Dealing with Technical Uncertainty

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SUMMARY Professional engineers are involved in managing risk through investigation and design. This involves anticipating what might go wrong. The risks must be balanced and allocated, through statutory, contractural and insurance means. Some of these risks are beyond engineering control and may be uninsurable. Others may not even be recognised, except with the benefit of hindsight.

It is inevitable there will be technical uncertainty. Strategies for dealing with this include expertise, good judgement, independent review and good communication. When a risk materialises, the cause and responsibility for any resulting loss and damage may be disputed. Consideration of the legal and technical factors involved is required to substantiate or refute claims.

In disputes which depend on the interpretation of scientific or technical data, there is a need to deal wisely with uncertainty. Traditional legal forums tend to encourage adversarial science and have difficulty in coping with complex technical matters. Collaborating is a process being used to deal with technical uncertainty, both in decision making and dispute resolution. A workshop on groundwater aspects of a proposed refuse landfill is a New Zealand example of applying this process to a technical issue.

1. RISK ASSESSMENT

Professional engineering is an art, not a science. There will always be uncertainties. The engineer's work involves anticipating what might go wrong and balancing risks to achieve practical and economic answers. There are also political, industrial and commercial risks, many of which may be beyond the control of the engineer or contractor and be uninsurable. However, the acceptance of risk may provide opportunities for increased profit.

Some of the geotechnical risks which may be present in construction projects arise from factors such as:

(i) physical conditions:
- unforeseen or differing site conditions
- instability of natural or constructed slopes
- soft ground, rock, old fill
- groundwater, subsurface erosion

(ii) artificial obstructions:
- underground services
- wells, pits, shafts, boreholes
- debris, refuse, contaminated ground

(iii) adverse weather and natural disasters
- affecting site conditions
- surface flooding, erosion, siltation
- earthquake, volcanic activity, tsunami, typhoon

(iv) defective materials or workmanship of contractor, sub-contractor or supplier
- lack of quality

(v) defective design

Risk assessment is important if decision-makers are to evaluate the potential gains and losses associated with any particular course of action. The odds may be unacceptable, in which case the course of action can either be rejected or a method found by which the odds are improved.

When new technology is involved, there may be no information on potential failures. Even when existing technology is to be applied, risk data may be inadequate or inconsistent. Moreover, useful information on past or potential failures may have been suppressed.

Limits on the extent of risk assessment have been described (IPENZ, 1983) as follows:

> "The law of diminishing returns applies where the purpose of a risk assessment is to provide information for decision-making. Because any assessment contains some uncertainties, a decision based on it must also be subject to uncertainties. Additional effort and money spent on an assessment to improve its quality will produce a less than proportionate improvement in the reliability of the decision. Ultimately a point will be reached where the costs of additional investigations and studies, plus the costs due to the delay in the decision, will exceed any benefits from a more reliable assessment."

2. RISK ALLOCATION

In construction projects, risk is allocated between the principal and contractor through the general and special conditions of

contract. Traditionally, the allocation of risk depends on:

(a) which party can best control the risk;
(b) which party can best foresee the risk;
(c) which party can best bear the risk; and
(d) which party most benefits or suffers if the risk materialises.

Basically, all risks should be those of the principal, unless transferred to or assumed by another party in return for fair compensation. However, the other party needs to have the competence to assess the risk, the opportunity and expertise necessary to control or minimise it, and the financial resources to pay for damages if the risk materialises. Indeed, control is the essence of risk allocation. The party who has control should usually accept the risk. Thus, during construction, the contractor has control of the site and usually takes primary responsibility.

The principal usually carries the risk of unforeseen physical conditions. Increased costs arising from conditions that could not reasonably have been foreseen by an experienced contractor are paid for as a variation. Thorough site investigation and evaluation, by a competent geotechnical engineer, will minimise this risk.

3. INSURANCE

Few construction contracts are undertaken without some form of insurance cover. Contract Works insurance is usually referred to as Contractors All Risks insurance, but it never covers all the risks! It insures the works against physical damage, and includes cover on material and plant on the site. Public Liability insurance covers property other than that owned by or in the charge of the contractor and other than the contract works.

The engineer will also need the protection of Professional Liability insurance. The policy should cover any claim arising from work done earlier in the insured's professional career, have automatic reinstatement (i.e. become fully operative again after a claim), cover employees as joint insured, cover legal costs (even if, in the final analysis, the claim does not involve any payment), etc.

There can be gaps between the various insurance policies. Also, claims may fail. For example, construction insurance is based on the assumption that events causing damage are not foreseeable and are therefore accidental. If damage can reasonably be foreseen or is expected to occur, it should be avoided by intentional design or action and not by wishful thinking. Where there is a lack of fortuity, the claim may be declined.

A common exception provides that construction insurance does not apply to "loss or damage caused by defective design". In this context, "defective design" may refer to the broad concept of the condition of a thing and not be limited to any non-compliance with proper standards by the engineer or by the contractor; i.e. it need not imply that there was any negligent designing. However, exclusions for defective design or faulty workmanship are now usually limited to the defective part, in which case damage to other property affected (i.e. to adjacent parts of the works) is covered.

It is absolutely essential that all relevant information (including all investigation results, reports, letters, etc), known to the principal or its consultants, be listed and made available both to tenderers and to insurers. The importance of this onerous task is often underestimated, with the result that the principal can be faced with unexpected costs due to avoidable claims for extras from the contractor or the declining of an insurance claim during or after construction.

4. UNCERTAINTY

The dictionary tells us that when something is "uncertain" it is not able to be accurately known or predicted, not precisely determined, liable to variation, or changeable. On the other hand, a "fact" is an event or truth known to have happened or existed, or a piece of information.

The law makes a distinction between "facts" (which rely on direct observation or other sensing of some thing or event) and "opinion" (which depends on the judgment of someone with special skill or experience in interpreting the facts). However, the reality is that many such "facts" are either generalised descriptions of variable things or faulty memories of complex events.

Human thinking is only a description of reality, not the real thing. Put another way, people respond to their map of reality, not to reality itself. We try to make meaning out of all the information which is constantly bombarding our senses. But where uncertainty is involved, human judgement can be unreliable. We may lock onto an answer too soon, focus on detail and overlook the context, or behave as if chance events are subject to control. Data that contradicts our opinion may harden rather than soften that opinion. Experts are particularly prone to getting stuck in grooves, while still insisting they are making subtle judgements.

Compounding all these potential judgement malfunctions, we tend to use language which makes fact out of opinion (e.g. using "it's" to preface our opinion, which makes it sound as if everyone agrees; turning verbs into abstract nouns, which sound more authoritative).

5. EXPERTISE

Geotechnical engineering attempts to apply logic to understanding the physical behaviour of the soil, rock and water which comprise the earth's surface. The art is ancient, but theory and numerical methods have mainly developed in recent decades.

Subsurface information is mostly obtained from borings or test pits. Only a small part of a site can be sampled, partly because of the cost but also because drilling and excavation are destructive test methods.

Groundwater, an important factor in all soil behaviour, can be used to illustrate the limitations of expertise. Theory may be based on the assumption that soil is relatively uniform, so there is a uniform increase in hydrostatic pressure with depth below a free water surface. In fact the soil is almost never uniform, and vagaries of rainfall and drainage through permeable strata result in a complex and changing pattern of groundwater pressure (Hollands, 1985).

Slope stability analysis is also fraught with difficulties. There are various methods of strength testing, options for interpreting stress-strain-pore pressure relationships, parameters to describe soil performance, assumptions regarding subsurface conditions, and methods of expressing results. Computer programmes convert all these uncertain factors into an apparently simple answer, which can lead to a false sense of confidence. Computers are of course helpful to check the sensitivity of models to variations in the assumptions.

Because we have developed scientific and mathematical models to encode our experience, engineers are perceived as dealing in facts. We tend to present our opinions as answers to problems. Indeed we are often so inordinately proud of them that we do not present their limitations to our clients or the community, leaving the impression that the models are precise and comprehensive. We hide our risk judgements in factors of safety, even convincing ourselves that nothing can go wrong. Nevertheless, failures do occur regularly and the public has become sceptical about expertise.

Sound judgement is important, especially in geotechnical engineering. Dr Ralph Peck said:

> "As long as the myth persists that only what can be calculated constitutes engineering, engineers will have little incentive or opportunity to apply the best judgement to the crucial problems that cannot be solved by calculation."

The report of the failure of the Teton dam shows the remarkable results that can be achieved when a great body of engineering judgement and experience is combined in a panel of experts. (Dunnicliff & Deere, 1984)

Equally important is the way engineering judgement is presented, through good communication that can be understood by both technical and non-technical people. Care is also needed to recognise the state of knowledge of others, and not take too much for granted.

6. LEGAL LIABILITY

Many engineering failures can be attributed, at least in part, to lapses in logical reasoning, misinterpretation of site conditions, inadequate construction control, or lack of maintenance. Some could be more bluntly described as resulting from incompetence, by engineers or contractors working outside the range of their training and experience. However, it is more common to find that some detail or risk or uncertainty has been overlooked. Professional liability claims also arise due to misunderstanding of the engineer's true role and legal responsibilities.

The courts have held that a professional person must exercise a reasonable degree of care and skill. Failure to do so is usually referred to as professional negligence. Liability in contract is governed by the terms of the contract. These can include duties which are more onerous than the basic obligation to exercise reasonable care and skill. An engineer can also be liable in tort to other parties, irrespective of any contract. A tort is a civil wrong, for which there are legal remedies which do not depend on any provisions of contract or criminal law.

The standard which the engineer must meet has been described as the reasonable skill, care and diligence of an ordinary and competent engineer. This usually means the degree of skill and care which the majority of the profession would have brought to the same task. However, the court is not bound to accept such practices as sufficient and retains its own freedom to conclude that the general practice falls below the standard required by the law. Employed engineers are bound by the same obligation to use reasonable care and skill.

The degree of skill to be expected from a specialist is higher than that to be expected of a general practitioner. Furthermore, with the increasing development of specialisation, the general practitioner is expected to know when a particular problem may require specialist advice. If it was reasonable to do so, a failure to obtain specialist advice, or at least to recommend it, may be considered negligent.

7. MANAGING PROFESSIONAL LIABILITY RISKS

The most effective way for an engineer to minimise professional liability risks is to be competent and thorough. Where appropriate, independent advice and review should be sought. Then, as far as possible, any remaining risks should be identified, be drawn to the client's attention and be clearly explained in terms that can be understood by non-technical people. Communication of risk is essential.

An engineer may feel that any review of work implies criticism or lack of confidence. On the contrary, the real professional encourages and welcomes independent review. It may identify some detail or risk that has been overlooked, thus helping to ensure that the project will be successful and enhancing the engineer's reputation. In the unlikely event of a future problem, the review itself will be good evidence that the care and skill of the profession has been exercised and that the problem could not have been reasonably anticipated by the ordinary competent engineer.

The engineer's liability can be inadvertently increased by the way work is described. The wording of reports, certificates, inspection records, contracts of engagement, and even

fee accounts, may imply a degree of involvement that exceeds the true function of a professional adviser. For example, words like "ensure" and "supervise" can lead to unintended warranties.

Experienced engineers are often asked to give an opinion on engineering matters, with a view to giving evidence in a court or arbitration hearing if a claim cannot be resolved. When giving evidence, the engineer must do so objectively and fairly. The expert witness is not there to advance a party's cause, but to assist the tribunal. If experience is lacking or preparation has been inadequate or there has been a lack of objectivity, the "expert" can be made to look a fool and this may be recorded in a decision for all to read.

When giving evidence on professional standards, the engineer is normally required to describe the general practices of an average competent member of the profession at the time, and not what the witness would have done in the circumstances. This requires careful research. Care must be taken to avoid any temptation to base such opinions on what is known now, with the benefit of hindsight, or on more recent practices.

8. TECHNICAL DISPUTES

The keys to resolving technical disputes are:

- identifying the main issues in dispute
- establishing the relevant "facts"
- interpreting the technical factors (technical opinions)
- interpreting the legal factors (legal opinions)
- recognising any possible different interpretations of technical and legal factors (grey areas/uncertainties)
- quantification (most losses are converted into money)

The person claiming must prove the claims, so good evidence is needed - e.g. minutes, instructions, correspondence, photographs, investigation results, expert opinion, etc.

An expert may give opinion evidence on the interpretation of facts. However, in adversarial proceedings both parties may produce experts. This often introduces two models, into each of which one can feed disputed "facts". Both models may give an impression of rationality and reality. Any fallibility may be concealed, consciously or unconsciously, but uncertainty still remains. Traditional judicial forums therefore have difficulty in coping with complex technical matters.

Arbitration is the preferred judicial method of deciding technical disputes. Construction contracts have a submission in their general conditions, providing for one or more arbitrators to decide any dispute. If necessary, a properly procured award will be enforced by the court as a judgement. Arbitration has potential advantages of privacy, informality, convenience, efficiency, finality, and the option to choose a technical tribunal. (Hollands, 1989)

Alternative dispute resolution (ADR) methods involve a neutral party as mediator or conciliator in voluntary processes to reach agreement. The parties retain the power to make their own decision. ADR seeks to minimise the costs inherent in adversarial processes; i.e. costs of money, time, self-respect, relationships with others, opportunities lost, etc. ADR can avoid a win-lose result by incorporating factors into the outcome which are beyond the scope of the contractual and legal remedies available from litigation or arbitration. It allows the parties to deal with the uncertainty inherent in differing legal and technical opinions. To realise its potential, ADR should be used at an early stage and emphasise getting the parties to work together as joint problem solvers. Dispute resolution can then be transformed into an opportunity to improve relationships and develop skills in avoiding and dealing with future problems. (Hollands, 1988)

9. COLLABORATING

Our traditional engineering methodology has not dealt well with technical uncertainty. For example, during initial project assessment, investigation, design and decision-making, a "we know best what is good for you" philosophy supported by "good public relations" (the "decide-announce-defend" syndrome) has too often resulted in opposition to technical proposals and to the professions involved. So-called public consultation has been unsatisfactory, due to such factors as: the use of complex technical reports, difficulties in validating information, inadequate involvement and power of the parties, etc.

Increased attention is being given to working together, in a consensual process called collaborating. (McCarthy, 1984; Gray, 1989; Susskind & Cruikshank, 1987; Hollands, 1991) Collaborating has been defined as the constructive management of differences. It provides a methodology for dealing with uncertainty, power imbalances, cultural differences, politics and problem solving. It is a form of ADR which is particularly applicable to multi-party decision making and environmental dispute resolution. Collaborating involves interweaving two processes: conflict resolution, and the advancement of common understandings and shared visions.

10. GROUNDWATER WORKSHOP

A workshop on groundwater issues is a New Zealand example of successfully applying collaborating to a specific technical issue. There were different technical opinions about leachate and groundwater aspects of a proposed Auckland Regional Council (ARC) refuse landfill at Mt Wellington, Auckland. For example, a concern that, if the landfill proceeded, there could be pollution of existing groundwater resources in the vicinity.

Twelve technical experts, who were advising the ARC and other parties including objectors, were involved. Several others attended periodically as observers and/or were on the mailing list and had the

opportunity to comment. The author, who had previously acted as auditor for the environmental impact assessment, convened and facilitated the workshop. The objective was to produce a "single-text" report (i.e. a report to which all participants could agree), to summarise the relevant information and deal with the groundwater concerns.

The process was funded by the ARC, as part of its public participation programme for the proposed refuse landfill. The author was not a consultant to the ARC, but an independent neutral facilitator endeavouring to assist all parties. The involvement of a geotechnical engineer advising a local community objector group was assisted by intervenor funding provided by the ARC.

Most participants had to rely on basic information provided by others. Also, some participants were only involved in particular facets of the topic. New and more detailed information could emerge in the future. It was therefore not intended that the report should represent the complete and final technical opinion of those involved. Nevertheless, it was intended to make the information clearer, more accurate, more complete, and more accessible to non-technical people.

Concern was expressed that design of the landfill's leachate and groundwater control systems continued to evolve during the workshop. This was because the workshop proceeded in parallel with on-going development of the conceptual design, and some changes were made in response to submissions by workshop participants other than the ARC and its consultants. However, it was finally agreed that this was quite normal, as engineering designs are not fixed but are developed and refined in response to further information, changes in technology, and new perceptions of the many factors involved. Indeed, it was considered important that further refinement should continue during the detailed design stage and in response to subsurface conditions actually exposed during construction, if the landfill proceeded.

The workshop met on six occasions over a period of six months. During that period, a sub-committee also met and developed wording and diagrams for the report. The concerns of each participant were incorporated. The author collated and edited the report, often rewording technical material in more neutral terms. The participants finally reached general agreement on the technical factors and complete agreement on wording of the report (Hollands, 1990).

11. CONCLUSIONS

It is inevitable that there will be technical uncertainty. We must acknowledge this uncertainty and identify the risks. Strategies for dealing with this involve both technical competence and risk management. Sharing the problem, through review or collaborative processes, is worthwhile. When disputes arise, an appropriate process is needed to resolve differences and improve future relationships.

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