

Beyond Compliance: Seeking Risk Models Beyond Everyday Structural Engineering



2017 NZSEE
Conference

A.G. Cattanach

Director, Dunning Thornton Consultants Ltd, Wellington

S.R. Dalziel

*Director of Emergency Medicine Research, Starship Children's Hospital,
Auckland.*

ABSTRACT: Professionals must manage risk and uncertainty. Since the Canterbury earthquakes, there has been an increasing focus on compliance as the way of improving structural performance. However, robustness, the “art” of good detailing and the ubiquitous “engineering judgment” are not found in detailed code provisions, they rely on the professional skill of the practitioner. Reactionary over-conservatism in the guise of compliance pushes up the cost of buildings, endangers built heritage, and stifles creative architecture.

This paper looks to the field of medicine, specifically emergency medicine, for qualitative frameworks in risk assessment that may complement “compliance”.

In emergency medicine, clinical uncertainty and risk is dealt with in every interaction. Clinicians must decide who needs urgent treatment, who warrants further investigation, and who is safe to send home. These critical decisions occur against a background of at times inadequate clinical histories, human variability, and inexact diagnostic tools. Risk needs to be stratified: discharging everyone home, or admit and investigate everyone, is neither feasible nor safe.

Alistair Cattanach, a Director of Dunning Thornton, Wellington, and Dr Stuart Dalziel, a Paediatric Emergency Specialist and Director of Emergency Medicine Research at Starship Children's Hospital, Auckland, will discuss attitudes to risk, uncertainty, and compliance in their respective fields. Topics include the necessity of considering broad consequences, acknowledging uncertainty, accessing evidence, different tolerances for risk, and embracing and encouraging intuition within a framework. Management of risk and uncertainty are fundamental to engineering practice, and lessons can be learned from how we approach risk and uncertainty from other professions.

1 INTRODUCTION

Management of risk and uncertainty are fundamental to engineering practice. The premise of this paper is that too much attention is currently being paid to the procedures around compliance and refining these to the nth degree. When one considers failures within structural engineering, the majority happen because of a lack of understanding of generalities: load paths, robustness, and/or unforeseen effects 3D geometry. Compliance is important, especially with respect to some of the details that provide robustness. However ensuring compliance could better be seen as a series of set procedures, carried out in an engineering design office within an overall framework and culture of communication, qualitative appraisal and risk analysis.

This paper is a result of discussing the similarities and differences between the roles a Wellington design office and the Accident and Emergency Department of Starship Children's Hospital Auckland.

2 “CODIFICATION” AND OVERSIGHT

Traditionally medical practice was overseen by the Hippocratic Oath based on the utmost respect for human life, maintaining confidentiality, placing the health of those cared for first and upholding the traditions of the medical profession. While these principles are important, medical practice in New Zealand is governed by legislation, in particular the Health Practitioners Competence Assurance Act 2003 amongst other statutes. The New Zealand Medical Council, whose purpose is to protect the health and safety of the public by providing mechanisms to ensure doctors are competent and fit to practise, provides advice regarding good medical practice. Specifically included in this advice is how to work in partnership with patients, allowing patients to make an informed choice on the treatment that they receive (ref: Medical Council of New Zealand. Good medical Practise). Such communication involves explanation of the risks and benefits of specific treatments, and modes of management.

The parallel framework of this in a design office is our Engineering Charter, forming the high-level principles of our approach to the work, and practice notes from IPENZ, ACENZ and the various societies adding to the New Zealand standards/Building Code to form the procedures underneath this. The intention of this framework is that before any design leaves the designer’s office, Reasonable Grounds should be established for compliance with the code or, more importantly in terms of this paper, providing the performance expected by the client. These two can be different.

Whilst the design may comply with codes, whether it complies with the expectations of the client or tenants of the building requires appropriate communication and recording of an engineering brief. This is often poorly done by engineers, but is analogous in medicine to properly taking the case history and wishes of a patient into account.

If a risk analysis is undertaken, the designer (with assistance) should be able to provide some insight to the strengths and weaknesses of their own design, and by implication assist a Building Consent Authority or peer reviewer in the checking process better, which theoretically is better for all. This implies a culture of accepting that we all make mistakes, and having the courage to positively seeking assistance within one’s practise, Peer Review and Consenting.

Compliance with the code is not black and white, regardless of the mathematical expressions contained within the standards. There is variety in both materials, construction processes, ground conditions, and most of all, our understanding of earthquakes.

There is a large amount of heterogeneity within humans, thus one patient may not respond to a given therapy like another, occasionally the reasons for this (genetic mutation for a given cancer drug) are known, but in most instances, it is not. However, within construction there is less heterogeneity, one piece of steel (assuming the Chinese are not cheating) has the same minimal properties as another constructed to the same standard, thus both pieces of steel can be expected to act the same. Where heterogeneity exists within construction is that very few buildings are identical in terms of the geological structures that foundations are built on, through to foundations, design, and external forces acting on the building. A common frustration amongst structural engineers is the Structural Performance factor. This “fudge” factor allows for various undefined aspects of seismic understanding, including that most buildings do better in earthquakes than calculations would suggest, and affects the design forces by up to 30%. This very much illustrates how seismic engineering is risk-based rather than just numerically determined.

3 METHODOLOGY

3.1 Precedent and research

Teaching in architecture is mostly based on precedent buildings, whereas in engineering it is mostly based on first principles. With our large and varied building stock, precedent is very relevant both to interaction with the client and determining their needs, and in producing details that are economic and buildable. Using precedent saves time, rather than working out all aspects from first principles: however, this time should be spent critiquing/improving the applicability and thinking about the risks associated with the relevant part of the design.

Robustness of clinical evidence in medicine has analogies in the choices when using proprietary products in design. Medical evidence is graded from lowest to highest quality from observational studies which can be subject to considerable bias, through to randomised controlled trials, which experimentally test two alternative treatments, and systematic reviews and meta-analysis that combine the results of more than one randomised controlled trial. High quality evidence only exists for a proportion of medical interventions. For example, approximately half the medications that are used in specialist children's hospitals are done so outside of their labelled indication. Often they are given where there is good randomised controlled trial evidence of benefit in adults, yet this is deferred to children, with the support of lower quality observational studies. In such situations patients and clinicians must be willing to accept this unknown risk of what the true benefit is in paediatric patients, thus medications are often cautiously used in such patients.

3.2 Communication

Though notorious for our poor communication skills, we engineers must improve our interactions with clients, users and other designers in today's more "performance-based" environment. A good design, with good logical load paths that provides a robust building can fulfil clients' and even the most demanding architects' desires if sufficient discussion occurs. There has arguably not been a time in New Zealand's history where there has been a greater public concern or understanding about seismic issues. By communicating with clients, architects, and the general public, we can provide a robust, integrated design. This process can not only draw on clients' and designers' recently acquired seismic knowledge, it can also overcome unfounded prejudices that have arisen from earthquakes in the last six years, e.g. that unreinforced masonry buildings do not perform well in earthquakes.

Awareness of risk, often through events or media exposure, should lead to more discussion regarding the risk. However, ultimately it should not lead to change in practise with regards to the risk, unless the risk has increased and is justified. For example, in the mid-1990s a single piece of medical research suggested a possible link between autism and the measles, mumps, rubella (MMR) childhood vaccination. Relatively quickly, this was subsequently found to not be justified. Therefore, while the research should have prompted more discussion regarding the adverse events associated with the MMR vaccine, it should not have resulted in a reduction in the numbers of children vaccinated. Yet this was the case. Failure or perceived failure by the public can result in many years to rebuild confidence.

3.3 Risk Analysis

As Earthquake Engineers, we try to provide designs and assessments against an estimated hazard based on our geophysical knowledge. It is not the remit of the structural engineer to necessarily interrogate this, however it is extremely important to consider the inevitable unknowns that are associated with a project. These include ground conditions, the level of seismic shaking, occupancy changes, quality of construction and degradation with time. There are also the "unknown unknowns", which is the performance of real structures that is not yet fully captured in our research and codes. The best way to carry out a risk analysis for a structure is to vary the risk through simulation or brainstorming, and through this evaluate the consequences to understand the sensitivity. In foundation engineering this is commonly done by doubling or halving assumed parameters and considering the effects on the structure. Just making things stronger may not mitigate consequences; it may be the linkages between elements that lead to a poor outcome.

Furthermore, long-term risk is difficult to conceptualise. Yet, this is important for both structures and medical practice. For example, a child presenting with a mild head injury has a <5% chance of having an intracranial lesion and a 0.4% chance of requiring neurosurgical intervention. The investigation of choice to determine the need for these interventions is a computerised tomography (commonly called CT) of the head. Yet CT carries risk; For children <5 years of age sedation is 18

times more likely to be required in order to allow the child to stay still in order to capture the imaging (personnel communication Franz E Babl, Royal Children's Hospital, Melbourne, Australia), for every 10,000 children undergoing a head CT scan who are <10 years at the time of the CT scan there are 1 excess case of leukaemia and 1 excess case of brain cancer (ref: Pearce MS et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. *Lancet* 2012;380:499-505). While clinical decision rules exist that help doctors to decide who is at increased risk, and therefore who to obtain a CT scan in, these rules are not perfect. In fact, the strict application of the rules in current Australian and New Zealand hospitals, may result in increased scans without clinical gain (ref: Babl FE, Borland M, Phillips N, Kochar A, Dalton S, McCaskill M, Cheek JA, Gilhotra Y, Furyk J, Neutze J, Lyttle MD, Bressan S, Donath S, Molesworth C, Jachno K, Ward B, Williams A, Baylis A, Crowe L, Oakley E, Dalziel SR. *Accuracy of PECARN, CATCH and CHALICE head injury decision rules in children. A prospective cohort study.* *Lancet* 2017 [In press]). The communication of this risk to patients and their families is important in allowing families to be comfortable with the treatment offered.

3.4 Uniform risk and Consequence basis

Our national seismic hazard model is established to provide somewhat of a uniform risk profile to any structure exposed to earthquakes within New Zealand. The only subtlety we apply to this is the Importance Level of a building. Structures with negligible occupation (IL1) and structures with post-disaster functionality (IL4) are clearly defined and in the author's opinion, the risk concepts are easily understood by most New Zealanders. The only other subtlety we have when considering risk is increasing a normal building to IL3 because of the age or number of the occupants. Consequences of failure on the urban environment surrounding the building are not factored in. From a resilience basis, the context is extremely important in two primary ways: redundancy (i.e. there are other alternative facilities that may be available) or impact (how the poor performance of one building may close large or important areas within a city). Currently this is left to local authorities to attempt to control via urban planning, with little power from a Building Control point of view.

It is extremely difficult to find any analogy in medicine where there is an expectation of uniform risk or hazard.

3.4 Change and Maintenance

Changes in earthquake design have been significant in the last 50 years and in the author's opinion are inevitable for the next 50, because the science still contains many unknowns. This can be very hard for building owners to understand or accept. This is mainly because we haven't addressed this issue culturally. Seismic compliance has an analogy in maintenance (or in medical terms, fitness and continued health), which requires regular attention over a building's life, especially as most buildings outlast their minimum design life of 50 years. It is the author's belief that some form of seismic upgrade is an inherent part of the maintenance to a building, and that both are essential to achieve longevity. In the heritage sector, this is overtly recognised: regardless of their seismic strength, well-maintained buildings tend to stay better tied together than ones which have degraded.

Our understanding of seismic risk will inevitably change with time, especially considering that over 50% of earthquakes recorded in recent history have happened on faults that were previously unknown. (NZSEE 2015 ***find reference).

Furthermore, the acceptance of risk may change depending on additional circumstances. For example, in a child presenting afterhours with a middle ear infection (acute otitis media) the literature suggests that the benefit of prescribing antibiotics is limited as antibiotics have no early effect on pain, a slight effect on pain in the days following and only a modest effect on the number of children with perforations of the air drum and abnormal ears one to two months after the episode. Yet for every 14 children treated with antibiotics one child experiences an adverse event (rash, vomiting or diarrhoea)

(ref: Venekamp RP, Sanders SL, Glasziou PP, Del Mar CB, Rovers MM. [Antibiotics for acute middle ear infection \(acute otitis media\) in children](#). Cochrane database of systematic reviews 2015). It is therefore not unreasonable not to treat with antibiotics, and provide good analgesia when seen early in the illness. However, if seen early in the illness, and about to undertake long-haul travel to Europe (increased risk of pain and perforation) it may be sensible to initiate antibiotic treatment.

4 CULTURE

4.1 Innovation

In all professions, technology is continually changing. In structural engineering “doing the same old thing” may be suitable in some circumstances, but we should be looking to provide better satisfaction of our client and public’s needs through these changing technologies. The author believes this is particularly so in the field of low-damage design, especially after the demolitions required in Christchurch and (and now in Wellington?).

When innovating, one looks at the building as a whole in a different way, and it often carries (as it should) a culture of greater rigour.

Participants in medical randomised controlled trials testing two interventions, a new agent versus current standard of care, do better regardless of the intervention they receive. By being part of the trial greater care is often given to implementing “current standard of care,” they are often observed more closely and so adverse events or deterioration can be identified earlier, and trials often occur with clearly defined clinical pathways that clinicians follow resulting in better more timely care. Thus, a research culture, and research participation, is often beneficial.

4.2 Intuition

Whilst intuition is rarely openly discussed in technical forums, to “sleep on a problem” or to “go with your gut feel” is common phraseology in the engineering industry. Fostering intuition is difficult, as with fostering creativity, although the means are similar.

Mentoring plays a key part. Peer discussion is also important. However, if peers all work in the same “institution,” or have similar behaviours that mean they are all employed or work together as they are a “natural fit” for that work environment, they may all suffer from the same confirmation or observational biases. Thus, these biases may be at an institutional level rather than at a personal level.

Intuition tends to be developed experientially. Both professions have traditions of apprenticeship: with medicine this is far more formal, stratified and lasts longer into your career than in most cases in Engineering. Often in engineering it is left to the individual to seek a breadth of work, often under the guise of achieving coverage for the 12 Charter points in the CPEng framework. This development however should extend throughout your career.

Ensuring one’s designs are reviewed by others with a different thought or working method from you assists this, whether this can be done within a single office culture or through collaboration, especially for smaller firms.

4.3 Confirmation Bias

Using procedures within codes or the like can lead to confirmation bias if it provides the “right” answer: the important thing to ascertain is the answer to the right question. This is where peer review is important, entraining both the technical skills and the intuition of parties who are independent from the design team.

4.4 Institutional Bias and Team Environment

How a design office works is very important both for fostering intuition and to celebrating the differences between people's thinking. This critical process will ensure higher quality review and potentially innovation, though it may not always be comfortable or be the quickest process for "getting the drawings out the door".

The author believes there has been insufficient focus on design office culture as a result of the Royal Commission into the Canterbury earthquakes, both in the way buildings are designed and subsequently how assessments of damaged buildings were carried out.

Contractors are important players in troubleshooting structural designs. In medicine, nurses are critical and I think the analogy is useful. But probably only in "Doctor XX would do this, so I think you should" to juniors. "Institutional biases" can exist if you always work alone, with the same individuals, or in a position of unchallenged authority.

4.5 Improvement Framework

Whilst compliance is often seen as a "stick" approach, using the stick and carrot analogy, it is important to foster a professional culture to drive ourselves (provide the carrot) to do better.

Once you make professional development and achievement part of the "rules" it becomes stick-based. However I think what you can do is create a culture of ambition, or aiming high, in your institution and also profession. Quality assurance activities can help improve this, particular if seen to be relevant by practitioners, and undertaken in a non-blame/non-identifying manor.

At what cost are we willing to pay for risk? New Zealand is unique in that within its public health system it has an agency that is responsible for determining which medications doctors may prescribe to patients, and thus which medications patients may access. PHARMAC is charged with keeping the national pharmaceutical spend within a capped budget, it does this by vigorously analysing the clinical and fiscal benefits of each new medication. Recently an analysis was undertaken comparing the medications available for treatment of cancer between New Zealand and Australia. Eighty five medications were available in both countries. Thirteen medications were available just in New Zealand. Thirty five medications were just available in Australia, but not New Zealand. Of these 35 medications, 10 had immature evidence, 17 provide only moderate or poor benefits (below American Society of Clinical Oncology definition of clinically meaningful improvement in survival), 5 potentially caused harm or worse health outcomes, and only 3 provided real clinically meaningful benefits (one of which has been subsequently funded in New Zealand and the other two are being considered). Together these 35 medications would cost New Zealand \$130 million per year, each year, and with the exception three of these, the unfunded medications would provide little, or relatively low, clinically meaningful health gain for our population. Conversely in engineering, how much additional money is spent on constructing to a higher standard, than what maybe of an acceptable risk. This increases our construction costs and effects our ability to build efficient buildings, particularly housing either in Canterbury post-earthquake, economically mitigating the high seismic hazard of Wellington, or sustainably developing Auckland during a residential property shortage.

5 CONCLUSION

A conversation between professions often highlights similarities: by definition this is because of the requirement to make difficult or more qualitative decisions, rather than a more technician's role dealing with black and white problems. In the Paediatric A&E department there is no such luxury: all problems and judgements are grey. Do we in Engineering do ourselves sufficient justice in developing or skills in these aspects of our jobs in the right proportion to continued technical learning?

The premise of this paper is that with the right culture the two develop together. If goals are set

beyond compliance on the higher goals of client understanding and satisfaction, innovation, and public good, the compliance aspects will fall into their correct place of being the procedures to aid achieving a more holistic view of quality and risk.

Intuition is commonly referred to in construction – the “gut feel”. If we have the right risk appraisal framework with the appropriate combination of the qualitative and the quantitative, we have the framework to foresee the big problems as well as the detailed ones.

Management of risk and uncertainty are fundamental to engineering practice. As we develop more complex compliance procedures, it is essential our overview frameworks develop in tandem to deliver or preserve buildings we not only understand deeply, but ones which satisfy the desires of the public as a whole.