White Rose Research Online

eprints@whiterose.ac.uk
https://eprints.whiterose.ac.uk
Universities of Leeds, Sheffield and York

Deposited via The University of Leeds.

White Rose Research Online URL for this paper:
https://eprints.whiterose.ac.uk/id/eprint/161096/

Version: Accepted Version

Article:
Oehmen, J, Locatelli, G, Wied, M et al. (2020) Risk, uncertainty, ignorance and myopia: Their managerial implications for B2B firms. Industrial Marketing Management, 88. pp. 330-338. ISSN: 0019-8501

https://doi.org/10.1016/j.indmarman.2020.05.018

Crown Copyright © 2020 Published by Elsevier Inc. All rights reserved. This manuscript version is made available under the CC-BY-NC-ND 4.0 license
http://creativecommons.org/licenses/by-nc-nd/4.0/

Reuse
This article is distributed under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs (CC BY-NC-ND) licence. This licence only allows you to download this work and share it with others as long as you credit the authors, but you can't change the article in any way or use it commercially. More information and the full terms of the licence here: https://creativecommons.org/licenses/

Takedown
If you consider content in White Rose Research Online to be in breach of UK law, please notify us by emailing eprints@whiterose.ac.uk including the URL of the record and the reason for the withdrawal request.

UNIVERSITY OF LEEDS
University of Sheffield
UNIVERSITY of York

Risk, Uncertainty, Ignorance and Myopia: Their Managerial Implications for B2B firms

Josef Oehmen (corresponding author)

Technical University of Denmark

DTU Management

Engineering Systems Design

Akademivej 358, 2800 Lyngby, Denmark

+45 4525 6039

jooehm@dtu.dk

Giorgio Locatelli

University of Leeds

School of Civil Engineering

Leeds, LS2 9JT, United Kingdom

+44(0)113 343 2296

g.locatelli@leeds.ac.uk

Morten Wied

Technical University of Denmark

DTU Management

Engineering Systems Design

Akademivej 358, 2800 Lyngby, Denmark

mowi@dtu.dk

Pelle Willumsen

Technical University of Denmark

DTU Management

Engineering Systems Design

Akademivej 358, 2800 Lyngby, Denmark

pwil@dtu.dk

Risk, Uncertainty, Ignorance and Myopia: Their Managerial Implications for B2B firms

Highlights

- Introduces four overall risk management perspectives regarding the current COVID-19 crisis: risk, uncertainty, ignorance, myopia
- Highlights both academic as well as practice challenges to inform future work , including: the need to reconcile conflicting definitions around risk and risk perceptions, tailor approaches to specific contexts, and operationalize mathematically advanced concepts for broad application.

Risk, Uncertainty, Ignorance and Myopia: Their Managerial Implications for B2B firms

Abstract

Rare events are common: Even though any particular type of 'rare event' - a world war, global economic collapse, or pandemic for that matter - should only occur once every 100 years, there are enough of those types of 'rare events' that overall, they commonly occur about once every 10 years. As we are currently experiencing, we do not sufficiently leverage the rich toolset that risk management offers to prepare for and mitigate the resulting uncertainty. This article highlights four aspects of risk management, and their practical and theorical implications. They are: 1) Risk (in the narrower sense), where possible future outcomes can be captured through probability distributions. 2) A situation of uncertainty, where there is transparency regarding what is not known, but probability distributions are unknown, as well as causal relationships influencing the outcome in question. 3) A situation of ignorance, where there is no understanding that certain possible future developments are even relevant. And finally: 4) The emergence of 'inter-organizational myopia' as an effect of risk, uncertainty and ignorance on collective human behaviour.

Keywords

Risk management; resilience; myopia

Risk, Uncertainty, Ignorance and Myopia: Their Managerial Implications for B2B firms

Abstract

Rare events are common: Even though any particular type of 'rare event' - a world war, global economic collapse, or pandemic for that matter - should only occur once every 100 years, there are enough of those types of 'rare events' that overall, they commonly occur about once every 10 years. As we are currently experiencing, we do not sufficiently leverage the rich toolset that risk management offers to prepare for and mitigate the resulting uncertainty. This article highlights four aspects of risk management, and their practical and theorical implications. They are: 1) Risk (in the narrower sense), where possible future outcomes can be captured through probability distributions. 2) A situation of uncertainty, where there is transparency regarding what is not known, but probability distributions are unknown, as well as causal relationships influencing the outcome in question. 3) A situation of ignorance, where there is no understanding that certain possible future developments are even relevant. And finally: 4) The emergence of 'inter-organizational myopia' as an effect of risk, uncertainty and ignorance on collective human behaviour.

Keywords

Risk management; resilience; myopia

1 Introduction

The outbreak of the current COVID-19 pandemic was not a practically unforeseeable 'Black Swan Event', as regularly claimed by media and online pundits (Bloomberg TV, 2020). Not only is a general pandemic preparedness (typically for a much more severe pandemic influenza) part of standard government's emergency planning, but it has been communicated as a practical near-future certainty in expert forums and the general public alike (Gates, 2015). Even a scenario worryingly close to what is currently unfolding (though with much higher mortality rates) was role-played by an international team of health experts in the fall of 2019 at the Center for Health Security at Johns Hopkins University. Their resulting recommendations (CHS, 2019) mirror precisely the shortcomings we are experiencing today. Sadly, their findings and those of earlier similar exercises collected dust in various drawers around the world.

Taking a step back, disruptive global events are not as rare as they may seem. The world is exposed to a significant amount of "1 in a 100 year" events, so that they occur with some regularity. They include for example: World War I (1914), Spanish Influenza (1918), The Great Depression (1929), World War II (1939), The Cuban Missile Crisis (1962), OPEC Oil Embargo (1973), US-on-Soviet Union nuclear attack false alarm (1983), Collapse of the Soviet Union and the Iron Curtain (1989), 9-11 Terrorist Attacks in the U.S. (2001), Subprime Mortgage Financial Crisis (2008), and finally the COVID-19 Pandemic (2020).

Several among them, such as the Cuban Missile Crisis of 1962, the false alarm regarding a nuclear attack in 1983, or the global near-collapse of the financial system in 2007/2008, were near-misses that could have just as easily rewritten the social and economic history of the world. The collapse of

the Soviet Union in 1989 did change history, and in hindsight we easily forget the tensions that existed when the cold war status-quo was changing to some unknown future state.

Organizations (governments, companies and even universities) have little influence on the occurrence of these "exogenous shocks" (Hartmann & Lussier, 2020), nor can the occurrence of any one specific event be pinpointed to an exact point in time in the future. Nevertheless, there exists a rich toolbox of risk management practices to support decision-makers across organizations. As the economic impact of the current COVID-19 disruption demonstrates, these tools are not leveraged effectively.

One fundamental barrier to successful use of risk management practices is that risk and risk management is a highly diverse field, and for better or worse, under constant debate and development. Moreover, decision-makers do not think in terms of risk, mostly because they have not been educated in those terms. They think in terms of cost-benefit analysis, a mental framework that is appropriated for simple short-term decisions but can lead to "organizational myopia" to long term, more complex decisions.

This article briefly illuminates the broader field of risk management and highlights practical and theoretical research challenges. We believe that all of them are relevant for businesses today during the COVID-19 crisis. We can broadly discern four contexts where organizations and decision makers face risk.

Contexts 1-3 are characterized by decreasing level of knowledge regarding the future:

1) Risk (in the narrower sense), where possible future outcomes can be captured through probability distributions. A typical response is risk management (Section 2).
2) A situation of uncertainty, where there is transparency regarding what is not known, but probability distributions are unknown, as well as causal relationships influencing the outcome in question. Robust Decision Making is a possible response (Section 3).
3) A situation of ignorance, where there is no understanding that certain possible future developments are even relevant. We discuss resilience as an organizational response (Section 4).

The fourth managerial context emphasizes not just the level of available knowledge, but how organizations culturally react to the resulting uncertainty:

4) The emergence of 'organizational myopia' (including inter-organizational myopia) as an effect of risk, uncertainty and ignorance on collective human behaviour. As a possible response, we discuss organizational mindfulness (Section 5).

In this article, we consider situations of 'practical' risk, uncertainty, and ignorance, i.e. we do not discuss if certain information would have theoretically been knowable at a certain point in time, but if it was practically known by decision makers. In that sense, the current pandemic falls into the category of "ignorance" for many organizations, although technically, it was a well understood, described and quantified risk. Lastly, the discussion of organizational myopia illuminates the practical effects on the organizational level. Table 1 summarizes the key theoretical and practice challenges.

Table 1: Summary of theoretical and practice challenges in risk management

Managerial context	Theoretical Challenges	Practice Challenges
1. Management of risk (Section 2) • Risk: Possible outcomes with known probabilities (Knight, 1921) • Risk management: Coordinated activities to direct and control an organization regarding its risks (ISO, 2018)	• Conflicting definitions of 'risk' and 'risk management' (Aven, 2012, 2016; Aven & Renn, 2019) • Articulation of organizational value of risk management (Willumsen et al., 2019)	• One-size-fits-all expectation of risk management standards vs. need for customization (Oehmen et al., 2014) • Idealized formal risk management neglects actual risk management (including its informal aspects) (Ahlemann et al., 2013; Elmar Kutsch & Hall, 2010) • Choice of appropriate risk management methods for given decision context and data quality (Tegeltija, 2018)
2. Management of uncertainty (Section 3) • Uncertainty: Possible outcomes with unknown probabilities (Knight, 1921) • Robust Decision Making: Assessing performance across a broad range of possible futures to minimize regret (Walker et al., 2013)	• Delineation of uncertainty and risk (Aven, 2012; Flage et al., 2014) • Development of some mathematically very advanced reasoning into actionable methods, while maintaining rigor (Tegeltija, 2018)	• Incorporation and communication of uncertainty in decision making (Funtowicz & Ravetz, 1990) • Implementing and operationalizing novel uncertainty management methods (Tegeltija, 2018)
3. Management of ignorance (Section 4) • Ignorance: Unknown outcomes with unknown probabilities (Michael Smithson, 1989) • Resilience: The ability to resist or recover from unexpected events without foresight (Holling, 1973)	• Theoretically sound operationalization of resilience concepts into organizational practice (Wied et al., 2020) • Reconciliation of expectation of productivity with need for resilience (R. L. Martin, 2019)	• Articulation of specific and explicit resilience strategies for organizations (Wied et al., 2020) • Orchestrate cultural shift from 'predict and plan' to 'monitor and react' (Hall et al., 2015; Rolstadås et al., 2011)
4. Individual and collective human behaviour under risk, uncertainty and ignorance (Section 5) • Myopia : An effect of risk, uncertainty and ignorance on collective human behaviour, limiting organisational sense-making (Chikudate, 2002) • Organizational Mindfulness: Learning from High Reliability Organizations (Sutcliffe et al., 2016)	• A large amount of individual 'cognitive biases' are currently discussed literature, without unifying framework, or clear differentiation between individual and organizational behaviour (McCray et al., 2002; Stingl & Geraldi, 2017)	• Accommodating our understanding of 'true' decision making under uncertainty in our formalized structures that expect rational actors (Stingl & Geraldi, 2017)

2 Risk Management: Dealing with probabilities

There exist a multitude of competing definitions on what 'risk' is (Aven, 2012, 2016). A definition following Knight (Knight, 1921) understands risk as uncertainty that can be modelled and quantified monetarily: risk is uncertainty that can for example be expressed as a probability distribution. As such, risk can be effectively insured against, or be weight and traded off against other risks and opportunities. To what extent this category is truly relevant in managerial practice is debated (Aven, 2012, 2017a; Ward & Chapman, 2003), but it is firmly established in organizational practice. Examples include the already mentioned insurances, resource allocation, or the design and optimization of investment portfolios. The ISO 31000 standard (ISO, 2018) defines risk more broadly as the 'effect of uncertainties on objectives', generalizing from financial impacts to impacts on any type of stakeholder value (including, for example, well-being or reputation). This general definition and understanding of risk promotes professionalization of risk management practice (Olechowski et al., 2016) and underpins many existing practitioner standards for risk management – from domains such as systems engineering (Incose, 2015), to finance (Allen, 2012), to supply chain management (de Oliveira et al., 2017; Zsidisin & Ritchie, 2008), to project management (PMI, 2019) and of course data analytics (Jaynes & Bretthorst, 2003). Despite multiple established standards in the field, there remain considerable foundational challenges. Very simply, for example, consider situations with unclear or conflicting objectives– what are 'risks' under those circumstances (Aven, 2012). It is an interesting paradox that risk management focusses on uncertainty and its potential impact, yet the prescriptions found in the risk management literature can be shrouded in uncertainty and hidden assumptions (Willumsen et al., 2019). In practice, risk management ranges from gut-feeling-based risk matrices with ill-defined (or undefined) evaluation scales for probability and impact (Cox, Jr., 2009), to highly sophisticated quantitative models (Allen, 2012; Jaynes & Bretthorst, 2003).

These foundational issues in risk management create challenges for practitioners. For example, risk management should be customized (ISO, 2018; Oehmen et al., 2014) as different risk management practices vary in their ability to create value in different contexts (Willumsen et al., 2019). The clear implication for the current COVID-19 crisis (that arguably affects all companies), there will be no 'one size fits all' risk management solution. One such difference relates to the availability and quality of data, which heavy influences if a method is applicable (Tegeltija, 2018). It has been shown that using inappropriate risk management methods can be worse than doing nothing, as it leads decision makers towards a false sense of certainty (Hubbard, 2009).

A common challenge is the use of expert judgement in the assessment of probability distributions of outcomes, or in simpler applications, in the estimation of probability-impact pairs for the occurrence of specific events. It can provide valuable insight in situations where available data is lacking(Cooke, 1991; Renn, 1998; Zio, 2009). However, careful consideration of multiple factors such as level of expertise, confidence and subjective bias is needed (Cooke, 1991; Fortin & Gagnon, 2006). Given the current scarcity of 'hard facts' during the COVID-19 pandemic,

The challenge of operationalizing risk management in practise extends to determining the maturity of such systems in their context (Chapman, 2019). Having 'more' risk management does not necessarily improve the management of risk (Oehmen et al., 2014). Rather, the contextual fit of risk management systems is of such importance that traditional process maturity scales falls short (Tegeltija, 2018).

A number of challenges exist regarding risk management theory. As mentioned, the definition of risk itself is an ongoing debate, and no consensus has been reached. Similarly multiple conceptualizations and interpretations of uncertainty exist, as discussed in the following sections. The different conceptualizations of uncertainty require different approaches in terms of modelling and approaches to address them, and the research into these foundational challenges is lacking (Aven, 2012, 2016; Tegeltija, 2018). When studying the empirical research it becomes clear that the management of uncertainty and risk stretches beyond the risk management process in a narrow sense. For example, other processes in a company might serve to manage risk, such as stakeholder or knowledge management (Neves et al., 2014; Xia et al., 2018), making it challenging to understand how risks are actually managed. There are reports of a discrepancy between theory and practice (Ahlemann et al., 2013; Elmar Kutsch & Hall, 2010). According to Kutsch (2009; 2014) there is limited research about how risks are actually managed or not managed in practice, and why.

3 Imprecision, Ambiguity, Robustness: Dealing with uncertainty beyond probabilities

The strict probabilistic interpretation of uncertainty discussed above as 'risk' makes several axiomatic and practical assumptions that are easily violated in application. These include the fundamental assumption of measurability of uncertainty (Bernardo & Smith, 1994), the identification and quantification of causal links influencing uncertainty (Renn et al., 2011), the availability of data (including quantitative data, expert judgement and experience) to evaluate uncertainty (Klinke & Renn, 2002; Lough et al., 2009), an infinite mental capacity to process information and draw factual conclusions (Simon, 1990), and an absence of ambiguity, i.e. divergence in the interpretation of identical factual information by different stakeholders (Klinke & Renn, 2002).

This is an area of significant ongoing research and debate (Aven & Cox, Jr., 2015; Aven & Zio, 2011; Flage et al., 2014; Zio, 2009). For simplicities sake, we refer to 'uncertainty' as opposed to 'risk' for situations where we do not have a probabilistic quantification of the uncertainty, but we are aware that (not probabilistically quantified) uncertainty exists.

This is a common challenge when dealing with the COVID-19 pandemic: We know that there are a lot of factors in play, and we are aware of some relationships and some of the data – but we also know that we do not fully understand their interact, or how reliable our data is, or how to model the future with some sufficient quality. Currently, significant resources are expended to better understand what impact what combination of non-pharmaceutical interventions has on reproduction numbers, or what the medium- and long-term economic effect of these actions is going to be for what part of the economy. This continues to the firm level, where we know that we are facing some supply chain disruptions and demand changes, but when, and where, and how bad, and with what exact consequences is difficult to pinpoint.

A host of methods and approaches exist to deal with this wide range of limitations: Bayesian Statistics builds a bridge between 'risk' and 'uncertainty' by explicitly modelling both aleatoric (i.e. stochastic) uncertainty, as well as epistemological uncertainty, i.e. uncertainty due to a lack of knowledge. Both are expressed in the language of probabilities (Bernardo & Smith, 1994). The domain of Imprecise Probability (Walley, 1991) extends the treatment of epistemic uncertainty, e.g. Coherent Upper and Lower Boundaries (Colyvan, 2008; Kozin, 1996) that relaxes one of the central assumptions of Bayesian Statistics by not requiring a single additive probability measure. It has found technical applications in the field of Artificial Intelligence and safety risk assessment. The

Dempster-Shafer Theory of Evidence (Beynon et al., 2000; Dempster, 1967) allows to also model ambiguity by accounting for the weight of evidence. Again, applications are mostly in technical domains such as facial recognition or medical diagnosis (Yen, 1989).

There are specific risk communication approaches that extend classic probabilistic methods, e.g. the NUSAP Scheme (Funtowicz & Ravetz, 1990). It was originally developed to facilitate the communication of probabilistic models in climate science to a non-expert audience. It addresses the question of how to communicate the complexities that underly a risk or uncertainty assessment by not only communicating the (N)umber, (U)nit and (S)pread (i.e. the basic probabilistic information), but also qualitative information through the (A)ssessment, describing quality of the underlying the information (i.e. epistemic uncertainty), and the (P)edigree, i.e. an overall assessment of the quality of the applied method and result. While currently not in wide-spread use, descriptive schemes like NUSAP are very promising to better communicate the quality (and inherent uncertainty) of assessments. This helps resolve latent issues that decision makers face when they need to decide what information to trust or consider in a decision. This is a common occurrence in the current COVID-19 situation, as executives are evaluating projections of spread of infection, associated government action, market reactions, and supply chain impact.

Finally, there is a class of methods based on the concept of Exploratory Modelling, where computational experiments are used to develop plausible future scenarios, and evaluate current decision options against those scenarios. The core idea is not to identify the 'optimum' solution to address uncertainties, as that solution may be very sensitive to assumptions (that had to be made due to a lack of knowledge). Instead, they seek to 'minimize regret', i.e. ensure that a decision avoids unacceptable outcomes under all plausible future scenarios, thus limiting the worse case scenario. All acceptable options can then be evaluated regarding their cost. A prominent example of such a method is Robust Decision Making (RDM) (Dewar et al., 1993; R. J. Lempert, 2002; Walker et al., 2013). RDM is used to decide on climate change adaptation actions (R. Lempert, 1996) or economic policy (Seong et al., 2005). The possible benefits of such a method for business decisions are obvious: Instead of attempting to 'maximize value' with little more than educated guesses, an approach of 'minimizing regret' emphasizes the survival of the organization while acknowledging uncertainties.

Some business challenges are addressed, for example accounting for a lack of knowledge in risk and uncertainty assessments, or better communicating the quality of those assessments. However, new challenges emerge, as approaches such Imprecise Probabilities or Exploratory Modelling require new quantitative modelling capabilities and corresponding maturity in the decision making processes. However, if organizations honestly want to address the novelty, uniqueness, and first-of-a-kind challenges that COVID-19 entails, they cannot rely on classic probabilistic approaches alone (Gidel et al., 2005).

On the academic side, significant work remains to apply and validate these more advanced methods of uncertainty modelling in business practice (Tegeltija, 2018; Tegeltija et al., 2017). At the same time, foundational discussions continue on the nature of risk and uncertainty, and how to coherently conceptualize them in the field of risk management (Flage et al., 2014). On the academic side, significant work remains to apply and validate these more advanced methods of uncertainty modelling in business practice (Tegeltija, 2018; Tegeltija et al., 2017). At the same time, foundational discussions continue on the nature of risk and uncertainty, and how to coherently conceptualize them in the field of risk management (Flage et al., 2014).

4 Resilience: Preparation, resistance and recovery without the use of foresight

We are ignorant about the future when we do not know possible future outcomes (including their probabilities of occurrence). As Knight (Knight, 1921) already pointed out, that this is the common state of affairs in real-world situations. Typically, the number of possible outcomes (and combinations of them) is vast and practically not feasible to enumerate, and there is no historical basis for assigning statistical probabilities to all of them that would sum neatly to 1. Under ignorance, Rolstadås et al. (2011) likened navigating the future to crossing an eight-lane city street packed with vehicles of all kinds, moving at varying speeds, and in both directions. Here, any detailed plan we might make by the road-side would likely be obsolete before making it across the first lane. Instead, all we can do is to broadly outline a general direction, try one lane at the time, and respond to whatever unfolds (see Wied et al. (Wied et al., 2020) for an in-depth discussion of the literature).

Resilience is an organization's ability to manage ignorance. Holling (Holling, 1973) first used the term to describe the ability to resist or recover from unexpected events, without the necessity of foresight. From a resilience perspective, ignorance is not the problem. Ignorance is the prevailing circumstance for most real-world organizations. Rather, the problem is unrecognised, unpopular, or wilful denial of ignorance. This is when we think we know the future (or pretend to), but we really do not (Taleb, 2007). When this happens, we irreversibly commit to over-specialized plans and businesses models (specialized for an expected future), and over-confidently head out into oncoming traffic. This may be a sentiment that managers can relate to in the current COVID-19 situation. In the words of Holling (Holling, 1973), specialization is an adaptive response to a stable environment, whereas resilience is an adaptive response to a dynamic environment.

While risk management, and to some lesser extent, management approaches focused on uncertainty (see above), rely on a 'predict and plan' mindset, resilience builds capabilities to 'monitor and react' (Hall et al., 2015): This includes building capabilities in four areas: 1) Preparation, financially and operationally, for unexpected disruption (Sheffi, 2017); 2) Resistance, the immediate crisis management that moves the organization out of its denial and complacency, and minimizes the negative impact without delay (Henry & Ramirez-Marquez, 2016); 3) Recovery, when the organization works to regain pre-crisis performance by repairing damage, improvising, and making do; and 4) Learning, implementing new solutions refining them than possibly surpassing pre-crisis performance (Taleb, 2013). Or to paraphrase the intrepid explorer Roald Amundsen: Preparation is called 'luck', whereas lack of necessary precautions is called 'bad luck'. During the COVID-19 pandemic, we have to give our organizations a chance to 'be lucky' during and after a disruption. As the COVID-19 situation evolves, disruptions will keep emerging across the value chain, and resilience will remain a core necessity.

Looking at instances of 'luck' during the COVID-19 epidemic, this is a virtual manifesto against over-specialization and towards local adaptation. In the first days of the crisis, long outmoded ventilators were brought out of storage (and dumpsters), and animal hospital ventilators were rapidly adapted for human patients. Anesthesiologists (close enough) were brought in and retrained in their use (Hershner, 2020). Whiskey manufacturers switched to distilling batches hand sanitizer (C. Martin, 2020). 3D printer hobbyists churned out face masks (Brooks, 2020). Super markets and drug stores became door-to-door delivery services overnight (TNN, 2020). Public and private spaces were re-organized for social distancing (Mehaffy, 2020). Churches, schools, and concert halls became online-

only entities within a week (Freedman, 2020). There is much to learn from these creative outbursts, outlining both practical and theoretical challenges for businesses.

In the past, crises were followed by complacency. When normality returns, resilience thinking will, once again, be swimming against the steady current of specialization and optimization. At no point is uncertainty harder to imagine than in predictable times (Taleb, 2005). Already, detailed 'post-crisis' plans are potentially obscuring the view to a future that is, essentially, no less surprising than before (Weick & Sutcliffe, 2007). Denial, nostalgia and arrogance of past successes quickly reassert themselves (Hamel & Välikangas, 2003), now amplified by survivorship and hindsight bias. Preserving and harnessing the creative, flexible, imaginative, engaged, 'one-day-at-a-time' state of alertness (Hall et al., 2015) will be a major challenge for businesses. Preparing for the next surprise will involve remaining in the sweet spot between complacency and panic (Oehmen, 2020).

Theoretically, the challenge is to move beyond a probabilistic and 'event-specific' understanding of risk, and toward a paradigm of 'general preparedness' (Aven, 2017b). There is some way to go to reconcile Holling's attitude of Socratic humility about the future (Holling, 1973) with the necessity of specialization, optimization and regular risk management. It is challenging to appreciate the value of 'post surprise' strategies like multi-functionality, redundancy, reversibility, incremental learning, modifiability and opportunism (Wied et al., 2020), before they are actually needed. Importantly, resilience thinking does not preclude sophisticated anticipatory planning, but encourages us to prepare for even our best-laid plans to be wrong.

5 Why risk may not be the biggest issue: Our inability to act even if presented with near-certainties

Despite all guidelines, mathematical models and software, risk management remains a human-centric activity. It is people deciding if and which risk management perspective and process to adopt, which scenarios or inputs to analyses, and what to with the results. These human-centric activities are subject to several limitations, that can be analysed at two different levels: individual and organizational.

At the individual level, humans dealing with risk, suffer from the so-called "cognitive bias". The term cognitive bias was popularized by the work of Tversky and Kahneman (1974) which identified cognitive biases as errors in thinking stemming from heuristics. These heuristics are principles which are used to reduce the complexity of decision making leading to errors in an individuals thoughts. Pohl (2004) imagines cognitive biases as illusions that can cause an individual's thoughts, memories or judgements to deviate from reality. Cognitive biases usually tend to affect complex decisions and individuals are not usually aware of the presence of such biases in their decision making. According to Reyna et al. (2014) experienced individuals were more likely to display cognitive biases in their decision making when compared to the group of inexperienced people. As the COVID-19 situation unfolds, we can individually reflect on our own thinking and decision making biases, particularly in the early phases of the pandemic.

Cognitive biases, such as optimism bias, have been popularised in project and risk management literature by Flyvbjerg's books and papers claiming that cognitive biases are key reasons why for example large-scale projects are often delivered over budget and late (Flyvbjerg, 2006, 2009). However, the idea of cognitive biases in project and risk management is at least 20 years old.

McCray et al. (2002) highlight the significant effect that cognitive biases may have on complex projects where project managers tend to rely on prior experience or rules of thumb (heuristics) that they have created over the years in order to deal with project complexity.

The number of cognitive biases described in the literature is probably on the order of 100. One bias that is relatively infrequently discussed, but very relevant for our discussion, is the Dunning-Kruger effect. The term was first coined in 1999 when David Dunning and Justin Kruger first observed the effects of incompetence on self-judgement (Kruger & Dunning, 1999); in addition to making wrong decisions, incompetent people are also unable to realize their incompetence. Kruger and Dunning (Kruger & Dunning, 1999) called this the "dual burden of incompetence". This poses a particular challenge in the COVID-19 pandemic: In order to recognize the competence of other people in a specific domain, an individual should possess a certain level of competence in that domain as well; since an incompetent person will not be able to judge their performance correctly, that person will tend to overestimate their ability, e.g. in performing an appropriate risk analysis.

Advancing to the organizational level, humans dealing with risk suffer from "Collective myopia", also called "organizational myopia" or "res" (Chikudate, 2002). Organizational myopia received less attention and research than cognitive bias but is no less important. "Collective myopia is a […] condition where the sense-making capabilities among the members in collectivities are limited to their contexts. Emerging orders or patterns are like the flocks of sheep that are nicely organized. Each sheep knows how to behave and watch out for each other in a collectivity. But none observes their collective behaviours as a whole. […] The sense-making of these members is, thus, confined to the limited context of their own concerns in certain organizations or communities." (Chikudate, 2015, p16).

The concept of collective myopia has been associated with the studies of ethics in organizational practices (Chikudate, 2002), where the ethical judgment of the individuals are suppressed by an overarching perspective from the organization. In this "Ethical Blindness" individuals, as part of an organization, might act unethically without being aware of it. They become ethically blind (Palazzo et al., 2012). This blindness has implications for risk management and decision making, like in the emblematic cases of the Ford Pinto (Gioia, 1992) and Fukushima Daiichi (Chikudate, 2015) where misjudged risk analyses had dramatic consequence on people, business and the environment. It is starting to become evident in the context of COVID-19, when for example certain groups start discussing very matter-of-factly how we should deliberately sacrifice vulnerable populations for the greater good, completely oblivious of their ethical transgressions and proximity to eugenics (Jones, 2020).

At individual level cognitive bias and, at an organizational level, collective myopia can at least in part explain how educated and intelligent people consistently failed to appreciate and take actions to mitigate a pandemic risk its implications. The risk management models reflected the bias and myopia of the people preparing them, and miserably failed.

Myopia, and ethical blindness, are major barriers in developing successful interorganisational relationships, as they push the organisation to develop a tunnel vision. The organisation loses its ability to develop empathy relationship with its stakeholders, including understanding what represents "value" for them, greatly diminishing their ability to address the various forms of risk. The

organisation might even fail to recognise key stakeholders that can support the organisation in achieving its objectives and responding to risk, uncertainty and ignorance.

A way for addressing organisational myopia is “organizational mindfulness" (Sutcliffe et al., 2016). Organizations can address the issues organisational myopia by closely monitoring failures (own failures and failures from other organisations), paying attentions to frontline operations, resist the temptation to oversimplifying the interpretations of events and situation privileging expertise over hierarchy (Catino, 2013).

The Case of the UK government failing to procure PPE for its healthcare system is an exemplar case of how myopia undermined the interorganisational relationships, discussed in the following section.

6 Risk, Uncertainty, Ignorance and Myopia in interorganisational relationships – the Illustrative Example of the NHS PPE Shortage During COVID-19

6.1 The National Health Service in the UK

On April 28, 2020, the BBC opened with a dramatic headline “The government failed to buy crucial protective equipment to cope with a pandemic” (BBC, 2020d). For the BBC, this news article was quite unique, as it showed two rare characteristics: (i) an almost alarmist tone, reminiscent of a tabloid, in stark contrast with the BBC’s usually softer tone; and (ii) the headline being a direct attack on the UK government. However the situation was dramatic: "The consequence of not planning; not ordering kit; not having stockpiles is that we are sending into the front line doctors, nurses, other health workers and social care workers without the equipment to keep them safe". According to the Government minister Victoria Atkins, "Like every other country in the world, [the virus] is unprecedented and the requirements for [Personal protection equipment] PPE have risen exponentially and we are doing our absolute best to address those needs and will continue to do so throughout this crisis" (BBC, 2020d).

The NHS is the UK’s national health care system. The NHS offers medical care across the UK to all those who reside there, including first aid, short and long-term hospital stay, and specialist services such as dental services. It came into operation on July 5, 1948. Most of the services are tax financed, and as such free of direct cost for patients.

6.2 Conditions of Ignorance

The issues related to the provision of PPE originated even before the COVID-19 was recognised by the World Health Organisation (WHO). A BBC report “found that vital items were left out of the stockpile when it was set up in 2009 and that the government subsequently ignored a warning from its own advisers to buy missing equipment. […] The expert committee that advises the government on pandemics, the New and Emerging Respiratory Virus Threats Advisory Group (Nervtag), recommended the purchase of gowns last June. Gowns are currently one of the items in shortest supply in the UK and they are now difficult to source because of the global shortage of PPE. Doctors and nurses have complained that there are also shortages of the life-saving FFP3 respirator masks. Panorama has discovered that millions of FFP3 respirator masks are unaccounted for. There were 33 million on the original 2009 procurement list for the stockpile, but only 12 million have been handed out. The government refuses to explain where the other masks have gone.” (BBC, 2020d).

While many of these facts were knowable (or known to someone), the central decision makers were largely in positions of ignorance. What caused the later escalation of the situation is that the general level of resilience – a sufficient capability of preparation and ability to resist, recover and learn from an incident, in our case specifically escalation PPE demand – was very low. Even the easiest option, stockpiling of cheap but critical items such as PPE, had not been realized.

6.3 Conditions of Uncertainty

During the early phase of the outbreak, very little statistically relevant information was available that could have informed classic probabilistic risk assessments, but it was known that a novel virus was spreading. Decision makers were no longer operating under conditions of ignorance, but significant uncertainty: According to WHO (2020), on the 31st of December 2019 Chinese authorities reported a group of cases of pneumonia in Wuhan. A new coronavirus was recognised. Shortly thereafter, on the 4th of January 2020, the WHO reported the news about a cluster of pneumonia cases with no deaths in Wuhan.

The following day the WHO distributed the first Disease Outbreak News about the virus. This type of announcement, intended for media, scientific and public health community, includes a risk assessment section, concluding that "there is limited information to determine the overall risk" (WHO, 2020a) – summarizing that decision makers are indeed operating under conditions of uncertainty, not risk.

We can observe several actions being taken under these conditions to 'minimize regret', i.e. taking actions to minimize the impact of a worst-case scenario. For example, on the 10th of January, the WHO issued a comprehensive package of technical guidance online with advice to all countries on how to detect, test and manage potential cases, based on what was known about the virus at the time. This guidance was shared with WHO's regional emergency directors to share with WHO representatives in countries. It is reasonable to assume that by the 10th of January, UK authorities were informed about the new virus, but it is not obvious that aggressive actions were taken to strengthen national capabilities. By January 12, China had publicly shared the genetic sequence of COVID-19 to facilitate scientific endeavours for diagnosis, treatment and vaccination.

On the 22nd of January, the Department of Health and Social Care and Public Health England to publish the first government statement. After another 9 days (31st of January), there are the first two cases of COVID-19 confirmed in the UK. A few days later (3rd of February), the WHO releases the 28 page 'Strategic Preparedness and Response Plan' (WHO, 2020b) to support states with weaker health systems. It includes an updated risk assessment, now being based on over 10'000 confirmed cases globally, confirmed human-to-human transmission, and robust quarantine and lockdown measures being taken in China.

6.4 Conditions of Risk

Arguably, the situation evolved into a scenario where larger amounts of data are becoming available, enabling probabilistic risk assessments. It is accompanied by increasingly aggressive EU-level activities to procure critical PPE. On the 31st of January Four UK countries (not including the UK) suggest a need for PPE "in case of an expanding situation in the EU". (The Guardian, 2020b).

On the 28th of February The EU launches its first joint procurement of £1.2m worth of gloves and gowns/overalls. The procurement fails due to a lack of suitable suppliers. It is relaunched on 15 March - the UK was not involved in either (The Guardian, 2020b).

One very visible turning point in the engagement with risk-based models was the publication of the so-called 'Imperial Model' by a research group from Imperial College London on March 16 (Ferguson

et al., 2020). Based on some of the most detailed modelling to-date and the latest known characteristics of the COVID-19 spread, it projected mortality figures for the UK and the US, which triggered the first significant actions in both countries in the following days regarding non-pharmaceutical interventions.

6.5 Instances of Myopia

As the COVID-19 situation evolved, instances of organizational myopia became more and more apparent: For example, by the 11 of February there were eight confirmed COVID-19 cases in the UK, but Steve Oldfield, chief commercial officer at the Department of Health and Social Care, reassured staff that the "NHS and wider health system are extremely well prepared for these types of outbreaks" (Financial Times, 2020). Only two days later UK dentists started to discuss the potential issue of lack of PPE (Express, 2020).

In another instance, on the 24th of February (two days after the first major lockdowns in Italy occurred), a meeting of officials, to which the UK was invited, hears an update from the European commission on the joint procurement of PPE. Commission officials call on countries to confirm "their exact needs latest today … to move forward with next steps". No representative from the UK attends the meeting (The Guardian, 2020b). Two days later Emergency units in the UK start to be overcrowded and patients have to be looked after in hospital corridors (The Guardian, 2020a).

On the 4th of March there is the 100 officially recognised victims in Italy, and the following day there is the first victim of coronavirus in the UK (BBC, 2020a). Over the next two weeks the number of victims in Italy increases to more than 3000 and the Italian healthcare system is, in the most affected zone, collapsing. However, still on the 18th of March (two days after the publication of the 'Imperial Model'), the UK Prime Minister Boris Johns declared "We have stockpiles of PPE equipment and we're proceeding in accordance with the best scientific advice." (BBC, 2020c). The UK is still largely operating 'business as usual' with children going to schools and pubs and restaurants opened (almost one month after the first lockdowns Italy).

On the 19th of March the UK eventually takes up an invitation to join the EU joint procurement agreement steering committee, which makes decisions on mass purchases. The UK does not join a procurement for laboratory supplies that is put out to tender on the same day (The Guardian, 2020b). The following day, in a unique historic escalation of the UK's response to the outbreak, the UK prime minister Boris Johnson orders all gym, restaurants, pubs, churches and other social venues across the UK to stay closed indefinitely (The Independent, 2020). On the 23rd of March, almost three months after the outbreak in China became public knowledge, the health secretary, Matt Hancock, confesses there have been "challenges" with suppling PPE after complaints by NHS staff (including doctors and nurse) from across the country. The UK army is drafted into the effort to support the distribution (The Guardian, 2020b).

6.6 Commentary on the NHS case of PPE shortage

While the presented case presents a rough progression from conditions of ignorance to those of uncertainty and risk, this cannot be generally assumed. As is the case in the example, this progression is also specific to each issue at hand. Furthermore, the role that organizational myopia plays as the behavioural reaction to risk, uncertainty and ignorance evolved as the situation evolved.

It is important to distinguish between ignorance and myopia, which are two distinct, yet complementary phenomena. At the beginning the government displayed prevalently ignorance. Before the crisis started there was already a shortage of PPE. The government ignored the warning coming from Nervtag, Bill Gate's now-famous TED Talk (Gates, 2015) and more generally the various

expert assessments of possible future pandemics. At the time, the UK government was focused on the issues related to the exit of the UK from the European Union ('Brexit'). Although these insights were technically knowable by UK Department of Health and Social Care (and most likely known by some), it was not considered for and implemented in the design of the healthcare and broader response system.

However, after the WHO alerts and the first deaths in Italy and Spain, the situation progresses from ignorance to uncertainty. The UK government 'knows' about COVID-19 but, for a long time, is refusing to acknowledge its relevance, that the system is poorly prepared, and the need for taking appropriate actions. Instead, it propagates an increasingly untenable narrative that the NHS well prepared to face the pandemic, ignoring available facts. Myopia reduces the number of options assessed by decision makers making them rely on their own bounded rationality. The "big picture" is lost and future opportunities are missed (Czakon & Kawa, 2018). In March, organizational myopia reaches a level where the government pretends to have PPE that does not exist. Still in May, the NHS is struggling to access to basic PPE (BBC, 2020b).

Arguably, organizational myopia was a moderating factor that negatively influenced UK government capability to adequately address all three conditions – risk, uncertainty and ignorance. As a result, prudent preparation where not taken, the lack of those preparations was ignored, timely steps to 'minimize regret' were not taken, and ultimately, even the increasing amount of scientific evidence and more advanced models only led to tangible action after significant delay.

7 Conclusion

We can draw a number of managerial implications from the previous discussion (see Figure 1):

First, it is important to note that the most widely used approach, risk management, is typically not geared towards providing meaningful responses to high-impact, low-probability events, such as the current COVID-19 pandemic. These events in the 'fat tail' of the probability distribution typically do not meet threshhold criteria for taking substantial action, as standard cost-benefit tradeoffs fail to appropriately capture low likelihood events, or events expected to occur in the 10+ year future. An obvious task is to revise risk management procedures to adequately prioritize mitigation actions for this type of event.

Second, we have to acknowledge that rare events are characterized – by their nature – by less available data. Our approaches to characterize those events must be chosen appropriately. If a quantitative risk assessment is not meaningful, organizations must employ methods that are appropriate for these situations, such as Robust Decision Making, or Resilience Thinking.

Third, related to the previous point, decision makers have to reflect on the level of (practically) available knowledge, and actively discuss their current decision making context. In situations of significant uncertainty, or where we can reasonably expect a large degree of ignorance regarding future devleopments, managers should again emphasize resilience (i.e. general preparedness for noticing, resisting, recovering, and learning from distruptions), and Robust Decision Making-type actions (e.g. minimizing regret under plausible future scenarios).

Fourth, the factual basis that is available to decision makers is only part of the equation. Equally, if not more, important are the cultural and behavioural actions at the individual and organizational level. These have to be understood and reflected in the way that decisions are made and communicated.

These implications are broadly supported by the ongoing discussions in the risk management domain, specifically regarding the need to tailor our responses to specific contexts (Tegeltija, 2018), as well as the discussions surrounding the relationship and integration of various models of and responses to uncertainty (Aven, 2018) .

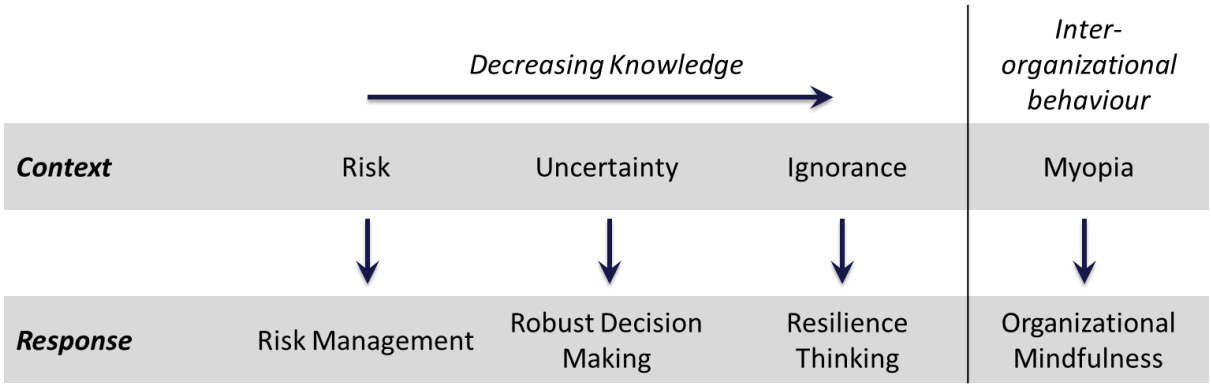

Figure 1: Context and responses to different levels of certainty

The U.K. National Risk Register of Civil Emergencies was last updated in 2017. In contains a detailed description of what would happen during a pandemic, the impact on the U.K., and what actions would need to be taken. It was ranked as the highest risk in the catalogue (National Risk Register of Civil Emergencies, 2017), with a near-certain probability of occurrence during our lifetimes. Reports of that kind existed for practically all governments. The failure to take action to mitigate an obvious risk is not just the failure of our governments, it is also the failure of (most) major corporations, and us as individuals.

We are paying a very high price for having neglected risk management in all its facets, as briefly laid out in this article. Even articulating what we mean by 'risk management' is difficult. We suggest to use resilience – for example as 'resilient organizations' and 'resilient inter-organizational relationships' – as a shorthand to summarize the goal of the much needed transformation. If interpreted in a wider sense, the preparation phase inherent in resilience can accommodate all necessary risk and uncertainty management activities. Additionally, the capabilities to resist, recover, and learn provide a framework to discuss other desirable attributes, such as flexibility, adaptability, or robustness.

For over 200 years, we have embraced productivity as the guiding star of our societal development. It took us more than 50 years to start taking serious actions regarding sustainability. Now is the time to embrace the third column that modern societies rest on – resilience.

8 References

Ahlemann, F., El Arbi, F., Kaiser, M. G., & Heck, A. (2013). A process framework for theoretically grounded prescriptive research in the project management field. *International Journal of Project Management*, *31*(1), 43–56. https://doi.org/10.1016/j.ijproman.2012.03.008

Allen, S. (2012). *Financial risk management : a practitioner's guide to managing market and credit risk + website*. John Wiley & Sons.

Aven, T. (2012). Foundational Issues in Risk Assessment and Risk Management. *Risk Analysis*, *32*(10), 1647–1656. https://doi.org/10.1111/j.1539-6924.2012.01798.x

Aven, T. (2016). Risk assessment and risk management: Review of recent advances on their foundation. *European Journal of Operational Research*, *253*(1), 1–13. https://doi.org/10.1016/j.ejor.2015.12.023

Aven, T. (2017a). *A Conceptual Foundation for Assessing and Managing Risk, Surprises and Black Swans* (pp. 23–39). https://doi.org/10.1007/978-3-319-32939-0_3

Aven, T. (2017b). How some types of risk assessments can support resilience analysis and management. *Reliability Engineering & System Safety*, *167*, 536–543. https://doi.org/10.1016/j.ress.2017.07.005

Aven, T. (2018). The Call for a Shift from Risk to Resilience: What Does it Mean? *Risk Analysis*, risa.13247. https://doi.org/10.1111/risa.13247

Aven, T., & Cox, Jr., L. A. (Tony). (2015). Introduction to Special Virtual Issue: Foundations of Risk Analysis. *Risk Analysis*.

Aven, T., & Renn, O. (2019). Some foundational issues related to risk governance and different types of risks. *Journal of Risk Research*, 1–14. https://doi.org/10.1080/13669877.2019.1569099

Aven, T., & Zio, E. (2011). Some considerations on the treatment of uncertainties in risk assessment for practical decision making. *Reliability Engineering & System Safety*, *96*(1), 64–74. https://doi.org/10.1016/j.ress.2010.06.001

BBC. (2020a). *Coronavirus: Man in 80s is second person to die of virus in UK*. https://www.bbc.com/news/uk-51771815

BBC. (2020b). *Coronavirus: Newly-promoted NHS consultant says "it's time to step up."* https://www.bbc.com/news/uk-england-52109469

BBC. (2020c). *Coronavirus: NHS staff "at risk" over lack of protective gear*. https://www.bbc.com/news/uk-51950276

BBC. (2020d). *Coronavirus: UK failed to stockpile crucial PPE*. https://www.bbc.co.uk/news/newsbeat-52440641

Bernardo, J. M., & Smith, A. F. M. (1994). *Bayesian Theory*. John Wiley & Sons.

Beynon, M., Curry, B., & Morgan, P. (2000). The Dempster–Shafer theory of evidence: an alternative approach to multicriteria decision modelling. *Omega*, *28*(1), 37–50. https://doi.org/10.1016/S0305-0483(99)00033-X

Bloomberg TV. (2020). *Nassim Taleb Says "White Swan" Coronavirus Pandemic Was Preventable*.

Brooks, C. (2020, April). Silverton-area man makes masks for health care workers with 3D printer.

Statsman Journal.

National Risk Register of Civil Emergencies, 71 (2017).

Catino, M. (2013). *Organizational myopia: Problems of rationality and foresight in organizations*. Cambridge University Press.

Chapman, R. J. (2019). Exploring the Value of Risk Management for Projects: Improving Capability Through the Deployment of a Maturity Model. *IEEE Engineering Management Review*, *47*(1), 126–143. https://doi.org/10.1109/EMR.2019.2891494

Chikudate, N. (2002). Collective Myopia and Disciplinary Power Behind the Scenes of Unethical Practices: A Diagnostic Theory on Japanese Organization. *Journal of Management Studies*, *39*(3), 289–307. https://doi.org/10.1111/1467-6486.00293

Chikudate, N. (2015). *Collective myopia in Japanese organizations: a transcultural approach for identifying corporate meltdowns*. Springer.

CHS, C. for H. S. (2019). *Event 201 – Public-Private Cooperation for Pandemic Preparedness and Response – A Call to Action*.

Colyvan, M. (2008). Is Probability the Only Coherent Approach to Uncertainty? *Risk Analysis*, *28*(3), 645–652. https://doi.org/10.1111/j.1539-6924.2008.01058.x

Cooke, R. M. (1991). Experts in Uncertainty: Opinion and Subjective Probability in Science. In *booksgooglecom*. https://doi.org/10.1016/0040-1625(93)90030-B

Cox, Jr., L. A. (Tony). (2009). What's Wrong with Hazard-Ranking Systems? An Expository Note. *Risk Analysis*, *29*(7), 940–948. https://doi.org/10.1111/j.1539-6924.2009.01209.x

Czakon, W., & Kawa, A. (2018). Network myopia: An empirical study of network perception. *Industrial Marketing Management*, *73*, 116–124. https://doi.org/10.1016/j.indmarman.2018.02.005

de Oliveira, U. R., Marins, F. A. S., Rocha, H. M., & Salomon, V. A. P. (2017). The ISO 31000 standard in supply chain risk management. *Journal of Cleaner Production*, *151*, 616–633. https://doi.org/10.1016/j.jclepro.2017.03.054

Dempster, A. P. (1967). Upper and Lower Probabilities Induced by a Multivalued Mapping. *The Annals of Mathematical Statistics*. https://doi.org/10.1214/aoms/1177698950

Dewar, J., Builder, C. ;, Hix, W., & Levin, M. (1993). *Assumption-Based Planning: A Planning Tool for Very Uncertain Times*.

Express. (2020). *Coronavirus face mask shortage: UK dentists issue desperate warning amid killer outbreak*. https://www.express.co.uk/news/uk/1241841/Coronavirus-uk-latest-warning-face-masks-shortage-spread-london-symptoms-china

Ferguson, N., Laydon, D., Nedjati Gilani, G., Imai, N., Ainslie, K., Baguelin, M., Bhatia, S., Boonyasiri, A., Cucunuba Perez, Z., Cuomo-Dannenburg, G., Dighe, A., Dorigatti, I., Fu, H., Gaythorpe, K., Green, W., Hamlet, A., Hinsley, W., Okell, L., Van Elsland, S., … Ghani, A. (2020). *Report 9: Impact of non-pharmaceutical interventions (NPIs) to reduce COVID19 mortality and healthcare demand*. https://doi.org/10.25561/77482

Financial Times. (2020). *How poor planning left the UK without enough PPE | Free to read*. https://www.ft.com/content/9680c20f-7b71-4f65-9bec-0e9554a8e0a7

Flage, R., Aven, T., Zio, E., & Baraldi, P. (2014). Concerns, Challenges, and Directions of Development

for the Issue of Representing Uncertainty in Risk Assessment. *Risk Analysis*. https://doi.org/10.1111/risa.12247

Flyvbjerg, B. (2006). From Nobel Prize to Project Management: Getting Risks Right. *Project Management Journal*. https://doi.org/10.1177/875697280603700302

Flyvbjerg, B. (2009). Delusion and Deception in Large Infrastructure Projects. *California Management Review*, *51*(2).

Fortin, M.-J., & Gagnon, C. (2006). Interpreting major industrial landscapes: Social follow-up on meanings, the case of two aluminium smelters, Alcan (Alma, Canada) and Pechiney (Dunkirk, France). *Environmental Impact Assessment Review*, *26*(8), 725–745. https://doi.org/10.1016/j.eiar.2006.06.002

Freedman, R. (2020). Local churches adapt to COVID-19. Go online … or keep doors open? *Times Herald*.

Funtowicz, S. O., & Ravetz, J. R. (1990). Uncertainty and Quality in Science for Policy. In *Uncertainty and Quality in Science for Policy*. Springer Netherlands. https://doi.org/10.1007/978-94-009-0621-1

Gates, B. (2015). *The next outbreak? We're not ready*. TED Conference TED2015.

Gidel, T., Gautier, R., & Duchamp, R. (2005). Decision-making framework methodology: an original approach to project risk management in new product design. *Journal of Engineering Design*, *16*(1), 1–23. https://doi.org/10.1080/09544820512331325238

Gioia, D. A. (1992). Pinto fires and personal ethics: A script analysis of missed opportunities. *Journal of Business Ethics*, *11*(5–6), 379–389. https://doi.org/10.1007/BF00870550

Hall, M., Turner, N., & Kutsch, E. (2015). Project Resilence: The Art of Noticing, Interpreting, Preparing, Containing and Recovering. In *Gower Publishing*. Routledge.

Hamel, G., & Välikangas, L. (2003). The Quest for Resilience. *Harvard Business Review*, *September*. https://hbr.org/2003/09/the-quest-for-resilience

Hartmann, N. N., & Lussier, B. (2020). Managing the sales force through the unexpected exogenous COVID-19 crisis. *Industrial Marketing Management*, *88*, 101–111. https://doi.org/10.1016/j.indmarman.2020.05.005

Henry, D., & Ramirez-Marquez, J. E. (2016). On the Impacts of Power Outages during Hurricane Sandy-A Resilience-Based Analysis. *Systems Engineering*, *19*(1), 59–75. https://doi.org/10.1002/sys.21338

Hershner, R. (2020). *Improvisation And Retraining May Be Key To Saving Patients In New York's ICUs*. NPR.

Holling, C. S. (1973). Resilience and Stability of Ecological Systems. *Annual Review of Ecology and Systematics*, *4*(1), 1–23. https://doi.org/10.1146/annurev.es.04.110173.000245

Hubbard, D. W. (2009). *The failure of risk management: why it's broken and how to fix it.* (18th ed). Wiley.

Incose. (2015). The Guide to the Systems Engineering Body of Knowledge (SEBoK). *Insight*. https://doi.org/10.1016/j.jpsychires.2013.10.009

ISO. (2018). ISO 31000:2018. Risk management - Principles and Guidelines. In *ISO Standard*. https://doi.org/10.1016/S1146-609X(03)00038-9

Jaynes, E. T. (Edwin T. ., & Bretthorst, G. L. (2003). *Probability theory : the logic of science*. Cambridge University Press.

Jones, S. (2020). Eugenics isn't going to get us out of this mess. *New York Magazine / Intelligencer*. https://nymag.com/intelligencer/2020/03/eugenics-isnt-going-to-save-you-from-coronavirus.html

Klinke, A., & Renn, O. (2002). A New Approach to Risk Evaluation and Management: Risk-Based, Precaution-Based, and Discourse-Based Strategies [1]. *Risk Analysis*, *22*(6), 1071–1094. https://doi.org/10.1111/1539-6924.00274

Knight, F. (1921). Risk, Uncertainty and Profit. In *Risk, uncertainty and profit, Houghton Mifflin Company, Boston, MA*. https://doi.org/10.1017/CBO9780511817410.005

Kozin, I. O. (1996). Obtaining reliability and safety assessments on the basis of non-probabilistic methods. *Intelligent Systems and Soft Computing for Nuclear Science and Industry*.

Kruger, J., & Dunning, D. (1999). Unskilled and unaware of it: How difficulties in recognizing one's own incompetence lead to inflated self-assessments. *Journal of Personality and Social Psychology*, *77*(6), 1121–1134. https://doi.org/10.1037/0022-3514.77.6.1121

Kutsch, E, & Hall, M. (2009). The Rational Choice of Not Applying Project Risk Management in Information Technology Projects. *Project Management Journal*, *40*(3), 72–81. https://doi.org/10.1002/pmj.20112

Kutsch, Elmar, Browning, T. R., & Hall, M. (2014). Bridging the Risk Gap: The Failure of Risk Management in Information Systems Projects. *Research Technology Management*, *57*(2), 26–32. https://doi.org/10.5437/08956308X5702133

Kutsch, Elmar, & Hall, M. (2010). Deliberate ignorance in project risk management. *International Journal of Project Management*, *28*(3), 245–255. https://doi.org/10.1016/j.ijproman.2009.05.003

Lempert, R. (1996). When we don't know the costs or the benefits: Adaptive strategies for abating climate change. *Climatic Change*, *33*(2). https://doi.org/10.1007/BF00140248

Lempert, R. J. (2002). A new decision sciences for complex systems. *Proceedings of the National Academy of Sciences of the United States of America*, *99 Suppl 3*.

Lough, K. G., Stone, R., & Tumer, I. Y. (2009). The Risk in Early Design Method. *Journal of Engineering Design*, *20*(2), 155–173.

Martin, C. (2020). *Washington distillers switch from spirits to sanitizer*. NPR.

Martin, R. L. (2019). Rethinking Efficiency. The High Price of Efficiency. *Harvard Business Review*, *January-February*. https://hbr.org/2019/01/rethinking-efficiency

McCray, G. E., Purvis, R. L., & McCray, C. G. (2002). Project Management under Uncertainty: The Impact of Heuristics and Biases. *Project Management Journal*, *33*(1), 49–57. https://doi.org/10.1177/875697280203300108

Mehaffy, M. (2020). "Sociable Distancing": How Stoops, Porches, and Balconies Connect Public and Private Spaces. *Blue Zones*.

Michael Smithson. (1989). *Ignorance and Uncertainty: Emerging Paradigms*. Springer-Verlag.

Neves, S. M., da Silva, C. E. S., Salomon, V. A. P., da Silva, A. F., & Sotomonte, B. E. P. (2014). Risk management in software projects through Knowledge Management techniques: Cases in

Brazilian Incubated Technology-Based Firms. *International Journal of Project Management*, *32*(1), 125–138. https://doi.org/10.1016/j.ijproman.2013.02.007

Oehmen, J. (2020). *Amidst the coronavirus chaos, businesses need resilience thinking*. LSE Business Review.

Oehmen, J., Olechowski, A., Robert Kenley, C., & Ben-Daya, M. (2014). Analysis of the effect of risk management practices on the performance of new product development programs. *Technovation*, *34*(8), 441–453. https://doi.org/10.1016/j.technovation.2013.12.005

Olechowski, A., Oehmen, J., Seering, W., & Ben-Daya, M. (2016). The professionalization of risk management: What role can the ISO 31000 risk management principles play? *International Journal of Project Management*, *34*(8), 1568–1578. https://doi.org/10.1016/j.ijproman.2016.08.002

Palazzo, G., Krings, F., & Hoffrage, U. (2012). Ethical Blindness. *Journal of Business Ethics*, *109*(3), 323–338. https://doi.org/10.1007/s10551-011-1130-4

PMI. (2019). *The standard for risk management in portfolios, programs, and projects.* Project Management Institute.

Pohl, R. F. (2004). *Cognitive illusions : a handbook on fallacies and biases in thinking, judgement and memory* (First edit). Psychology Press.

Renn, O. (1998). Three decades of risk research: accomplishments and new challenges. *Journal of Risk Research*, *September 2015*. https://doi.org/10.1080/136698798377321

Renn, O., Klinke, A., & van Asselt, M. (2011). Coping with Complexity, Uncertainty and Ambiguity in Risk Governance: A Synthesis. *AMBIO*, *40*(2), 231–246. https://doi.org/10.1007/s13280-010-0134-0

Reyna, V. F., Chick, C. F., Corbin, J. C., & Hsia, A. N. (2014). Developmental Reversals in Risky Decision Making. *Psychological Science*, *25*(1), 76–84. https://doi.org/10.1177/0956797613497022

Rolstadås, A., Hetland, P. W., Jergeas, G. F., & Westney, R. E. (2011). Risk Navigation Strategies for Major Capital Projects: Beyond the Myth of Predictability. In *Springer Series in Reliability Engineering*. Springer. https://doi.org/10.1007/978-0-85729-594-1

Seong, S. ., Popper, S. ., & Zheng, K. (2005). *Strategic Choices in Science and Technology: Korea in the Era of a Rsing China;*

Sheffi, Y. (2017). *The Power of Resilience: How the Best Companies Manage the Unexpected*. MIT Press.

Simon, H. A. (1990). Bounded Rationality BT - Utility and Probability. In *Utility and Probability*. Palgrave Macmillan, a division of Macmillan Publishers Limited. https://doi.org/10.1007/978-1-349-20568-4_5

Stingl, V., & Geraldi, J. (2017). Errors, lies and misunderstandings: Systematic review on behavioural decision making in projects. *International Journal of Project Management*, *35*(2), 121–135. https://doi.org/10.1016/j.ijproman.2016.10.009

Sutcliffe, K. M., Vogus, T. J., & Dane, E. (2016). Mindfulness in Organizations: A Cross-Level Review. *Annual Review of Organizational Psychology and Organizational Behavior*, *3*(1), 55–81. https://doi.org/10.1146/annurev-orgpsych-041015-062531

Taleb, N. N. (2005). *Fooled by Randomness : The Hidden Role of Chance in Life and in the Markets*. Random House USA Inc.

Taleb, N. N. (2007). *The Black Swan: Second Edition: The Impact of the Highly Improbable*. New York: Random House.

Taleb, N. N. (2013). *Antifragile: Things that Gain from Disorder Paperback* (F. Edition (ed.)). Penguin.

Tegeltija, M. (2018). *Assessing the capabilities of advanced risk quantification methods for engineering systems management*. Technical University of Denmark.

Tegeltija, M., Oehmen, J., & Kozin, I. (2017). Risk Management Challenges in Large-scale Energy PSS. *Procedia CIRP*, *64*, 169–174. https://doi.org/10.1016/j.procir.2017.03.023

The Guardian. (2020a). *"Corridor nursing" becoming norm in packed A&Es, warn medics*. https://www.theguardian.com/society/2020/feb/26/corridor-nursing-becoming-norm-in-packed-aes-warn-medics

The Guardian. (2020b). *Timeline of UK's coronavirus PPE shortage*. https://www.theguardian.com/politics/2020/apr/13/timeline-of-uks-coronavirus-ppe-shortage

The Independent. (2020). *Coronavirus: A timeline of how Britain went from 'low risk' to an unprecedented national shutdown*. https://www.independent.co.uk/news/uk/home-news/coronavirus-uk-timeline-deaths-cases-covid-19-nhs-social-distancing-a9416331.html

TNN. (2020). Door-to-door delivery of supplies begins. *The Times of India*.

Tversky, A., & Kahneman, D. (1974). Judgement under uncertainty - heuristics and biases. *Science*, *185*(4157). https://doi.org/10.1126/science.185.4157.1124

Walker, W. E., Haasnoot, M., & Kwakkel, J. H. (2013). Adapt or Perish: A Review of Planning Approaches for Adaptation under Deep Uncertainty. *Sustainability*, 955–979. https://doi.org/10.3390/su5030955

Walley, P. (1991). Statistical Reasoning with Imprecise Probabilities. In *Statistical Reasoning with Imprecise Probabilities*. https://doi.org/10.1007/978-1-4899-3472-7

Ward, S., & Chapman, C. (2003). Transforming project risk management into project uncertainty management. *International Journal of Project Management*, *21*(2), 97–105. https://doi.org/10.1016/S0263-7863(01)00080-1

Weick, K. E., & Sutcliffe, K. M. (2007). *Managing the Unexpected: Resilient Performance in an Age of Uncertainty* (2nd ed.). John Wiley & Sons.

WHO. (2020a). *Pneumonia of unknown cause – China. Disease outbreak news*. https://www.who.int/csr/don/05-january-2020-pneumonia-of-unkown-cause-china/en/

WHO. (2020b). *Strategic preparedness and response plan*. https://www.who.int/publications-detail/strategic-preparedness-and-response-plan-for-the-new-coronavirus

WHO. (2020c). *WHO Timeline - COVID-19*. https://www.who.int/news-room/detail/27-04-2020-who-timeline---covid-19

Wied, M., Koch-Ørvad, N., Welo, T., & Oehmen, J. (2020). Managing exploratory projects: A repertoire of approaches and their shared underpinnings. *International Journal of Project Management*, *38*(2), 75–84. https://doi.org/10.1016/j.ijproman.2019.12.002

Willumsen, P., Oehmen, J., Stingl, V., & Geraldi, J. (2019). Value creation through project risk management. *International Journal of Project Management*. https://doi.org/10.1016/j.ijproman.2019.01.007

Xia, N., Zou, P. X. W., Griffin, M. A., Wang, X., & Zhong, R. (2018). Towards integrating construction

risk management and stakeholder management: A systematic literature review and future research agendas. *International Journal of Project Management*, *36*(5), 701–715. https://doi.org/10.1016/j.ijproman.2018.03.006

Yen, J. (1989). GERTIS: a Dempster-Shafer approach to diagnosing hierarchical hypotheses. *Communications of the ACM*, *32*(5), 573–585. https://doi.org/10.1145/63485.63488

Zio, E. (2009). Reliability engineering: Old problems and new challenges. *Reliability Engineering and System Safety*, *94*(2), 125–141. https://doi.org/10.1016/j.ress.2008.06.002

Zsidisin, G. A., & Ritchie, B. (2008). *Supply chain risk : a handbook of assessment, management, and performance*. Springer.