Success by risk management: A risk glossary in the context of civil engineering projects

ICE Briefing Sheet *by the ICE and Institute and Faculty of Actuaries' Risk Management Group*

Introduction

Civil engineering at its very heart is all about preventing failure. Good practice calls for civil engineers to approach all key decisions and designs from the perspective of risk.

Civil engineers primarily manage health and safety related risks, which is required by the CDM (construction, design and management) Regulations 2015. However, risk management in a broader sense is such an essential practice that it is universally applicable and deeply embedded into every single industry and business and everyone's life. Bringing an infrastructure project from paper into reality requires civil engineers to collaborate with numerous other practices such as architecture, finance, law, etc. Each of these practices invariably manages risk from its own perspective, but there needs to be a shared understanding of the meaning of the differing words used to describe risk. Even within the civil engineering profession, individuals may sometimes attach different meanings to the same words.

As such, the purpose of this document is two-fold: 1) to introduce civil engineers to different definitions associated with risk management that other professionals may use. Civil engineers need to be in possession of some basic understandings of these definitions in order to achieve effective collaboration with others. 2) to try and create a 'common language' for all professions that collaborate on infrastructure projects, in order to reduce 'communication friction'. This document is the product of a great deal of thought jointly by civil engineers and actuaries, and is consistent with the RAMP Handbook. [Note: The RAMP Handbook, 3rd edition, has been prepared by the Risk Group of the Institution of Civil Engineers and the Institute and Faculty of Actuaries, and is a comprehensive guide to risk management for projects].

Core Concepts

Risk

We define **Risk** as the possibility of outcomes different from those expected. However, people often use the word in a different sense, for example in relation to a specific undesirable outcome, e.g. the risk of bridge collapse, or as a measurement of the chance of a particular event: e.g., there is a 10% risk of a flood occurring.

Risk under a larger framework has two components – the possibility of outcomes worse than expected (i.e. **threats**) and the possibility of outcomes better than expected (i.e. **opportunities**). Very often in practice the word "risk" is used to mean only the first of these components, which should be called **downside risk**.

A great number of risks in civil engineering practice are well-known and well-studied. These risk events typically have happened so many times that there is already a considerable amount of information about them. For example, injury from construction activities is a risk with a long history of monitoring and a vast database to indicate likelihood and severity.

Uncertainty

Uncertainty is a concept often confused with risk. This section clarifies the difference between risk and uncertainty.

Uncertainty is having a lack of sufficient knowledge and can also be seen as an acknowledgement of the variability of potential outcomes. For example, one may say there is uncertainty over the demand of an under-construction metro line. It may turn out to be overly popular if it coincides with a major regeneration scheme or market boom. It may also turn out to be severely underused if the regeneration scheme fails to attract buyers or a wave of unemployment crisis hits. There is often uncertainty over the economy, market, political regime and future climate.

Uncertainty always stems from insufficient information, either about the project itself, or the wider context the project is situated within. Simply put, the more you know, the less uncertain it becomes.

Possible sources of lack of knowledge may include:

- Fuzziness, i.e. a degree of imprecision about estimates of probabilities and impacts of risks, in which the margin of error may be wider than is believed
- The possibility of future scenarios and events that have not been foreseen
- Connections between risks that have not been recognised
- Unawareness of some of the ways in which materials under extreme stress may react
- Hidden problems buried in the site
- No understanding of chemical or biological hazards in certain circumstances
- The extent and timescale of future climate changes
- Pressures or inadequacies within the project organisation that could precipitate future crises.
- Not enough information about the context within which the project will be constructed, operated or eventually decommissioned, or about the political, social, environmental and economic changes which may take place during the project's lifetime.

Uncertainty is judged in the light of a person's or organisation's previous knowledge and experience. Hence different people/organisations may perceive different degrees of uncertainty about a given situation, even if they have the same information.

In order to avoid or reduce dangers and identify opportunities, it is always worthwhile to reduce uncertainty as far as reasonably practicable, which means that the benefit from the additional information should grossly outweigh the effort spent on collecting it. For example, this can be done by sharing knowledge with colleagues and by conducting a focused search for additional knowledge. Some uncertainty will always remain and may cause unexpected situations to arise, so it is important to retain a high level of flexibility to deal with them when experienced.

A lack of enough information about the risks in a project will affect the accuracy of the risk analysis, so as much information as possible about the risks should be obtained at an early stage. Some of the ways of acquiring information are:

- Desktop studies, including literature reviews and internet searches
- Lessons learned from similar projects, present or past, in the same or other organisations,
- Brainstorming and workshops
- Consultations with experts, including specialists.

The confusion between risk and uncertainty

In civil engineering practice, **risk and uncertainty** are easily confused terms, as 'uncertainty' is typically blended into risk and listed as risk on the risk register. In fact, risk and uncertainty have completely different meanings – risk addresses the range of possible outcomes, whereas uncertainty stems from insufficient information. Therefore, the problem with listing uncertainty as risk is that the lack of knowledge from uncertainty affects perceptions of the risks, i.e. the possibility of outcomes different from expected, and their expected likelihoods and impacts. The perceived values of these could change after more information is obtained. It is desirable to reduce uncertainty as far as possible before conducting a risk analysis, by obtaining as much relevant knowledge as possible. If further knowledge about the risks is obtained after the initial risk analysis has been completed, the risk analysis should be revised accordingly.

Risk Response

Mitigation is the action engineers take when facing a significant downside risk. Some mitigations reduce the probability of an adverse scenario or event occurring, whereas other mitigations reduce the severity of adverse consequences should the event occur.

For example, when mitigating the risk of working at height, installing edge protection reduces the likelihood of a fall from height, but the consequence of falling from height remains exactly as before; whereas installing a fall-arrest net does not prevent anyone from falling, but reduces the bodily damage resulting from the fall.

Secondary Risks. The mitigation measure itself can sometimes generate risks itself, which are called **'secondary risks'.** For example, as temporary support to a tunnel crown and face, a sprayed concrete lining is commonly used to avoid working at height. However, spraying concrete, particularly within a confined space, generates dust which is hazardous to health. The risk to health is therefore a **secondary risk** to the mitigation measure of eliminating work at height. Secondary risks can sometimes be important and must be managed in their own right.

There are other principles when it comes to risk mitigation:

1. A risk (or the mitigation of it) should be allocated to the party(ies) best able to manage it.
2. The level of mitigation should be approximately proportionate to the level of risk: a big mitigation effort for a big risk, and a small one for a small risk. In hindsight, there is always something that could have been done more, in order to prevent a risk event from happening in the first place. However, mitigation can only be taken so far as not to let its cost become a significant burden.
3. A risk should be mitigated at the earliest possible opportunity. The earlier a mitigation is brought in, the more cost-effective it usually is.

Risk Response is the set of actions which are intended for the mitigation of downside risks and the optimisation of opportunities. These actions, once decided upon, are included in a **Risk Response Plan.**

Exploration of opportunities

The identification of **opportunities** at an early stage is essential. This can include big opportunities such as an alternative project altogether. Risk management requires ensuring adequate time to be spent at the front-end stage to enable the 'right' option to be identified. Without this the opportunity is lost, probably never to reappear, and the potential for identifying high-value alternatives is lost. It can also include less dramatic opportunities, such as considering the use of materials alternative to those which first appear suitable.

Catastrophe Risk

Catastrophe Risk is the possibility that an outcome will occur which has an extremely high negative impact. Some catastrophe risk events occur very rarely, and some had never happened before in history until they occurred. Such events could include extreme earthquakes (e.g. 1 in 100,000 years), terrorism at the scale of 9.11, global warming resulting in a sea level rise of 5m, or a financial crash at the scale of 2009. They are sometimes referred to as **Black-Swan events**.

Catastrophe risks are hard to forecast and manage. They might tend to be ignored because the chance of occurrence is thought to be almost negligible – though this assessment may sometimes be incorrect. The impact, if such an event were to occur, may extend well beyond the project itself and be impossible to measure accurately.

Catastrophe risks should always be taken out of the risk matrix and analysed separately. Do not let the low likelihood score cause such risks to be buried in the risk register as these risks can be show-stoppers and game-changers. The engineer must analyse these risks individually, to assess whether the potential outcomes might be tolerable and what mitigation options exist.

Risk tolerance should be taken into consideration when dealing with catastrophe risks. **Risk tolerance** is the amount of downside risk that is acceptable to the sponsor of a project. Some high-risk industries have regulated risk tolerance, for example, the nuclear power industry. When risk tolerance is low, catastrophe risks should be mitigated to a greater extent.

Robustness and Vulnerability

Robustness and **vulnerability** are concepts included in the Eurocode. When we say something is **robust**, we mean that a small damage to it is unlikely to cause disproportionately severe consequences. When something is designed to have high **robustness**, it has low **vulnerability, and**. vice versa. **Robustness** and **vulnerability** are antonyms for each other.

A system that is designed to have high robustness, or low vulnerability, is achieved by good practice of risk management. For example, a building may have columns exposed to live traffic. A car crash into the columns may result in the partial or total loss of structural capacity of the columns. When the building has a 'vulnerable' design, the loss of a single column to car crash may result in the collapse of the entire building; whereas a 'robust' design prevents such a catastrophe from happening.

Failing to apply risk management best practice may lead to disasters. For example, the Ronan Point high-rise block of flats in London in 1968 was a vulnerable structure because a small domestic gas explosion in one apartment caused the whole side of the building to collapse. The Grenfell tower fire is another case of vulnerability – a fire started by a malfunctioning fridge-freezer within a single flat spread rapidly up the building's exterior, bringing fire and smoke to all the residential floors, killing over 70 people.

Processes for managing risk and uncertainty

Risk assessment

Risk assessment is a term that civil engineers could not be more familiar with. It is a legal duty by law, such as Management of Health and Safety at Work Regulations 1999, to carry out risk assessment

Risk Register

A popular way of managing well-studied risks systematically is the '**risk register**' (or '**risk matrix**'), a method well known to civil engineers. Each risk is given two attributes – **likelihood** and **severity**. In a **quantitative risk analysis**, a nominal risk value is calculated by nominal risk value = likelihood X severity. For example, a risk that has a 10% chance happening, and will result in a loss of £100, has a value of 10% X £100 = £10. In the civil engineering industry, a qualitative rating, usually in a numerical form ranging from 1 to 5, is given to the likelihood and severity for each risk. An overall risk score is obtained by multiplying likelihood and severity. This is an effective and well-established practice for evaluating the majority of common risks. However, it is not without weakness – 1) it heavily relies on historical data to be able to assign likelihood and severity 2) it is constrained by a given numerical range, e.g. 1 to 5, and is unable to reflect correctly the true severity of some extreme risks.

The greatest value of a risk register lies in the process of compiling it. Compiling a risk register prompts the engineers to think through comprehensively and systematically the hazards and the potential mitigations. It should not be used as a tick-box exercise, but should be used as a useful tool to stimulate thinking and communication.

Extending from the conventional practice of compiling a risk register, the **RAMP handbook** emphasizes the importance of delving deeper into the underlying causes of risk. Some risks may have links to other risks, and they can be traced back to the same underlying cause. This will facilitate the study of such risks jointly at a later stage of the analysis. An advantage of joint risk treatment is that there are opportunities for a single mitigation to address multiple risks simultaneously, at a lower overall cost than addressing each separately.

For example, it may first appear that there exist the following risks associated with a project: 1) high risk of flooding 2) risk of traffic congestion resulting in delay in delivery of construction materials 3) noise and vibration during construction resulting in negative impact to local communities 4) risk of vessel collision. If an engineer were to address these risks separately, potential mitigation measures could be: 1) construct flood defences 2) reconfigure/widen local roads 3) limit working hours to day time only 4) construct collision protection barriers or strengthen the structures to be resilient to collision impact. Obviously, each of these mitigation measures will either increase cost or put significant constraint over the working method/speed. After delving a level deeper into the underlying cause of each risk, it becomes obvious to the engineer that all these risks stem from the location of the work site – 1) it is a high flood risk area 2) it is far away from trunk highways 3) it is surrounded by residential buildings 4) it is next to the river with busy barge and ship traffic. Therefore, selecting another worksite could potentially eliminate all these 4 risks altogether.

See **RAMP Handbook** for further guidance on how to construct and use a risk register, and how to determine which of the identified risk mitigation options would be cost effective if adopted.

The **Risk Register** is not a one-off effort. Once it is established, for it to be continuously useful, it must be a well-maintained live document – it should be regularly reviewed and refreshed so that it is kept up to date.

Risk analysis

In the case of major projects, the project is usually driven by many external forces beyond the project itself, such as the economic, market demand, politics, environment, etc. The **risk register** will bear a myriad of risk items, where lot of them will have complex interwoven relationship. As such, the sophistication of risk assessment must be brought to a whole new level defined as '**risk analysis'**.

Risk analysis is a comprehensive process of identifying, quantifying and treating risk, including:

- Reduction of uncertainty,
- Exploration of connections between risks,
- The development of possible risk responses and consideration of their cost effectiveness,
- Scenario analysis,
- Formulation of a recommended risk response package,
- Identification of residual risks and checking them against the organisation's risk tolerance level,
- Input into the overall project decision-making process.

Risk analysis is an iterative process that usually entails multiple iterations throughout the life cycle of a project, continuously incorporating changing and newly emerging risks into further analysis. For more details refer to the **RAMP Handbook**.

Risk Review

A Risk Review is an overall assessment of the risks involved in a project, their magnitude and their optimal management, held at regular intervals or at particular development stages of a project. Risk reviews can in principle be held at any stage in the life of a project, with each review building on the results of previous ones. When risks are found to have expired, consideration can be given to releasing the contingency allowances to cover them which are held in the budget. When risks still outstanding have increased, further mitigation measures may have to be considered.

Risk Reviews should generate information for inclusion in the **risk register** and **risk response plan**. The **Risk Response Plan** is a plan for executing risk responses and optimising risks once implementation of the project begins.

Horizon Scanning should be carried out regularly **to feed into risk reviews**. It is a methodical pro-active process to identify changing and newly emerging risks as early as possible, while there is still time to do something about them.

'**Scenario Analysis**' is a useful tool for dealing with risks and uncertainties. It is a process in which certain key scenarios that might arise in future are selected for detailed analysis, in which each is thought to be reasonably representative of a group of real-life events or scenarios. In other words, scenario analysis asks 'what-ifs' in a structured, analytical and realistic way.

For example, a project is about to conduct a large and complex concrete pour for a massive base slab structure of a metro station during summer time. The quality of the pour is highly sensitive to the temperature during and immediately after the pour – the higher the temperature is, the higher the risk of concrete cracking and honeycombing. The temperature is expected to be high since it is summer time; however, the exact temperature is uncertain and can be anywhere between 17 degrees and 33 degrees based on historical data. A scenario analysis is carried out for high temperature scenarios, including the possibility of exceeding 33 degrees because of the uncertainty of the extent of climate risk. Contingency actions can be prepared beforehand with appropriate triggers specified, so that they can be executed depending on monitored temperature. The contingency actions can include aggregate shading, use of icy water and delay of pour.

Engineering success on a wider scale

Success of an infrastructure project can be assessed on many levels and from numerous perspectives. This section elevates the view of success to a much higher level.

Success

Risk management is intended to increase the chance that the project will be deemed to be a success - but what do we mean by **success**? In a narrow sense it may mean success in achieving the planned costs and timescales, but for the project sponsor and the community as a whole this is insufficient and civil engineers need to look also with a broader perspective. Civil engineers should be aware of this broader definition of success and draw attention to any actions which they believe could be taken to maximise the likelihood and extent of its achievement.

Success is extremely difficult to be assessed systematically and consistently across different projects. There are many possible angles for assessing success once the asset comes into operation – commercial, financial, environmental, social, political, just to name a few. For example, a new road scheme delivered to exact time, budget and specification may turn out to be of little use in its operational phase and would therefore not have achieved success. The purpose of projects (their benefits) is usually realised when they are operational. And operational success requires key decisions during project planning, development and construction are made with operational success in mind.

Different levels of risk

It is sometimes useful to refer to different levels of risk at various stages of the project. For example, for a metro project, a **project risk** could be the collapse of the ground during tunnelling; an **operating risk** could be faults persistently arising in the signalling system; a **strategic risk** could be the low ridership of the trains due to low demand, which could be caused by competition from alternative means for travel.

In simple terms, the overall **strategic risk** for a project is that the final outcome of the asset's design, construction and commissioning is such that the asset cannot fully achieve the anticipated benefits. The overall **project risk** for a project is that as a result of risks occurring during the design, construction and commissioning process, the asset does not meet its specification, or costs more than anticipated, or takes longer than required to become operational. Tackling project risk requires detailed risk identification, analysis, mitigation and management. The overall **operational risk** for a project is that the asset does not perform as well as expected, requires higher maintenance costs than anticipated, or fails to achieve revenue forecasts. Tackling operational risk must be done throughout the design, construction and operational processes, rather than just leaving it to the stage when the asset comes into operation.

The delivery of the project will only be regarded as successful if its anticipated benefits are achieved, and it is therefore very important to take **operating** and **strategic risks, as well as project risks,** fully into consideration when designing, constructing and commissioning the asset. This requires adequate front-end thinking. The **Front-end Thinking Guide** (Lewin, 2018) by the Risk Group sets out some key questions which need to be addressed at the outset of the planning for a project.

References

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