Group 4 - Critical Reflections

(Denis Sparish, Felix Treis, Gorpudolo Seleweyan, Nikhil Sennik)

Introduction

In this review, the group will be analyzing and reviewing three major interlinked topics as they relate to risk management by way of articles. Firstly, we will use the work of Haimes 2009 ("*On the Complex Definition of Risk: A Systems-Based Approach"*) who explores the complex definition of risk and how we may approach the problem with a system-based approach. When dealing with such system-based approaches, we must also consider the elements of uncertainty that we must contend with (input and output) along with the accuracy of the models that we utilize to drive our predictions, which brings us to the findings of Cox in his 2011 paper ("*Clarifying Types of Uncertainty: When Are Models Accurate, and Uncertainties Small?"*). Finally, we will look at current methods of hazard ranking/prioritization of sources of risk, their weaknesses and a revised approach as suggested by Cox in his 2009 paper (*"What's Wrong with Hazard-Ranking Systems? An Expository Note"*). As we go through these topics, we will look to relate them with our own understanding, examples and call out relevant strengths and weaknesses of the articles.

On the Complex Definition of Risk: A Systems-Based Approach

The paper can be understood as an introduction of the field of risk and its analysis. First out, Haimes underlines the enormous difficulty of finding an appropriate and acceptable definition of risk in general. Risk is highly dependent on the states of the observed system and its environment, which holds true for natural, societal and economic concepts and systems. It is important to understand its multidimensional character and can be, as an example, best observed with regard to global warming. Stakeholders perceive subjectively the risk by living in different countries, facing increased possibility of flooding, storms or heat, and having different financial and infrastructural resilience.

Modelling the risk must therefore include the consequences for each risk scenario, which is the outcome of the threat, vulnerability and resilience of the system, and the time to recover, as Haimes states. Vulnerability and resilience should be the key concepts of each risk analysis. As this is essential, the time to recover from a yet unknown and maybe unpredictable hazard should be always assessed by implementing a security buffer and this is missing in Haimes' paper.

An effective risk assessment and management is only as effective as to the extent of understanding of the underlying system and its interactions with its environment. To assess risks from within and from outside the system Haimes presents the theory of scenario structuring (TSS) by Kaplan and Garrick to be the best applicable solution to this approach. This includes the one scenario, its likelihood and its consequences for each risk per definition.

However, as the set of scenarios should be complete, which often implies impossible modelling efforts, the above-mentioned buffer would be reducing the “true” risk, as Haimes word it.

This leads to multiple-criteria decision-making (MCDM), where different competing objectives and scenarios are traded off. The weakness of this approach lies in the system boundaries, defined by the modeler himself, and the integration of subsystems, which are interdependent and are consequently intricate to model. In addition, the wrong interpretation of the process’ outcome could lead to ignoring still significant risks with low probabilities.

Haimes concludes that for all described steps within the process of risk management the time domain is an additional critical parameter. Especially communicating risk and its management becomes difficult, once the probable consequences are far away. This is a serious problem in fighting global warming if current stakeholders only focus on short-term goals. To make complex risk modelling and analyses understandable to most of the society is therefore of high importance.

Although significant modelling efforts are performed, risk analysis can never be precise and simple. But as it is also failing to be precise, while being real and complex, the “true” risk may be only transferred from the real world to model-based uncertainties.

Clarifying Types of Uncertainty: When are Models accurate and Uncertainties small?

In this paper Cox addresses some issues associated with defining the concepts of "accurate" prediction models and "small" input uncertainty. He refers to Professor Aven’s notes in this regard who has himself attempted to clarify such terms as “uncertainty” and “scientific uncertainty”. We focus on Cox’s attempt to define what is meant by these via examples in which he effectively demonstrates his observations via experiment and highlights difficulties some may face while trying to define these clearly.

Firstly, there are scenarios where a large uncertainty in model input results in small uncertainty in model output. This is paradoxical as one would expect that the greater the input uncertainty, we should expect a greater output uncertainty which Cox himself highlights. However, the proof is based on a rather simplistic example. The example shared by Cox is useful when we already know the output to expect for a select range of the input and if this is the output that we have an interest in e.g., we are specifically interested in probability where G(X)=1 for the range of X provided (0<=x<=198). If there were a significant no of outputs for the function G(X) i.e., more than 0 or 1, and we had an interest in the probability of occurrence of all of these then the output uncertainty levels would still be high.

In the second example, Cox raises problems with attempts to compare or rank the prediction models by their “accuracy”. He argues that even models with perfectly described and measured inputs can fail in providing valuable output. He proves this statement modeling the prediction of the epidemic duration with demonstration how the relatively slight change in input parameter results in significantly different prediction as relatively small differences in the input parameters diverge widely as these small differences are amplified exponentially. This is a beneficial point for Cox to highlight as this can readily occur when modeling complex systems. However, it doesn't mean that model is completely unusable. Moreover, depending on purpose the same model can provide excellent predictions. It leads us to the conclusion and one of the key learnings derived from this paper that the value of the same model is highly dependent on context. Risk management decision-makers should be aware of limitations in choosing a model based on some degree of "accuracy", especially in such complex problems like epidemic or climate change.

Lastly, Cox states that we do not always need to understand causation in order to predict risks accurately. Therefore, there is no reason to demand that the forecasting model is accurate only when the causality is clearly defined. Moreover, sometimes causal and statistical relationships are different, but the statistical model predicts correct outcomes and can be quite suitable for risk management.

These claims seem even more reasonable when Cox explores the disadvantages of Hazard-Ranking systems.

What's wrong with Hazard-Ranking systems?

If we consider the example of dealing with the risks of climate change which vary considerably in nature, how do governments or organizations determine which hazards to prioritize first? Such prioritization exercises are undertaken by all private and governmental organizations who operate on limited annual budgets and must maximize their return on such investments. Cox examines the techniques currently being used for rank ordering different sources of risk, identifies the limitation of these methods and outlines a preferred approach for hazard ranking.

Cox outlines the hazard ranking process which entails assigning priority scores to the various hazards/risks that need to be ranked. These scores can be non-negative integers, grades ("High"," Medium", "Low") or derived from priority scoring formulas. However, a problem with such categorized scoring methods is there is much subjectivity when defining and valuing certain benchmarks. These scores indicate perceived level of current risk. A strength of this paper is Cox's ability to pinpoint examples of the use of such scoring methodology, especially by major government organizations such as the DOD and military which gives the reader an understanding of the criticality and widespread use of these scoring practices.

As an example, the Climate Change Risk Assessment (CCRA) in their November 2015 paper (*Observations from the first UK Climate Change Risk Assessment by Iain Brown*) used a combination of formula and point categorization scoring as part of their methodology to rank order various climate change associated risks. Factors such as magnitude of risk, likelihood of risk occurring before the 2080s and urgency in their need to address the risks was utilized and applied in the following fashion:

Risk Score = 100{(Magnitude: Environ+Social+Economic)/9}*{Likelihood/3}*{Urgency/3}*

As stated by Cox it is necessary to assign a measurable value to these risks that allow us to understand differences between scenarios, namely the state before the hazard is addressed to after it is addressed, we can refer to this measurable value as x_j and for any budget we maximize total benefit by addressing hazards in order of their decreasing values of x_j. For example, it may be worth the government spending $5 million USD for improved flood prevention/defence mechanisms now as this may save them $60 million USD in flooding damage vs investing in addressing another risk with a similar priority score but less of a monetary impact of addressing the risk.

Another key strength of Cox's articles is his highlighting scenarios where such priority scoring methods fail (with evident examples), namely that these rate each uncertain hazard on its own attributes and are not able to recommend an optimal subset of correlated risks. This can lead to poor resource allocation. For example, if a city wants to reduce its carbon emissions, one approach would be to make carbon dioxide more expensive via use of a carbon tax, or alternatively a green buildings approach can be utilized where plants are grown on buildings to increase natural carbon dioxide absorption. Priority scoring may hypothetically indicate that all the budget should be assigned to one of these methods, say a carbon tax, but in reality a better outcome may be achieved by diversifying the budget within both these approaches (optimised portfolio) to allow for larger risk reduction value for resources spent. If we look at another previously stated example of flood defences, hypothetically should a city invest $10 million USD in Diversion Canals or Dams? Again, priority scoring may indicate decreased vulnerability (0.03 to 0.02) by investing solely in Dams vs Diversion Canals (0.03 to 0.025) due to a larger decrease in vulnerability score, but overall vulnerability may be in fact reduced by investing in a 50-50 split which would leave an improved residual risk of 0.15 (vs 2.0 had we invested solely in Dams). As Cox states, this is an ignored opportunity for coordinated defenses.

There are some weaknesses to Cox's arguments, namely that it is not always easy to identify scenarios where risk reducing measures may have some level of correlation, especially if we utilize our example of Global warming where there are a significant number of uncertainties and how they all relate. This task can be difficult for firms and government organizations to approach and at times requires much speculation which may explain why it is not exploited as much as Cox suggests it should be. Cox has shared some good examples to illustrate the weaknesses of current priority listing methods, but they are hypothetical and very simplistic vs the reality of real-life scenarios.

Cox could have further improved the paper by stating some hypothesis as to why the optimization methods for selecting subsets of risk reducing investments are not being widely used and why companies are sticking to traditional priority list scoring methods. This would have been an interesting viewpoint for the reader.

Conclusion

In conclusion, all three articles discuss critical elements in the general processes of risk management that are insightful to those wishing to undertake such processes. Haines clearly calls out the need to model risk in a systematic way that involves understanding the model, defining the complexity of risk, vulnerability and resilience, and enforces the view that the states of the system constitutes the essence of the analysis. This is a fundamental starting point when evaluating risk. Cox in his 2011 paper takes this a step further and ensures the reader has a clearer idea of “scientific uncertainty” with regard to defining "accurate" prediction models and "small" input uncertainty. He reveals insights not immediately obvious such as the relationship between large input uncertainties and small output uncertainties, along with the need to define the “accuracy” of models within the right context. Despite the simplicity at times in conveying these points in his examples, they are highly relevant and should be considered in the risk modeling process and in relation to what we expect as the output of such models. Lastly Cox in his 2009 paper helps the reader understand the benefit of grouping and addressing together sources of risk with high levels of correlation in order for organizations and governments to maximize the return on their investments. There are challenges in understanding which risks correlate and how, however, Cox mathematically shows his logic is sound and significant returns in spend are possible through such portfolio optimization.