SCIENCE-BASED MANAGEMENT OF CIVIL ASSET RISK

Objectives, Principles, Process and Analytical Techniques

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Abstract

These introductory lectures are framed in terms of a "top-down" view of risk management, risk assessment and risk analysis ranging from overarching legal considerations to details down to the details of methods of analysis, prioritisation and risk management. The objective is to provide a comprehensive outline of as many aspects of the risk management process as possible as well as specific details of methods of risk analysis. The comprehensive outline describes setting of risk management expectations, down through the various levels of analysis and decision-making to the detailed scientific analysis of risk at the structural performance level, and back up to acceptance of the risk control solution. This comprehensive outline is intended to describe a framework for integrating all of the other lectures in this advanced course in a single framework. The details of risk analysis methods are provided to provide a means of transforming phenomenological (particularly mechanics) and data driven (statistical and empirical) models into risk constructs.

The scope is very broad and only a superficial account of many aspects of the process can be provided in the time available. The text of the lecture is supported by an extensive range of authoritative references and some conference papers.

Issues to be considered include:

- Legal framework considerations: How one goes about managing risk is determined to a large degree by the legal and political regimes where the risk activity is being carried out. It will also be determined by the owner's appetite for risk-taking and the views of the affected public. In the case of risks with trans border implications, international laws and agreements apply. Depending on the legal regime, the management of risk might be highly prescriptive with strict rules to be followed at one extreme, to little more than general high level legal duties of care at the other extreme. Between these extremes the extent to which government influences risk management will be a matter of political choice in any particular jurisdiction, thereby defining to some degree the governance arrangements.
- Risk governance: Risk governance is fundamentally the responsibility of Governments, usually through directives, regulations and standards, and the owners conducting the activity that generates the risk. In some cases with respect to commercial matters, governance will be the sole responsibility of the owners. The matter of how the significance of risks are evaluated and how risks are to be assessed in general are determined at this point and communicated to the public and the organisations that create the risk. What actually gets communicated may be real or perceived and there may be inconsistencies in the messages transferred to operators and producers.
- Owner's considerations: Owners considerations apply at all levels in the organisation, albeit in different ways. At the top of the organisation the values and principles of the organisation are set in the context of the societal expectations concerning risk evaluation and risk assessment as communicated by government, together with supporting policies and standards. These upper level management instruments cascade down through all levels of management and across all aspects of

the organisations activities, one of which is the control of risk. As such the principles for risk management must be compatible and operate in harmony with the other operational principles.

- Owner's activities within the framework: Within the parameters set by the laws, regulations, external influences, governance structures and owner's values, principles and policies, the operational activities that generate the risk should be addressed in a systematic way. Control of risk involves ensuring that there are no perturbations in the operational activities, or there are means of minimising the effects of any perturbations and returning to normal operations as soon as possible.

- Risk management principles: Once the owner's principles are defined at a policy level, principles and standards for analysis and engineering design are established. These principles and standards, which nowadays will include life-cycle asset management considerations, provide a basis for performing the safety assessments and the engineering design. By working in terms of principles, and by recognising the need to make trade-offs between principles (because design involves compromises), the designer is permitted flexibility in achieving the overall objective.

- Risk and uncertainty: This topic will explain the fundamental nature of uncertainty; the underlying reason that risk arises. Because the term uncertainty means different things to different people, clear definition of the meaning of uncertainty with respect to the performance of civil assets is required. This definition of uncertainty then defines the meaning of the term risk which also means different things to different people. For example, in healthcare, risk = hazard, whereas in insurance, risk = loss, and in many people's mind, as Professor P. Sandman observed, risk = hazard + outrage (and we are seeing a lot of outrage at this time of economic turmoil). The meaning of the term probability will also be explained as will methods of obtaining probabilities in a scientifically proper and defensible way.

- Systems and Models: Most things in life function as systems of parts, and the functioning of any system provides the outputs or performances required for whatever the endeavour is. So although much modern education focuses on "disciplines", and components or parts of systems, the actual output or performance is achieved by the parts functioning in harmony as a system. Even a simple structure such as a single span bridge involves several disciplines to produce the desired outcome. While one individual might be sufficiently experienced and broadly educated to design and oversee the construction of everything, the endeavour involves many areas of expertise including; geometric design for the approach and layout; soil mechanics and foundation design, structural design including materials design (an architect might do the aesthetic design, a structural engineer, the physical design); temporary works design and construction to erect the structure; road surface design. All of these things are really of little interest to the user of the bridge provided that the bridge system as a whole or those parts that the user interfaces with, function properly. Models are essential to the understanding of how systems work, and in general it is necessary to use several types of model to characterise the nature of the system and how it functions. Spatial, functional, phenomenological and data-focused models (statistical) all have a role in risk analysis and the various types of model are introduced.

- Hazard identification and analysis: For civil assets, hazards are the phenomena that cause disturbances in the functioning of the system. These hazards can be external to the system (e.g. floods or earthquakes) or internal to the system (e.g. control system failure). The term hazard is not a particularly flexible term and the term threat is often used synonymously. In other instances the term threat might be used to describe the manifestation of a hazard. Hazards themselves are not always uniquely defined, for example, a dam is considered to represent a hazard to the downstream public or the environment, whereas floods and earthquakes are hazards to the dam and to the downstream public, individually and in combination with dam failure. The modelling endeavour accounts for how hazards are represented in the analysis of the influences that cause disturbances external to and within in the system. Hazards are identified in essentially four ways; the obvious; testing; check lists; and formal HAZOP studies. Once identified, the characteristics of the hazard might need some degree of specification, in terms of the nature of the magnitude and perhaps the duration of the disturbing influence. Specification of loads on structures (e.g. wind, water, earthquake shaking etc.,) are now amenable to quite sophisticated analysis and characterisation, and are no longer considered to be “acts of god”.

- Consequence analysis: Modern computing and modelling capability permits sophisticated analysis of the consequences of the failure of an engineered system. Typically, the consequences of failure of an engineered system are obtained through modelling and analysis of the system that is affected by the failure of the engineered system. For example the failure of a bridge will have adverse effects on the transportation system that in turn will have an adverse effect on the economic and societal systems that rely on the transport system. In the modern world, everything is connected in some way, and while it is not usually possible to model the ultimate consequences of everything that is connected, artificial boundaries must be drawn around the systems under consideration, while specifying the influences that cross the boundaries of the system that can influence other systems.
- Failure analysis: Failure analysis takes many forms, with “functional failure” being one of the most versatile. It may be argued that “functional failure is an effect of some type of breakage where demand exceeds capacity. In general, both functional failure and failure in terms of excessive demand on the system or a component have an important role in risk analysis of civil assets. The selection of the method of failure analysis will be problem specific as will the degree of sophistication and complexity of the model. However, in general the complexity of the failure analysis depends on the complexity of the system being analysed and the degree of precision required of the risk analysis. The general methods of systems analysis used in risk analysis; HAZOP, FMEA, Event Tree Analysis and Fault Tree Analysis are described. Structural reliability analysis methods (e.g. First Order Reliability Method) are also introduced. These systems analysis methods provide the framework for analysing risk using traditional and specially developed analytical techniques.
- Risk = P X C: For engineered systems, risk is typically considered to be the product of probability x consequences. However, it is always useful to represent risk in non-product form, both for communication purposes and for understanding the nature of the risk and the consequences and how they might be managed. The implications of using either and both the product and non-product representations of risk in decision-making are described.
- Risk management system: Once risks are analysed and characterised, management action follows. This is best done in a systematic way with modern management systems approaches providing the necessary frameworks. The relationship between the analysis of risk, the management of risk and how it can be systemised in a management system is described.
- Transparency and defensibility of risk-informed decisions: Although risk can be calculated or otherwise estimated, it is not a physical quantity that can be measured and its characteristics objectively demonstrated. This problem of verification arises because probability is not a physical quantity whereas consequences are real. This means that it is impossible to prove that any probability is right. Two people who assign quite different probabilities to the uncertain future event, can both claim to have assigned “the right” probability. Scientific procedures have been developed address this problem with independent review playing an important part of the process. It is extremely important for the analysts to be able to demonstrate the reliability of the information that they are providing to the decision-makers.
- Some examples: Examples of risk analyses, and risk management activities carried out for dams are provided.