Risk Analysis Lab Assignment 1
Group 3

Authors

Stefanos Sakellariou
Maha Vajeeshwaran Navaneethan
Chandra Sekhar Rachannagari
Youheng Lü

Contents

1. Introduction

The assignment is presented in three chapters. In Chapter 1, we summarize the points of the articles Cox 2009[4], Cox 2011[5] and Haimes 2009[6]. In Chapters 2 and 3, we discuss the content of the articles and give our own opinion which will be supported in Chapter 4 with our case study.

2. Review of summaries

2.1 Cox (2009)

In his 2009 article '*What's Wrong with Hazard-Ranking Systems? An Expository Note'* Cox discusses the use of priority scoring and rating systems by most of the organizations today. More specifically, he examines the limitations of these methods and claims that they generally make suboptimal risk management recommendations. To support his opinion Cox gives five examples of applied priority- scoring systems. He starts by describing two important applications of such systems.

Firstly, he refers to the common vulnerability scoring system (CVSS) and the method of scoring consumer credit risks and how they are widely used, for example by the US government and international companies like FICO and BEACON. He continues by giving three more examples of alternative priority - scoring systems that fail to recognize correlations between the items in the applied formulas, thus leading to questionable outcomes.

Cox then attempts to outline the three elements of a general priority setting process, for situations where the consequences of addressing different hazards are clear. This consists of a set of items to be ranked or scored (e.g. hazards, threats, customers etc.), an ordered set of priority scores (for instance “high”, ”medium”, ”low”) and a priority-scoring rule that assigns a corresponding priority score to each item. When uncertainty in measuring hazards exists, he uses a different method to prioritize risk reduction opportunities, where hazards are treated as random variables.

However, he then adds *“Selecting a best portfolio of hazards to address [..] cannot, in general, be accomplished by priority setting if uncertainties about the sizes of risks are correlated.”* He underlines this point by giving four examples where priority systems recommend poor decisions by overlooking important correlations among risk opportunities. These theoretical examples have in common that all resources are funneled into one risk reducing strategy even though a combination of different strategies would be more successful.

Therefore, Cox concludes by suggesting that risk priority score systems should be replaced by optimization techniques that consider the dependencies among risk reducing interventions, as the former often produce misleading results.

2.2 Cox (2011)

Cox (2011) looks into the works of Professor Aven, who has been trying to clarify the importance of the term "Scientific uncertainty" for the use in risk management and policy decisions. Risk is something we can mitigate when we know the probable outcome. But we can't predict the outcome as it is uncertain, it may happen or may not happen. Cox uses three theoretical examples in his 2011 work to counter some misconceptions about predictive models.

In his first example, he argues that it is unclear why scientific uncertainty should be assumed to be a function of input uncertainty. He demonstrates this with an example where a larger uncertainty in input will result in a smaller uncertainty in output. The second example is a SIS disease process, where he shows how a model might produce proper results (as evaluated by standard deviation, error range, and other metrics) yet still be inaccurate if there is a minimal inaccuracy in the inputs. It shows that while certain models are valid for short-horizon predictions, they may not be as good for long-horizon predictions. The third example demonstrates that a correct model is not always causal. Causal is the capacity of one variable to influence another. Cox argues that there is no need to have a causal interpretation for a prediction to be accurate and that a good model can also be just based on statistics.

Cox therefore concludes that the models and uncertainty that matter in risk analysis are too complex to permit useful classifications in terms of concepts such as larger or smaller, accurate or inaccurate.

2.3 Haimes (2009)

As a potential solution to address complex systems Haimes (2009) uses the systems-based approach to define and quantify the risk, vulnerabilities, and resilience of a system. He suggests that the modeling must evaluate consequences of each and as functions of the threat risk is a measure of the probability and severity of consequences.

In determining the elements of risk, Haimes discussed the "*Theory of Scenario Structuring*" (TSS) introduced by Kaplan and Garrick, they raise the triplet questions into the risk assessment process: *"What can go wrong? What is the likelihood? What are the consequences?"*. To answer these questions, he stresses the importance of looking at the probability of adverse effects occurrence and severity of occurrence, consequences, and importance of vulnerability. Next, he defines resilience and vulnerability. “Resilience” is a vector of a system state, manifestation of events, threats with time dependency. “Vulnerability” is a multidimensional output of the system, which leads to natural hazard, damage, or disruption to the system.

He claims that risk analysis and modeling is a systems engineering approach. An ad hoc basis approach without studying the system cannot understand and model the multifaceted composition of the system risk. Haimes also explains the use and misuse of the expected value in risk metrics. Low probability of high-consequence events is equal to high probability of low-consequence events even though this does not necessarily represent reality. Another common misuse is the evaluation of extreme events: Non regular occurrences with extreme impact can sometimes be undervalued because human nature makes us believe that they will never happen.

Haimes concludes that the correctness of a risk management model can only be proven after some time has passed. Still, by trying to understand the different states of a system through a system engineers’ approach, we can get a better understanding of complex multi- and large-scale systems, which will give us a basis for Risk analysis.

3. Our opinion

Cox (2009) makes the strong statement that hazard-ranking systems should be replaced by optimization techniques. We have found two weaknesses in his argumentation. Firstly, we cannot use the same approach for every single situation and for some situations Hazard-ranking systems might be the best solution. Consider the following example: If you have a large company with many different risk vectors, it might be too complex to analyze every correlation between the different Risks. If you have a very small company, it might be unnecessary to create such complex optimization techniques for Risk Analysis.

The second weakness is that all his examples assume that a Hazard-ranking system will allocate all resources, if possible, in one place. It cannot be generally assumed that this is the case. One can easily construct an example where the Risk-mitigation strategy has scores with diminishing returns if resources are allocated in only one place. Another caveat is that Risk Analysts can still make their own decisions based on the Risk-score and can decide to properly spread out their resources. We therefore conclude that Hazard rankings can still be used, something that we will underline more in our case study.

Cox (2011) contains the three statements that each merit their own analysis. We agree with the general statement that we cannot generalize complex systems in terms of “accurate” and "inaccurate". The example given that input uncertainties may generate smaller output uncertainties makes sense. The second example uses a faulty equation that differs from the SIS disease model that uses a completely different function from Wikipedia [1]. Consider the following R-Code that uses Cox formula and numbers to analyze the flow of the pandemic.

```
I <- c()
N <- 100000
k <- 0.00004
I[1] <- 0.10117 * N

for (t in 1:100000) {
  if(t == 1){
    print(k)
    print(I[t])
    print(N-I[t])
  }
  I[t+1] <- round(k * I[t] * (N-I[t]))
}
plot(I[1:100], type = "o", xlab = "number of weeks", ylab = "Number of People Infected")
```

It produces an interesting development of the pandemic (Figure 1) where we can see that the number of people infected jumps around every week in Cox's model. Comparing that to how the SIS model should look based on Wikipedia [1] (Figure 2), we can say that his model is not a model that describes the true evolution of the epidemic with perfect accuracy. But even though his example is clearly flawed we can say that the argument still makes sense. There are volatile systems like the weather forecast that have a wide range of outcomes that are impossible to predict in the long term. Still, we need to rely on models to make our Risk Analysis. As a positive example based on the past financial crisis, we constructed models to understand what it takes for a business to rebuild itself. In the next financial crisis, we can rely on a model that uses the data from the former financial crisis as input to help us make better decisions to save the business. Of course, there will always be risk and uncertainty in the input. But we cannot avoid that.

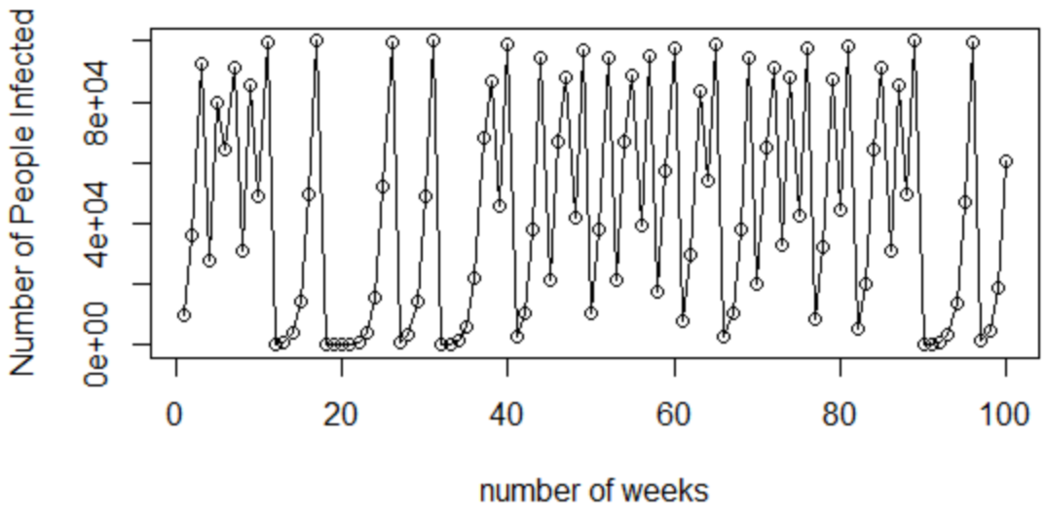

Figure 1: First 100 weeks of the "pandemic" of Cox's SIS model based on his formula

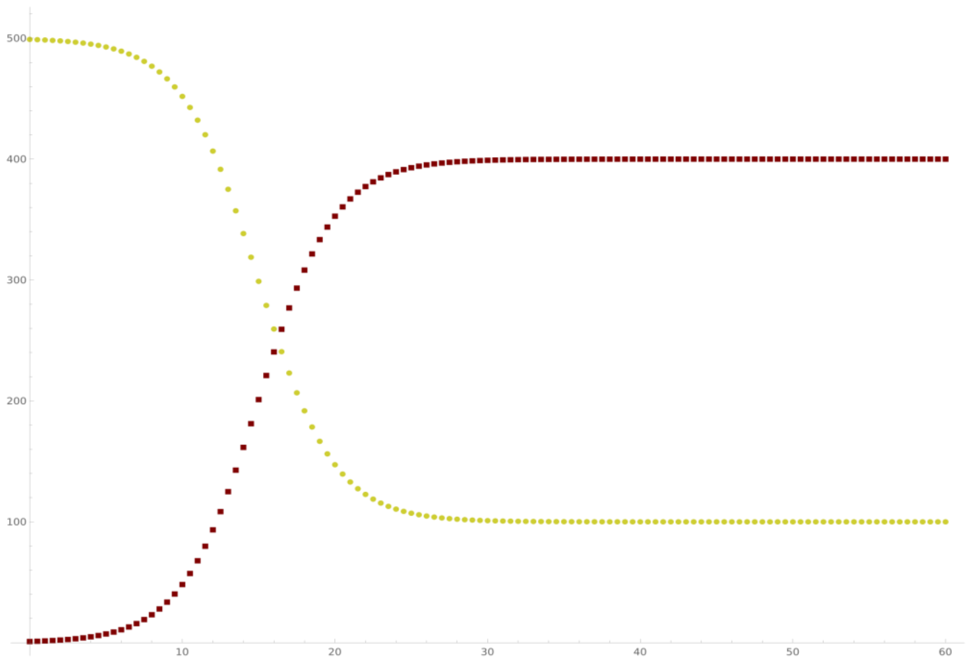

Figure 2: Wikipedia representation of a SIS model, the x-axis is the timeline and y-axis the number of infected. The red line represents the number of infected and the yellow the susceptible population.

For Haimes (2009) we think that the results are generally valid, but different applications require different risk definitions. We should use Haimes' approach when feasible. For small projects a system-based risk analysis can create an unnecessary overhead. But in general, we should systematically approach risk. If we don't, the cost and time may be even 2 or 3 times as costly. As a real-world example, Sweden is putting a lot of money into fire prevention even though this Risk Analysis tells us that it is not relative to the possible damage. This means that our intuition alone is not enough to analyze complex systems. We also need to consider the snowball effect. A risk that seems small now, may explode in the future. That is why the time variable that Haimes proposes is very important to consider.

4. Case Study

As a case study, we analyze a practical example of Risk Analysis in the real world. In the New South Wales government document "Risk prioritization, scoring and reasons fact sheet" (Published by NSW Department of Planning, Industry and Environment, July 2020) [3], we can observe the successful implementation of a typical priority-scoring system.

This model uses a methodology for assessing environmental risk for unsewered towns and villages. A specific score is assigned to each level of hazard likelihood. This score is then multiplied by the population score which occurs by grouping the serviced population into five groups, based on their population size. This product corresponds to the total environmental risk impact score (Figure 3). The particular methodology is in line with the Australian Standard, AS 4360/AS ISO 31000.

Table 6. Environmental risk priority ranking based on population size and inherent risk.

		Inherent risk score					
		5	4	3	2	1	
Population	>2500	5	4	3	2	1	Risk impact score
	>1000-2500	4	4	3	2	1	
	>500-1000	3	3	2	2	1	
	>100-500	2	2	2	1	1	
	≤100	1	1	1	1	1	

Figure 3: Calculating the final risk impact score by combining population with the inherent risk score.

Even though Cox (2009) argues against Hazard-Ranking systems, we believe that this example demonstrates how the use of a priority scoring system can be successfully applied without considering any correlations between risk factors.

For Cox (2011) we believe that we have an accurate system because it follows ISO standards. It is believed that without proper research and study the Australian government won't implement this system. Cox's third argument states that causality is not needed in order to achieve accurate models, but in this model NSW water security assessed risk profile based on causality: The Risk to the town water supply system is dependent on the water source, size of the storage, population, and climate.

5. Conclusion

We agree with Cox (2011) that it is hard to quantify the quality of a Risk analysis system, because these systems can be complex. This holds true even though we found flaws in his example. We like the approach of Haimes (2009) to systematically approach Risk to understand better all the different vectors of a complex system. We disagree with Cox (2009) that hazard-ranking systems should generally be replaced, it differs from domain and size of the system. In our case study we demonstrate a modern hazard ranking system to support our argument.

References

[1] Compartmental models in epidemiology

[2] File:SIS System Graph.svg - Wikipedia

[3] Risk prioritisation, scoring and reasons fact sheet (nsw.gov.au)

[4] Cox, Jr, Louis Anthony. "What's wrong with hazard-ranking systems? An expository note." Risk Analysis: An International Journal 29.7 (2009): 940-948.

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[6] Haimes, Yacov Y. "On the complex definition of risk: A systems-based approach." Risk Analysis: An International Journal 29.12 (2009): 1647-1654.