experience and familiarity inform individual judgements (Renn, 1998).

Aven (2019) raises the case for situations in which the knowledge underlying the phenomena is weak and consequences are undesirable, but societal values are clear and incontrovertible as is the case with Covid-19 pandemic, where the protection of human lives is the overriding goal.

As such, Aven (2019) envisages as to whether an opposite type of principle for which the consequences are desirable and positive, while the uncertainties (scientific or otherwise) remain, could be formulated.

Without discounting the importance of clarity of uncertainties faced as they inform the decision making context, Aven (2019) presents the case for a broader understanding of risk and underlying uncertainties where the nature of the uncertainties faced is not of utmost importance but rather the actions to mitigate the risk.

As such Aven (2019) introduces the concept of anti-cautionary (anti-precautionary) principle at the intersection of societal values of protection and development, which the forementioned author posits would have the benefit of stimulating actions and measures with highly positive values. The forementioned author sets forth five criteria for the applicability of the anti-cautionary principle that reflect the potential consequences (positive), underlying knowledge (weak) and uncertainties in line the criteria used for both cautionary and precautionary principle (see Aven (2019)).

Aven (2019) suggests that the anti-cautionary principle stipulate as such:

“If the consequences of an activity could be highly positive and subject to uncertainties, then the activity should be carried out and supporting (stimulating) measures should be taken.”

While the anti-precautionary principle could stipulate as such:

“If the consequences of an activity could be highly positive and subject to scientific uncertainties, then the activity should be carried out and supporting (stimulating) measures should be taken.” (Aven, 2019)

While both principles are pro-development, they are conditional on positive outcomes as such the principles are also protection oriented. The anti-cautionary (anti-precautionary) principles would in sense be an expression of risk seeking behaviour while also being cautionary focused.

## 4 Brief review of examples of individual and societal behaviours

### 4.1 Case 1: Use of a new vaccine as a remedy to Covid-19 virus pandemic effects

While person to person transmission of corona viruses were generally considered to be via respiratory droplets either inhaled or deposited on mucosal surface (Ciotti et al., 2020), the ECDC report on infection prevention control and preparedness for Covid-19 (2021) notes that transmissibility for SARS-CoV-2 virus at different stages of the disease remain unclear. The ECDC report on PPE needs in healthcare settings (2020) acknowledged just as much pointing to the knowledge limitation with regard to the rapid evolution of the epidemiological and clinical characteristics of 2019-nCoV infection. The ECDC report on SARS-CoV-2 pathogen (2023) notes that the Covid-19 virus like all viruses evolves and adapts itself through mutation, while emphasizing that some mutations or combination of mutations could provide the virus with selective advantage either through increased transmissibility or ability to evade the host immune response.

Several researchers pointed out that people with mild or no symptoms contributed to the spread of Covid-19 (see He et al. (2020); Liu et al. (2020); Rothe et al. (2020)), however, uncertainties as to relative role of transmission by symptomatic versus asymptomatic persons remained, the implication of which were to efficacy of prevention measures in place particularly in healthcare settings, as infected persons (i.e., the symptomatic) were required to self- isolate, but that is only after the fact. Furthermore, the ECDC report on infection prevention control and preparedness for Covid-19 (2021) acknowledges that the duration of infectivity for SARS-CoV-2 virus was not known with certainty, with some patients identified as PCR- positive over prolonged periods of time after infection and clinical recovery.

The ECDC report on infection prevention control and preparedness for Covid-19 (2021) highlighted the variation in efficacy of Covid-19 vaccines against both symptomatic and asymptomatic infection. As a result of the variation in vaccine efficacy, vaccinated people may still become infected with SARS-CoV-2, asymptotically or symptomatically, while there is insufficient evidence on the efficacy of vaccination on asymptomatic, hence chances of transmission of virus by the vaccinated people.

While ECDC report on infection prevention control and preparedness for Covid-19 (2021) suggests that the neutralizing effect of current vaccines may be reduced against emerging and increasingly more transmissible SARS-CoV-2 variants of concern, however, it holds that vaccination overall would reduce the symptomatic and asymptomatic infection, thereby reducing SARS-CoV-2 transmission. This is consistent with the information from Norwegian Institute of Public Health (2020) demonstrating that the vaccinated people had a lower risk of serious illness than the unvaccinated. As such we suggest that the use of a new vaccine as



remedy to effects of Covid-19 pandemic is an expression of a mix of both risk seeking and cautionary behaviour within the society.

The WHO report on global Covid-19 vaccination strategy (2022) notes that goals underlying the vaccination program include minimization Covid related deaths; reduction of the disease severity and the overall disease burden; the curtailing the Covid-19 pandemic impacts on health system; reduction of virus transmission; and full reopening of socio-economic sectors. As such vaccination as remedy in Covid-19 pandemic is both a protection and development strategy.

#### 4.2 Case 2: The use of football helmets within American football relative to rugby

American football is the most popular sport by broadcast viewership in American sport distinctly epitomized by the football helmet, yet it was not always an essential protective head gear in the sport. Today, the football helmet is a mandatory head gear used as protective equipment in American football at all levels of the game. Like helmets used in alpine skiing, it consists of outer hardened plastic shell with and inner layer of soft shock absorbing cushions, but with varying face masks made of plastic-coated metal bars depending on the football player's position.

The head helmet is mandated as a protective device to improve player safety and reduce incidents of head injuries and concussions suffered by the players. While American football is generally considered a risky sport, the use of football helmet in American football across all levels can be regarded as an expression of cautionary behaviour within the society. Unfortunately, even with improvements in helmet design and advancement in technology, incidents of head injuries and concussions in American football remain as the Washington Post article on Concussions in NFL (3 February, 2023) noted, with dedicated websites tracking football players suffering from concussion during the season as can be seen with the Sharp football analysis website (29 December 2022).

While helmets are mandatory at all levels of American football, rugby, a similar close - contact team sport that involves tough tackling, scrums, rucks and mauls, does not have an essential requirement for protective head gear. Whilst rugby is a more global sport than American football, it is still largely an amateur sport played predominantly in schools, colleges and universities in former British colonial countries. Furthermore, it is neither a sport of national regard in these countries with the exception of a few countries including Wales, Georgia, South Africa, Madagascar and Oceania countries of New Zealand, Samoa, Tonga and Fiji (Rugby union wikipedia page, 2005).

### 4.3 Case 3: Rocket Launch sequence

Modern orbital rocket vehicles are made of very expensive, light-weight materials like titanium and aluminium encasing highly complex technologies. In addition to that cost and complexity of the rocket, the time from manufacturing to launch of rocket is generally long.

While the orbital rockets are generally long and heavy with much of that weight being the fuel – usually highly flammable liquid propellants, as such, in cases of failure, the consequences due to the explosion of combustible propellants depending on the nature of the payload, can be very costly and/ or catastrophic with potential loss of life. As was the case of space shuttle challenger (NASA, 29 January 2021) and the explosion of SpaceX rocket carrying Facebook satellites (The Guardian newspaper, 2 September 2016). Whilst an explosion of rocket at the launchpad could destroy the platform and surrounding support infrastructure, this too would not only be very costly, but also take long time to rebuild.

With the possible risk sources in orbital rocket launch likely including the very technology used, the manufacture process of rocket and the sub-components, the transportation of the launch vehicle, the weather, human error, or even economic factors and political pressure (see Report of the presidential commission on the space shuttle challenger accident (1986)). It is no surprise, therefore, that there are flight readiness protocols regarding the status and conditions of rocket launch vehicle and its constituent components and technologies, weather updates, launchpad and surrounding areas. While the space companies for example SpaceX institute certain flight readiness sequences that are akin to five principles of concept of mindfulness employed by HROs, they use of these protocols in such a high-risk operation is a demonstration of society appetite for risk while also reinforcing safeguards to reduce the risk and uncertainty. As such this is an example of a mix of both cautionary and risk seeking behaviour.

### 4.4 Case 4: The diversification of portfolio

Portfolio management as an investment strategy entails selection of investment assets with foresight of market risks with the financial goal of maximizing of returns for the investors. In essence, portfolio management entails resource allocation to achieve a set defined investment objectives including maximization portfolio value, obtain a balance of mix of assets, and achieve a strategically aligned portfolio with limited resources available. Cooper et al. (1997) accentuates the importance of portfolio management including maximization of returns, efficient allocation of resources, and achieve the right balance between long- and short-term prospects, high risk and low risk assets – as such it is about reducing risk exposure.

Markowitz (1952) advocated that holding diversified investment portfolio was a reasonable practice to reduce the impact of unsystematic risk as the risks in one asset of the portfolio

could be offset by the benefits/ rewards in the other assets of the portfolio. Christensen et al. (2016) acknowledge earlier research works by Domian et al. (2007) on diversification in portfolios, noting the fact that unsystematic risk decreases with increasing assets in portfolio, however, the risk can never be fully eliminated. As a result of the unsystematic risks and interdependencies within financial markets, the design of an investment strategy necessitates creating a diversified asset portfolio to minimize the market risks while still resulting greater returns. As such, Christensen et al. (2016) study whether further diversification benefits may be possible under delegated portfolio management where an investor utilizes multiple portfolio managers. Christensen et al. (2016) suggest that investing in more actively managed portfolios generated significant diversification benefits in terms of risk reduction.

Cooper et al. (1997) define portfolio management from a new product development perspective as a dynamic decision process whereby a business assets are constantly updated and revised. But, the portfolio decision process is typified by complexity due to uncertainty and everchanging information, conflicting interests, interdependencies among prospects, while the process involves a continual decision-making procedures including periodic reviews of the entire portfolio (Cooper et al., 1997). According to Lin and Hsieh (2004), the selection of a strategic portfolio necessitates taking into account a number of conflicting criteria including corporation goals, risk level, tangible and intangible benefits, available resources and constraints. They assert that in multi-business institutions, the evaluation and selection of suitable strategic portfolios entails business strength/ industry attractiveness analysis (Lin & Hsieh, 2004). With optimal financial resource allocation, the diversification of investment portfolio should in theory ensure flexibility of portfolio while also facilitating risk optimization as it reduces investment portfolio exposure to market risks. As such, we review the diversification of portfolios as an expression of a mix of both risk seeking and cautionary behaviour within the society.

#### 4.5 Case 5: Venture Capital financing

Sharma (2015) accentuates the role of venture capitalists in an increasingly knowledge-based economy as they highlight the importance of VCs in identifying and financing of new and highly innovative companies. These venture capital-backed startups are usually within high technology sectors such as clean energy technology, biotechnology, information technology, pharmaceuticals etc., and as such the startups tend to require substantial capital investment which necessitates seeking outside financing (Gompers & Lerner, 1999). However, the forementioned researchers point out that these startups are often characterised by possession of intangible assets like intellectual property, uncertainty with regard to business opportunity, long period of net losses due to development costs, as a result are unattractive to banks, leaving venture capital firms as the only potential source of financing (Gompers & Lerner, 1999). Venture capital firms will bet on these high risk and potentially high- reward projects in return for equity stakes (Gompers & Lerner, 1999).

Due to the several factors including complexity of the technology, risk linked to the new technology, long development and maturity of these technologies, government regulations, etc; these companies are typically associated with high risk and large uncertainties. While the financial benefits can be astronomical in the event of a successful exit either through acquisition or public listing, startups generally have high failure rates. With Krishna et al. (2016) suggesting that based on an industry standard, on average 90% of startups fail, while the Wall Street Journal article on venture capital backed startups (20 September 2012) notes that venture-backed start-ups fair slightly better at a failure rate of 75%. Bergemann and Hege (1998) assert that venture-backed start-ups carry substantial risk in part due to the innovative nature of these projects, with less than 20% of the venture-backed projects successfully exited, while Gornall and Strebulaev (2021) show that 29 percent of the 300 largest US public companies are VC-backed compared to 4% of the top 300 public listed companies in the other G7 countries. While data from the U.S. Bureau of Labour Statistics (2022) shows that roughly 20% of the startups fail within their first year of operation.

Clearly, investing in early-stage startups is risky business, as such venture capital firms take on the financing of these risky startups well knowing that the probability of success are very low and that most will lose money. As such, venture capital financing is an expression of risk seeking behaviour within society.

#### 4.6 Case 6: Participation in extreme sports

Buckley (2018) defines extreme sports as activities, conditions and levels where participant survival is dependent on individual skill while any error will likely to prove fatal. While risk acceptance and avoidance differs between individuals relative the nature of risk, Buckley (2018) asserts that the evaluation of risk and reward provides insights into human psychology and behaviour, which in turn offers perspective into potential management and safety strategies. The motivation for participation in extreme and adventure sports is the thrill, long term self-esteem, personal transformation and social recognition (Buckley (2018); see also Brymer and Oades (2009)).

However, in acknowledging the complexity of emotions, Buckley (2018) notes that the evolutionary functions of emotions such as thrill are far less clear. Buckley (2018) highlights that the research on thrill seeking or sensational seeking has focused on largely on its influence on behavioural patterns and therapy as a mechanism for overcoming phobias (see Sandseter and Kennair (2011)), however, Buckley (2018) notes that it is common component of commercial tourism.

Activities such as surfing, snowboard, whitewater kayaking, rock and ice climbing etc, can be considered extreme adventure sports. Depending on the level of difficult, undertaking in these activities necessitate skill, focus and experience in order to avoid an any error as any failure

will likely prove fatal. Buckley (2018) notes that in many extreme sports activities, any error is likely to cause immediate and irremediable consequences. As such the participation in these sports involves overcoming fear (see Brymer and Schweitzer (2013)). It can thus be deduced that participation in extreme outdoor sports is an expression of risk seeking behaviour.

## 5 Discussion

### 5.1 The Case for Vaccination as a remedy to Covid-19 pandemic

Kriebel et al. (2001) argue that the rationale for the precautionary principle is grounded in great complexity, scientific uncertainty and potential for catastrophe, this is more self-evident with Covid-19 virus where the phenomena is associated with limited understanding of the transmissibility, infectiousness and incubation of SARS-CoV-2 virus (see ECDC report on infection prevention control and preparedness for Covid-19 (2021)). The ECDC report on SARS-CoV-2 pathogen (2023) accentuates the viral characteristics of SARS-CoV-2 virus particularly in its ability adapt through mutation resulting in increased transmissibility and reduced immune response, while Kriebel et al. (2001) raise the issue regarding interaction effects, as such with a weakened human immune response becoming susceptible to other health ailments.

The distinguishing feature of the precautionary principle is decision under scientific uncertainty, as the Covid-19 virus was loaded with unknowns, while the scientific community could not agree on the possible intermediate host of the virus, its incubation period was unknown, and as was the infectivity of virus. In the face of scientific uncertainty, the precautionary principle sought to mitigate the consequences of Covid-19 pandemic by prioritizing the protection of human lives while encouraging searches for all potential preventative alternatives.

According to Ciotti et al. (2020), a vaccine to prevent Covid-19 was the best hope for ending the pandemic, with the forementioned researchers highlighting the concerted effort by international alliances and governments to provide necessary resources to speed up vaccine development. However, given the shortened timelines for vaccine development, vaccine might have side effects or with varying effectiveness towards the Covid-19 virus. The Norwegian Institute of Public Health (2022) and WHO report on global Covid-19 vaccination strategy (2022) list the identified side effects of current Covid vaccines. In essence Covid vaccines imposed new risks to the society, however, Kriebel et al. (2001) presents a “lesser of two evils” argument for the precautionary principle, stating that in the face of incomplete information, the society can choose to accept one kind of risk to avoid another risk. Aven (2019) advances the anti-precautionary principle in which he posits that if intervening actions and measures would result in highly positive values, despite the underlying scientific uncertainty, then they ought to be implemented. The anti-precautionary principle is in a sense a manifestation of the balance in societal values of protection and development, in which the government authorities, private sector and scientists chose to develop a new Covid-19 vaccine and inoculate every eligible person. This they undertook knowing that the vaccines might have short term and long-term side effects, but on the balance, the benefits of vaccination outweighed the catastrophic consequences associated with Covid-19 virus.

In hindsight, the WHO report on global Covid-19 vaccination strategy (2022) acknowledges that the massive and unprecedented roll-out of Covid-19 vaccines has led to reduction in disease severity among the infected, while also accounting the reduction in hospitalization and deaths and the subsequent relaxation of government restrictions and society re-opening. The same report notes that an estimated 15 million lives have been lost to Covid -19 as of July 2022. As such the WHO cautioned on the effects of lower disease risk perception, lower demand for Covid-19 vaccines from populations and emerging shifts in political priorities as drawbacks to the progress made through vaccination and public health and social measures (see WHO report on global Covid-19 vaccination strategy (2022)).

## 5.2 The case for the use of football helmet in American football relative to rugby

Kasperson et al. (1988) suggest that risk only has a meaning within a context of the interaction between risk events and social processes. As such they Kasperson et al. (1988) present the social amplification of risk framework (SARF) whose central tenet is rooted in the in societal experience of risk events. They note that information processes, institutional structures, social or group behaviours can influence the experience of risk events (Kasperson et al., 1988). As such the SARF captures the duality of risk as a threat and social construct.

Kasperson et al. (1988) suggest that SARF is dynamic in the sense that it embraces the time variability of risk through continual social learning and interaction with risk. By incorporating the time component to risk, it is possible to encapsulate the influence of SARF on individual and societal behavioural responses particularly the secondary effects which can amplify or attenuate risk itself. For example, the research initiatives carried out at universities on traumatic brain injuries particularly among current and former NFL and college football players (see Coughlin et al. (2015); Mihalik and Guskiewicz (2015); Small et al. (2013); Vos et al. (2018)), is an illustration of the convergence of social learning and the interaction with risk. While the origins of the use of football helmet is grounded in an instinctive human behaviour of caution. The mandatory requirement for use of football helmets at all levels of the sport is supported by both experience (historical data) and science. The continual advancement in helmet design and research (see Darling et al. (2016)) in an effort to improve player safety is an exemplification of secondary effects of risk as societal response to risk could spur innovation through research and development.

Renn (1998) speaks to public perceptions of risk, noting that people generally overestimate highly publicized health, technological and environmental risks. The National Football League (NFL) is widely popular American pass time with the largest broadcast viewership among big five American sports; baseball, hockey, basketball and soccer; and the largest league by revenue in all sport. While Kasperson et al. (1988) emphasize that information systems may intensify or weaken signals that are part of risk events profoundly altering the form and content of risk information produced. As such inference can be made that with the large viewership, injuries

during an NFL match have greater visibility and attention in both broadcast media and online publications - as with the case of websites tracking concussion of NFL players over the season (Sharp football analysis website, 29 December 2022) ensures institutional accountability. Consequently, societal advocacy for improved player health and safety within the NFL is consistent with Kasperson et al. (1988) assertion that in situations where risk is grossly underestimated, social amplification serves as a corrective mechanism.

However, the fact that rugby is largely an amateur sport played mostly in schools and universities, implies it has limited or no print/ online media and broadcast attention through which the risks to health of players could be intensified in instances of on field injuries. Just as several researchers have emphasized the aspects of risk such as familiarity, voluntariness on societal choice and response (Kasperson et al., 1988; Renn, 1998), and the hypothesis that the underpinnings of SARF are rooted in social experience of risk both directly and indirectly through information mechanisms that can amplify or attenuate risk events, thereby informing risk tolerance or avoidance strategies. On the basis of the rationalization presented by Kasperson et al. (1988) that social attenuation of risk is a coping mechanism to the multitude of risks and risk events encountered daily, it can be argued that in case of rugby, the society displays little interest in risk associated with the sport.

### 5.3 The case for rocket launch sequence

Orbital launch rockets are by design characterised by complex systems and technology, while the manufacturing process is long, and materials used very expensive. The application and use orbital rockets are in rather challenging and hazardous environments, whilst in operation, they could be carrying persons or expensive high tech gadgets like satellites, or telescopes.

Weick et al. (1999) asserts that HROs intentionally organize their resources with the objective of increasing awareness to details such that they can detect the slightest subtle ways in which contexts may vary, thus enabling them to track small failures, resist oversimplification of what they face, remain sensitive to current operations, maintain capabilities for resilience, while taking advantage of shifting locations of expertise. The flight readiness protocols are an excellent illustration of the five principles of the concept of mindfulness. The flight readiness protocols have in several built-in holds where additional verification can be made.

The flight readiness protocols define a set of milestones for check and verification of systems comprising among others of backup flight systems – flight software and display systems, navigation systems, onboard computer, clear launch pad or flight deck platforms, loading fuel or cryogenic propellant, preparation of flight crew module (if astronauts on board), launchpad sound suppression system, preparation of main engines, fuel cells, communication system, weather updates etc. The deference of mission director or test director to mission management team, meteorologists, engineering teams, and the use of built-in holds that could last from



minutes to days to allow for verification and correction in case of system malfunction is a manifestation of space organization preoccupation with failure, reluctance to simplify, sensitivity to operations, commitment to resilience, and deference to expertise.

Khorsandi and Aven (2014) suggest that the concept of mindfulness entails cognitive processes that account for the situational awareness of their surroundings and the risk they face, this in turn promotes an elevated understanding of uncertainties thus facilitating their interpretation, evaluation and communication. Khorsandi and Aven (2014) have posited that organizations, for example NASA, are preoccupied with search for new and novel ways to reduce uncertainties doing so by updating existing information coupled with augmentation of communication systems for this new information. Communication within space exploration industry is critical, especially during the orbital launch sequence. As such the comprehension of the vast information available to launch control and mission control centre is critical to the operational safety and efficiency of the launch. Roberts and Bea (2001) have submitted that empowerment and development of organizational human resource capabilities is critical in enhancement of safety and performance under uncertainty of these organizations.

Several researchers have suggested that HROs operate in complex and hazardous environments, operating complex processes and technologies with the scale of possible consequences in case of an error precluding learning through experimentation (Khorsandi & Aven, 2014; Roberts & Bea, 2001; Sutcliffe, 2011). While Khorsandi and Aven (2014) underscore the increased system complexity as is the case space exploration vehicles, Sutcliffe (2011) accentuates HROs embrace systems with interdependence, operating in a continuously changing environment resulting variability in system performance. Complex systems are synonymous with non-linearity and interaction effects, a case in point, several operating systems within launch vehicle could run simultaneously and interact with each other during flight, collecting information in real time, processing the data, and adjusting to the operating conditions all without human intervention. Khorsandi and Aven (2014) elucidates that due to the magnitude and seriousness of the consequences, HROs like NASA and European Space Agency cannot afford to learn from trial and error, as such have to use every opportunity to learn and improve their systems. For example, in flight readiness protocols, these organization continuously monitor fluctuations in real time allowing them to solve any potential failures before they can escalate. However, when errors occur, space exploration organizations and companies' ability to absorb, manage and recover from these failures and disasters encapsulates their organizational resilience.

#### 5.4 The case for diversification of portfolios

While investors by behaviour seek to maximize return on investment, Markowitz (1952) through the portfolio theory proposed the use of expected return and variance of portfolio as criteria for portfolio selection. By accounting for co-movements in portfolio assets allowed for optimum portfolio selection which results in reduced exposure to risks (Elton & Gruber, 1997). Aven (2019) finds the justification for portfolio theory is grounded in the law of average

numbers in which the expected values approach the average value with unlimited diversification, however correlation in assets lead to variance between average and expected values – where the variance is risk component of the portfolio.

Indeed, Markowitz (1991) assents to diversification as a common and reasonable investment strategy to reducing uncertainty and risk, Elton and Gruber (1997) argue that allocation of scarce resources by both individuals and financial institutions is complex and challenging. The complexity in portfolio selection is rooted in the rapidly changing market information, and associated interdependencies within market information – this in part accounts for the intrinsic uncertainty in economics. In case of optimum portfolio selection, Cooper et al. (1997) points out the benefits of portfolio management including maximization of portfolio value and returns, while with efficient allocation of resources, a balance between long-term and short-term assets, as well as high risk and low risk assets can result in the reduced risk and uncertainty in portfolio.

To illustrate the case for diversification of portfolio, we refer to an article from McKinsey and company in which the stock market performance of 5000 of the world's biggest companies were studied in an article on the impacts of Covid-19 on capital markets one year in, the authors Bradley and Stumpner (2021) note that while the pandemic triggered a freefall in share prices, it also accelerated fundamental trends such as online shopping and payments, remote education and telemedicine driven by policy responses towards the pandemic.

Bradley and Stumpner (2021) observed the average shareholder returns of the world's largest companies through their respective sectors over the year. In their findings, sectors such as advanced electronics, high tech, medical technology, media, logistics and trading, chemicals, automotive and assembly, consumer durables, apparel, fashion and luxury had overall a positive total shareholder returns, whereas sectors such as real estate, air and travel, aerospace and defence, oil and gas, telecommunication, banking, insurance had on average negative total shareholder return (see Bradley and Stumpner (2021)). As such investors with diversified portfolio across these sectors would have had an overall reduced exposure to market risks associated with Covid-19 pandemic.

## 5.5 The case for venture capital financing

While Kahneman and Tversky (1979) established that people tended to overweight outcomes that they deemed certain, relative those outcomes considered probable in a phenomenon called certain effect, they, however, appended caveats to this supposition. They augment that certain effect not only contributes to risk aversion in the positive domain, but it also explains the risk seeking behaviour in the negative domain in an effect the describe as reflection effect (Kahneman & Tversky, 1979). Based on the submission by Krishna et al. (2016) that 90 per cent of startups fail or the the Wall Street Journal article on venture capital backed startups (20 September 2012) reported that 3 out 4 venture-backed startups fail, an assertion could be made

that investment financing of early stage startups is a money losing prospect. As such the assertion could be extended to interpret investment finance in startups through the negative domain. If the assertion holds, then venture capital investment is subject to the reflection effect, in which the outcomes of the prospects are losses, with Kahneman and Tversky (1979) alluding to the reversal of preference order which they argue accounts for the prevalence of risk seeking behaviour.

Kahneman and Tversky (1979) surmise that in cases of low probabilities, most people choose an outcome with the largest returns on investment, while attributing this observation to the overweighting of low probabilities. Several researchers have highlighted the low survival rates of startups (Krishna et al., 2016). Holding the assumption that the successful exit of VC-backed startup include Initial Public Offering (IPO), based on the findings of Gornall and Strebulaev (2021) that show that 29.3% of US public listed companies are VC-backed while the other G7 countries account for a dismal 4% VC-backed among the publicly listed companies. Then an assertion can be made that the probabilities for survival of VC-backed companies are low. Kahneman and Tversky (1979) supposition that risk seekers tend to overweight low probabilities would explain the investment in startups.

Paulsen et al. (2012) presents the argument for emotional affect on risk and decision context, while Kahneman and Tversky (1979) accentuate the individual attitudes towards loss and gain as they highlight that the value function for losses is steeper than value function of gains, as such the upset from an experience of loss is greater than satisfaction from an experience of success. However, Chan et al. (2020) advance the influence of experience of loss on individual attitudes to risk, as they assert that risk seekers are more likely to take risks following losses. This is consistent with hypothesis presented by several researchers who have noted the narrow focus of risk assessments on consequences fails to capture other aspects associated risk for example familiarity with hazard and voluntariness that influence individual and societal choices and responses (Kasperson et al., 1988; Renn, 1986, 1998). Venture capital firms' exposure to risky startups suggests their familiarity and voluntariness to the financial risks associated with startups. This may as well explain the establishment of incubation centres and clusters of technology as the investors seek to reduce the uncertainty by exploiting the synergies associated with innovation parks such as knowledge transfer.

Chan et al. (2020) present the framing effect as an explanation for risk seeking behaviours, in which risk context influences the individual risk attitude, this is consistent with the isolation effect introduced by Kahneman and Tversky (1979) in which people tend to disregard the characteristics that the different alternatives share, while focusing on what distinguishes them, this the forementioned researchers suggest leads to inconsistencies in preferences as a set of prospects can be decomposed many different ways. The isolation effect as posited in the prospect theory could explain the findings of Gornall and Strebulaev (2021) who have suggested that one out of every thousand companies receive venture capital funding.

## 5.6 The case for participation in extreme sports

While several researchers accentuate that extreme sports entail high levels of physical risk and as such require higher levels of skill (Buckley (2018), see also Arijs et al. (2017); Feletti et al. (2017)). Buckley (2018) notes that the probability of making an error is influenced by individual skill, as well as the features of physical environment, however, the consequences of poor execution are only weakly influenced by individual skill, but rather primarily predisposed by the physical environment. However, extreme outdoor sports are innately characterised by uncontrollable environmental variables such as weather, and terrain that can influence the successful execution of the activity.

Due to variability and randomness in randomness in risk, Aven (2015a) contrasts with Taleb (2012b) assertion that antifragility is only associated with positive outcomes, while noting that surprises will occur, as such for any real-life systems, there is likelihood for negative consequences even with antifragile systems. As such, Aven (2015a) suggests that incremental improvements over time should trend towards antifragility which is associated with improved learning and performance under variability and uncertainty. Buckley (2018) suggests that the emotion of thrill might drive individuals to test and practice their skills, possibility in part due to the high physical risk attributed to severity of the consequences. As such, extreme outdoor sports require fitness, training, practice, skill, control, focus and judgment (Buckley, 2018).

There is consonance in antifragility concept's emphasis on improvements over time, with extreme outdoor sports requirement of higher levels of technical skill, concentration and experience which necessitate fitness training, practice and equipment testing. This is consistent with Aven (2015a) argument that trends towards antifragility reveal themselves over time with improved levels of concentration, control and judgement in the case of involvement in extreme sports.

Overall, the discussion identifies the risk characteristics of the selected examples, and using risk science concepts and theories analyses how individual and societal behaviours could be explained. In the case of vaccination against covid-19 virus, the overall implementations of government policies were grounded on precautionary principle, hence the earlier suggestion that a new vaccine against Covid-19 pandemic was an expression of cautionary behaviour in society, however, when analysed through the anti-precautionary principle, the use of a new vaccine to remedy covid-19 pandemic is an expression of both risk seeking and cautionary behaviours. The study of the case illustrates the overlap of societal values of protection – save lives, and development – find a medication, full reopening of socioeconomic activities. In the case of use of football helmet in American football relative to rugby, we observe that the interaction of social processes and risk over time leads to positive secondary effects as evidenced with innovation in helmets, social advocacy and institutional accountability. In the case of rocket launch sequence, the flight readiness protocols are an exemplification of five principles of high reliability organizations, but also note that human resource is core to the enhancement of safety and performance under uncertainty of these organizations. In the case

for diversification of portfolios, the nature of the increasingly globalized and industrialized society renders it vulnerable to systemic risks as seen with Covid-19 pandemic whose rippling effect could potentially disrupt the financial markets. As such diversification across different sectors may offer respite to market forces. In the case of venture capital financing, the secondary aspects of risk such as familiarity, voluntariness and experience inform the decision making under uncertainty. With participation in extreme sports, the potentially catastrophic consequences and voluntariness to the hazard influence the interaction with risk, but also inform risk avoidance strategies.

## 6 Conclusion

In the face of deep scientific uncertainty and catastrophic consequences associated with Covid-19, the precautionary principle was invoked to prioritize the protection of human lives while encouraging the exploration of all possible preventative alternatives. As with old adage that a problem shared is a problem halved, Ciotti et al. (2020) note the unprecedented commitment by both governments and private sector actors to develop a Covid-19 vaccine, as a demonstration of social unity. Given the scale of possible catastrophic consequences, time and resource constraints, government regulatory agencies streamlined the drug development process and merged resources to fast track the development of a Covid vaccine. Illustrating the intersection between two conflicting societal interests of protection and development.

In the example of development of a new covid vaccine as remedy to Covid-19 pandemic, while the society chooses to treat SARS-CoV-2 virus with an entirely new drug developed under shorter drug trial schedule with the best of intentions to reduce number of Covid related deaths, reduce the disease severity and overall disease burden, reduce virus transmission and achieve full reopening of socio-economic sectors as stipulated in the WHO report on global Covid-19 vaccination strategy (2022), the society knowingly or otherwise accepts the possible new risks associated with the Covid vaccine. Unfortunately, the Covid vaccines do have varying side effects as communicated by the Norwegian Institute of Public Health (2022), however, Kriebel et al. (2001) presents a lesser of two evils argument stating that in the face of incomplete information, the society can choose to accept one kind of risk to avoid another risk. As such even solutions to existing risks can impose new risks. Renn (1998) suggests that people will bear risk if it is justified, or it serves as means to other goals. Seen through this prism, Aven (2019) concept of anti-precautionary principle which posits that in case of highly positive outcomes, despite the scientific uncertainty, the necessary measures should be implemented, more aptly describes the development a new Covid-19 vaccine to remedy the effects of the virus on society.

With the example of use of football helmet within American football relative to rugby, while we acknowledge that the society accepts the risks the associated with playing American football, however, we also observe a drive to improve safety with the advancement in helmet in design and technology. This reflects how auxiliary aspects of risk such as familiarity and voluntariness can inform risk evaluation and management. Furthermore, this illustrates not only that the interaction of risk and social processes over time can foster continual social learning and spur innovation through research and development, but also the convergency of society's risk acceptance and risk avoidance strategies.

The website tracking the identities and number of NFL players suffering concussions during the season (Sharp football analysis website, 29 December 2022) is an illustration of how the

society can through information systems harness the power of social advocacy to bring about institutional accountability. The Washington Post article on Concussions in NFL (3 February, 2023) is as much an acknowledgement from the NFL Commissioner of the existential risks faced by NFL players as it is an acceptance of institutional accountability for the occupational hazard associated with the sport. Even though the society chooses to be involved in the American football, thus interact with the associated risk, it demands institutional accountability for players health and safety.

In the example of rocket launch sequence, the task at hand necessitates the launch of a technologically advanced orbital space vehicle carrying either expensive high-tech gadgets such as telescopes, satellites or to deliver astronauts or cosmonauts to the International Space Station. To do so, space companies like SpaceX use a set of flight readiness protocols in which Go/No-go polls are conducted. In the process, the launch director defers to technical personnel responsible for critical components of space vehicle as to whether the launch should proceed, hold or be postponed. While the launch of the orbital vehicle into space is extreme risky, the flight readiness protocols are an expression of caution. However, in the process of carrying out the Go/No-go polls, the launch director inadvertently expresses the five principles of collective mindfulness associated to HROs. For example, in the deference to various component system engineers, component manufacturers, technical personnel or to the meteorologists, the launch director illustrates that the success of HROs hinges on the organizational human resources. This is consistent with Roberts and Bea (2001) supposition of the importance of human capital development in the enhancement of safety and performance in organization. The empowerment of employees either through delegation of responsibilities or training, is critical in the establishing situational awareness that is essential to the elevated understanding of uncertainties and their interpretation, evaluation and communication, evidenced in space exploration organization such as NASA or SpaceX.

Given that 3 out 4 venture-backed startups fail (the Wall Street Journal article on venture capital backed startups, 20 September 2012), investment in early-stage startups could be analysed through the negative domain. If the assertion holds, then venture capital investment is subject to the reflection effect, in which Kahneman and Tversky (1979) allude to the reversal of preference order, where investors will choose a larger loss that is merely probable over a small loss that is certain. This not only accounts for the risk seeking behaviour among venture capital investors, but also explains why venture capitalist back high growth, capital intensive startup companies.

While venture capitalists are willing to take risk and invest in risky high growth startups prospects, they do carryout due diligence to vet both the educational and managerial competency of the people behind prospective venture, idea or technology, scalability of venture, market and growth potential, competition and competitive advantage of the startups etc. As such many of the ventures that seek out venture capital financing, one in thousand receive funding (Gornall & Strebulaev, 2021). It is my argument that the isolation effect as proposed by Kahneman and Tversky (1979) could explain this finding. The isolation effect

occurs when people disregard characteristics that the different alternatives share, while focusing on what distinguishes them. As such the isolation effect (or framing effect) reinforces the importance risk communication as context of risk information will influence risk perception and shape behavioural response.

Given that startups have very high failure, they still attract venture capital financing. While the behaviour could be attributed to overweighting low probabilities (Kahneman & Tversky, 1979), or as several researchers have alluded to, overconfidence and individual biases (Parhankangas & Hellström, 2007; Zacharakis & Shepherd, 2001), I submit that while all these explanations are valid, it also possible the aspect of familiarity and voluntariness to risk could also explain this risk-taking behaviour. Available literature on venture capital (see Agrawal (2018)) suggests that venture capital firms tend to mentor the new startups by attracting experienced business and technology executives and investors to the boards to these new startups who offer guidance on business planning, marketing, product development, recruitment etc. The venture capital firms exposure to risk over time allows for continual learning through acquired knowledge and experience in business development, product development, marketing or building human capital from which they can draw on when needed. With breadth of knowledge, experience and resources, venture capital firms are able to reduce their uncertainties associated with new startups. This could explain the difference in the findings between Krishna et al. (2016) who suggested that as high as 90% of startups fail and the Wall Street Journal article on venture capital backed startups (20 September 2012) which stated that 3 out of 4 startups fail. As such, familiarity and voluntariness of risk aspect incentivizes the reduction of uncertainties through knowledge acquisition and transfer (mentorships programs), resource accumulation - human or financial capital, or establishment of incubation/ innovation centres.

The antifragility concept's embrace of variability and randomness as means to improved learning and future development offers one possible insight into living with rare and random events associated with deep uncertainty. With hindsight to lessons from extreme sports, the concept could elevate situational awareness as evidenced by improved levels of concentration by participants in extreme sports, but also spur innovation through research and development in order to improve safety and performance.

In conclusion, the review and study of the examples of risk behaviours in which the society express cautionary thinking, risk seeking behaviour and mix of both, we find that society's experience and interaction with risk often carries auxiliary effects. For example, in the case of using a new Covid vaccine to remedy the SARS-CoV-2 virus not only do observe society resilience and unity, but also we observe that the solution to one risk imposes a new risk to society, while in the case of orbital rocket launch sequence as expression of both cautionary and risk seeking behaviour, we observe the importance of empowerment and development of organization's human resource capital. In the case of use of football helmet in American football relative to rugby as expression of cautionary thinking, we observe how society can enhance information systems to hold institutional organization like NFL accountable. We also observe a shared characteristic among the examples of risk behaviours including participation



in extreme sport, venture capital financing and playing American football in which football helmet is mandatory, that is their interaction with risk attributes of familiarity and voluntariness. In these examples, familiarity and voluntariness of hazard are associated with risk seeking behaviours, however, in studying these cases, it becomes apparent that these aspects of risk have secondary effects. In an effort to understand the risks and consequences involved, the society seeks to reduce uncertainties or mitigate the consequences of the hazard resulting in innovation. Further, we realize that while government policies upon which the vaccination program were based were justified using the precautionary principle, however, the relatively new idea of anti-precautionary principle may very well explain the government policy.

Risk science, thus, more aptly explains the individual and societal behaviours in the face of risk and uncertainty in part due to the interdisciplinary nature of the risk field as it draws on fundamental knowledge from broad scientific disciplines.

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