Toward the Application of Anticipatory Thinking in Support of Risk Identification

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Abstract

Risk management is a critical process for organizations to manage and navigate environments that are uncertain, complex, and dynamic. The first step of the risk management process is risk identification, which has the goal of identifying a diverse space of specific and relevant potential risks. Despite the central role of risk identification in the risk management process, limited work has investigated cognitive processes in risk management. This paper conceptualizes risk identification as a type of anticipatory thinking—the process by which we imagine alternative states of the world. It explores how three anticipatory thinking metrics (novelty, specificity, diversity) can be used to assess risk identification.

Introduction

Risk management has increasingly become a required process for organizations, within both public and private sectors, that are attempting to navigate uncertain, complex, and dynamic environments (Baird, Skromme, and Thomas 1986; Hood and Rothstein 2000). It is employed across as diverse topics as information security (Gerber and Solms 2005), product development (Chin et al. 2009), construction (Chileshe and Boadua 2012), and water supply (Ameyaw and Chan 2015). The first step of risk management is risk identification, which plays a critical role in the success of any risk management process. Unidentified risks can pose major threats to an organization (Australia & New Zealand Standards 2004; Greene & Trieschmann 1984), and even specialists have cognitive biases and can experience miscalculations due to failure of anticipating all possible factors (Freudenburg 1998). Despite the fundamental role of risk identification in the risk management process, there is a paucity of research on how analysts effectively engage in risk identification, what cognitive processes are involved, and how it can be assessed.

The exploratory nature of risk identification is similar to that of anticipatory thinking, which is the process by which an individual imagines alternative futures and is a critical component for successfully navigating complex circumstances (Anderson 2011; Hines and Bishop 2006). The extrapolation component of anticipatory thinking (Klein et al. 2007) is the process of anticipating alternative futures based on the current situation, and directly ties into the objectives of risk identification.

This paper presents an analysis of linkages between the mechanisms and processes of risk identification and anticipatory thinking to support a deeper understanding of assessing risk identification. It considers how metrics devised for the assessment of anticipatory thinking can be used to measure the quality of risk identification.

Related Work

Risk Identification

Risk management is a widely used technique in management, engineering, finance, defense, and public health, to determine the allocation of resources in order to monitor and minimize the impact of unfortunate events and maximize the potential of opportunities (Hubbard 2009). It is a cyclic process that involves identification, evaluation, and prioritization of risks. Among these, risk identification is the first step of the process and often introduces a bottleneck for the success of following steps due to the vast problem space (Department of Defense 2017). During risk identification, an analyst employs detailed knowledge and systematic methods to generate a set of risks and their impacts, which are sometimes accompanied by other features of the identified risks such as vulnerability, speed of situation development, potential gain from taking the risk, and others depending on the context. The risks could be threats, opportunities, or uncertainties in general. All the information is gathered for subsequent qualitative and quantitative analyses.

Two qualitative risk assessment methods, bow-tie analysis and risk classification charts, are of particular relevance in the application of anticipatory thinking. A bow-tie analysis aims to identify the causes and preventive measures of a particular risk (Hancock 2016), making links among risk, impact, and cause (which could be the impact of another risk). This method, wherein an analyst generates risk-impact pairs, shares commonalities with the anticipatory thinking methodology. A risk classification chart is a grid plot of impact against likelihood for each particular risk. It is created to quantify the diversity of identified risks and their impacts.

Despite the challenges of risk identification, research has shown several promising methods that can improve risk identification performance. For example, there is evidence that risk identification is a trainable skill and that part of this skill may be domain general as experience within a domain is not sufficient to fully support superior performance (Maytorena et al. 2007). In addition, based on observations by risk and project practitioners, assembling a panel of individuals with relevant but diverse backgrounds can yield better risk identification outcomes (Emmons et al. 2018). These methods generally align with ways that may support divergent and anticipatory thinking.

Anticipatory Thinking

Anticipating how situations may evolve into the future is a significantly challenging task, yet this form of anticipatory thinking plays a central role in strategic decision-making and risk identification activities in areas such as military planning, business planning, and medicine, where individuals must generate ideas about the conditions under which events occur, identify second and third-order effects, and develop explicit potential alternatives to a given scenario in order to avoid tactical or strategic surprise.

Anticipatory thinking relies on many connected cognitive components including attention, memory, executive function, situational awareness, and domain expertise (Koziol, Budding, and Chidekel 2012; Mullally and Maguire 2014). Each of these components serves an important role in perceiving the status, attributes, and dynamics of relevant elements in the environment and projecting how these elements could lead to different future states.

Anticipatory thinking can take three distinct forms: prospective branching, backcasting, and retrospective branching (Figure 1). *Prospective branching* involves anticipating future system states and identifying indicators that may lead to these system states. *Backcasting* involves examining a particular future system state and thinking back in time to identify warnings and indicators that lead to its occurrence. *Retrospective branching* is the identification of possible unknown past system states and their paths towards the present one. All forms of anticipatory thinking focus on the mapping of alternative system states and paths towards them through uncertain conditions, and the goals of the analyst influence where the uncertainty is mapped out.

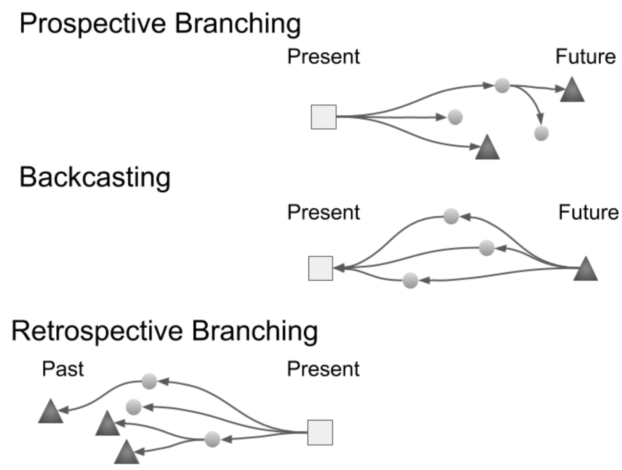

Figure 1. Three forms of anticipatory thinking with arrows representing the temporal direction in which the individual is anticipating.

Divergent thinking is central to anticipatory thinking. Individuals with strong divergent thinking skills are hypothesized to be able to generate creative ideas by exploring many possible solutions. Strong divergent thinking skills may be particularly useful during the generative phase of anticipatory thinking wherein individuals anticipate potential futures and generate indicators tied to those events. In fact, recent research shows strong correlations between performance on anticipatory thinking activities and divergent thinking skills (Geden et al. 2019).

Anticipatory thinking is essential for effective risk identification. Prior to assessing and weighing risks, organizations and individuals must identify high and low-likelihood events and determine the level of risk associated with each event. Identifying vulnerabilities and risks requires individuals to think across time and identify causal links between events, causes, and consequences. For instance, if a risk has been realized, then a risk management team may need to engage in retrospective branching to identify indicators that led to the risk. Conversely, if a team is engaging in a strategic risk identification exercise to reduce vulnerability, then team members will need to engage in prospective branching to identify leading indicators and causal dependencies of future scenarios.

Geden et al. (2019) developed an anticipatory thinking assessment that may be relevant for assessing risk identification skills. The assessment presents respondents with a future-oriented prompt (e.g., “The impact of smart home technologies on older adults in 10 years”), and asks them to generate as many pairs of potential future events (uncertainties) and their subsequent consequences (impacts) as they can within a short ten-minute window.

The format of the assessment uses a similar dyadic pairing form that risk identification can take (i.e., cause → risk; risk → consequences). Individuals are able to generate and reuse multiple impacts and uncertainties to generate a list of novel and specific outcomes tied to the scenarios (Table 1). This simple methodology allows for significant flexibility while also assessing the extrapolation component of anticipatory thinking. Individuals' anticipatory thinking performance is assessed using three metrics that aim to capture the novelty and uniqueness of each response, the level of diversity across responses, and the level of detail in the description of the responses.

Table 1: Example responses on anticipatory thinking task with the prompt: "Nutritiously and sustainably feeding 8.5 billion people in 10 years" (Geden et al., 2019; adapted from World Economic Forum, 2017). Uncertainty and impact responses in the same line forms a dyadic pair.

Uncertainty	Impact
More international trade	Resource efficient food production
Rapid adoption of new food technology	Increased preference for vegetarianism
Increased preference for vegetarianism	Lower resource requirements for production

Translating Anticipatory Thinking Metrics

Traditional risk identification metrics typically focus on assigning each risk with characteristics such as likelihood and impact ratings. These numeric ratings are then used to produce rankings or visualizations, such as heat maps or scatterplots, to categorize the most important risks for further analyses (Figure 2). Risk plots can provide information about which risk categories are not being sufficiently explored and regions of unexplored risk space (e.g., high impact / low likelihood). These metrics, while informative, miss out on the actual quality of the ideas being generated, providing a limited view into the quality of the risk identification process.

The AT metrics complement this process, as they can be used to assess the quality of individual risks, and provide a more complete picture of the set of risks identified. Overall, three AT metrics were identified that related to risk identification (Geden et al. 2019). They are meant to broadly investigate the depth of the ideas generated and the breadth across the search space that individuals explored.

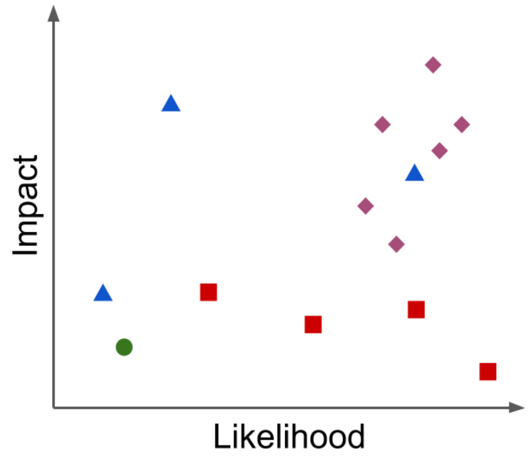

Figure 2: Example plot of identified risks using likelihood and impact ratings. Shapes and colors represent different categories of risks.

Novelty

Novelty is an AT metric that describes the level of uniqueness of a given response. Ideally, this would be assessed relative to other responses for a given prompt, though practically it can often only be assessed relative to a portion of all generated responses. In divergent thinking research, novelty is also sometimes referred to as originality (Guilford 1967).

An important goal of the risk identification process is to identify risks that may be unexpected so that proper monitoring or identification of risks can take place. Novelty is an important metric for this goal, as it can provide a measure of how similar identified risks are, and demonstrate that the ideation process has not shifted toward premature convergent thinking and evaluation.

Specificity

While novelty/uniqueness are important characteristics of a response, even the most creative response is not useful if it is not clearly elaborated and appropriate to the problem. Specificity attempts to capture this by rating how clearly a given response is described.

This metric relates to risk identification, as a risk needs to be clearly described in order to enable a proper evaluation of its likelihood and impact, as well as how it relates to other risks. Experts in a given domain may score higher on specificity due to extensive knowledge in the given context compared to novices. In a practical context, a low level of specificity across responses could lead to difficulties later in the risk assessment process, when trying to determine mitigation and monitoring strategies or more directly quantify the severity of potential impacts.

Diversity

Diversity seeks to measure how well a set of responses covers the breadth of the problem space. For AT, this was measured by looking at how many different categories a participant generated a response for. This metric helps to contextualize the quantity of submissions generated, while also helping to identify areas of the problem space that may have not been fully explored in the ideation process.

For application to risk identification, a key challenge is identifying categories for a particular domain. While individual organizations or domains may have their own categorization structure, there are also more generalizable paradigms such as PESTLE (Political, Economic, Social, Technological, Legal, Environmental) or PMESII (Military, Infrastructure, Information Systems). General categorization schemes can be used across domains (Tchankova 2002) without requiring a labor-intensive grounded theory approach at the cost of specificity. This metric is especially important, as the risk identification process has been shown to be susceptible to cognitive biases (Emmons et al. 2018), and analysts often will allocate too much attention to a particular category of risk while overlooking another (Letens, Nuffel, Heene, and Leysen, 2008).

Example Application of Anticipatory Thinking Metrics

To illustrate the application of anticipatory thinking metrics, consider an example of risk identification in an industry that regularly employs risk management: construction. The construction industry is an inherently dynamic, risky, and unpredictable field with risks able to detrimentally impact the productivity, quality, and budget of a construction project (Maytorena, Winc, and Kiely, 2007). For this example, we will take the perspective of a construction company, which we will refer to as Build, working on a site in the northern panhandle of Texas.

As part of Build's typical risk identification process, the company considers environmental risks such as fires or flash flooding. One employee notes the increased risk of earthquakes due to fracking (Magnani et al. 2017) in the northern panhandle and suggests that earthquakes should be added to the list of environmental risks, even though they historically have been atypical for the region. The *novelty* metric would identify this suggestion as being new and creative, and due to its lack of previous consideration worth further exploration.

This risk sparks a conversation about liability and safety regulations involving earthquakes, and whether Build would be at fault for any accidents due to insufficient design for environmental factors. The *specificity* metric would identify this precise new liability risk as being useful, as there is enough detail for further exploration as opposed to a vaguely identified risk, such as "legal liability".

As part of Build's risk identification process, they categorize risks according to Al-Bahar & Crandall's (1990) taxonomy: financial and economic, design, political and environmental, construction related, physical, and acts of god. After continuing on with the risk identification process, they decide to review their identified risks to see if they have reached a reasonable stopping point. They note that according to the *diversity* metric there is one risk category which they have not identified any risks, and another category for which they have only identified one risk. They decide to flesh out these risk categories before finishing the risk identification process in order to improve the breadth of considered risks.

This example, while simplified, illustrates how the anticipatory thinking metrics could be applied toward real circumstances employing risk identification. In a real risk assessment exercise, many risks would be identified and the novelty, specificity, and diversity of the generated risks would be evaluated.

Limitations of Anticipatory Thinking Metrics

The AT metrics described here (i.e., novelty, specificity, diversity) have several limitations. First, they are resource intensive to calculate as they are hand coded, which limits their scalability. A second limitation is that it is not clear how to calculate a single score for each analyst based on the response level metrics. One potential method is to take the mean of the top *n* responses, which unlike the total mean, would not punish for analysts who create many low/medium quality responses. However, this does not account for overlooking key risks, such as environmental impact of a nuclear meltdown. Ideally, individual metrics should account for both the presence and absence of relevant risks, but it is currently unclear how to create a composite that provides this more holistic perspective.

Conclusion

Risk identification is the critical first step in risk management. However, current understanding of the cognitive processes underlying risk identification is limited. There appears to be a strong relationship between anticipatory thinking and risk identification, and anticipatory thinking metrics originally developed for anticipatory thinking hold promise for assessing the quality of a risk assessment. These metrics may serve as powerful research tools to develop an empirical understanding of the cognitive process of risk identification.

Future Work

Future studies should be conducted to evaluate the psychometric validity of these metrics within the domain of risk identification beyond the construct validity detailed here. Another promising direction for future work is improving the generalizability of the proposed metrics by developing natural language processing models to support the automatic assessment of identified risks. Additionally, an important extension of this work is to use these metrics to investigate how the quality of risk identification can impact the downstream phases of risk management, such as risk assessment, planning, and system resilience.

Acknowledgement

This work was supported by the North Carolina State University Laboratory for Analytic Sciences.

References

Al-Bahar, J. F., & Crandall, K. C. 1990. Systematic risk management approach for construction projects. *Journal of Construction Engineering and Management* 116(3):533-546.

Anderson, B. 2011. Population and affective perception: Biopolitics and anticipatory action in US counterinsurgency doctrine. *Antipode* 43(2):205-236.

Ameyaw, E. E., & Chan, A. P. 2015. Risk ranking and analysis in PPP water supply infrastructure projects: an international survey of industry experts. *Facilities* 33(7/8):428-453.

Australia and New Zealand Standards 2004. *Risk Management - Principles and Guidelines*.

Baird, I. S., & Thomas, H. 1985. Toward a contingency model of strategic risk taking. *Academy of Management Review* 10(2):230-243.

Chileshe, N., & Boadua Yirenkyi-Fianko, A. 2012. An evaluation of risk factors impacting construction projects in Ghana. Journal of Engineering, *Design and Technology* 10(3):306-329.

Chin, K. S., Tang, D. W., Yang, J. B., Wong, S. Y., & Wang, H. 2009. Assessing new product development project risk by Bayesian network with a systematic probability generation methodology. *Expert Systems with Applications* 36(6):9879-9890.

Department of Defense 2017. *Department of Defense risk, issue, and opportunity management guide for defense acquisition programs*. Office of the Deputy Assistant Secretary of Defense for Systems Engineering.Washington, DC: Author.

Emmons, D. L., Mazzuchi, T. A., Sarkani, S., & Larsen, C. E. 2018. Mitigating cognitive biases in risk identification: Practitioner checklist for the aerospace sector. *Defense Acquisition Research Journal* 25(1):52-93.

Freudenburg, W. R. 1988. Perceived risk, real risk: Social science and the art of probabilistic risk assessment. *Science* 242(4875):44-49.

Geden, M., Smith, A., Campbell, J., Spain, R., Amos-Binks, A., Mott, B., Feng, J., & Lester, J. 2019. Construction and Validation of an Anticipatory Thinking Assessment. https://doi.org/10.31234/osf.io/9reby

Gerber, M., & Von Solms, R. 2005. Management of risk in the information age. *Computers & Security* 24(1):16-30.

Guilford, J. P. 1967. Creativity: Yesterday, today and tomorrow. *The Journal of Creative Behavior* 1(1):3-14.

Hancock, B. 2016. The Bow-Tie Analysis: A Multipurpose ERM Tool. Available at: https://erm.ncsu.edu/library/article/the-bow-tie-analysis-a-multipurpose-erm-tool

Hines, A., & Bishop, P. J. 2006. Thinking about the future: Guidelines for strategic foresight. Washington, DC: Social Technologies.

Hood, C & Rothstein, H. 2000, Business Risk Management in Government: Pitfalls and Possibilities. *CARR Discussion Paper No. 0*. http://dx.doi.org/10.2139/ssrn.471221

Hubbard, D. W. 2009. The Failure of Risk Management: Why It's Broken and How to Fix It. Hoboken, NJ: John Wiley & Sons, Inc.

Klein, G., Snowden, D., & Pin, C. L. 2007. Anticipatory thinking, *Proceedings of the Eighth International NDM Conference*, Pacific Grove, CA, June 2007

Letens, G., Van Nuffel, L., Heene, A., & Leysen, J. 2008. Towards a balanced approach in risk identification. *Engineering Management Journal* 20(3):3-9.

Magnani, M. B., Blanpied, M. L., DeShon, H. R., & Hornbach, M. J. 2017. Discriminating between natural versus induced seismicity from long-term deformation history of intraplate faults. *Science Advances*, 3(11), e1701593.

Maytorena, E., Winch, G. M., Freeman, J., & Kiely, T. 2007) The influence of experience and information search styles on project risk identification performance. *IEEE Transactions on Engineering Management* 54(2):315-326.

McLennan, J., Elliot, G., & Holgate, A. 2009. Anticipatory thinking and managing complex tasks: Wildfire fighting safety and effectiveness. In *Proceedings of the Industrial & Organisational Psychology Conference*, 90-95.

Tchankova, L. 2002. Risk identification–basic stage in risk management. *Environmental Management and Health* 13(3):290-297.

World Economic Forum (2017). Shaping the Future of Global Food Systems: A Scenarios Analysis.