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Making decisions in the face of uncertainty: Understanding risk

Part 2
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Part 2: Risk perception, communication and management

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Aim and Scope

This essay is the second in a three-part series on how we make decisions in the face of uncertainty. In reality most decisions involve some degree of uncertainty, including the many that we make collectively as a society and that governments make on our behalf. All such decisions involve some assessment, conscious or otherwise, of the risks and benefits of one action versus those of another, which may include taking no action. As we progress as a society we are continually accumulating more knowledge, but paradoxically we are also opening the door to more uncertainty. But as we become more knowledgeable we also expect, and indeed need to be able to make informed decisions over increasingly complex matters, ranging from issues of social development and environmental protection through to how to use or limit the application of a raft of new technologies.

Part 1 of this series outlined the basic concepts of risk and how it is evaluated, both objectively and subjectively, as we seek to make decisions when we (both individually and as a society) don't know or cannot know all of the possible outcomes. In reality this occurs with almost every decision we make.

This second paper (Part 2) explores these issues in more depth by considering how we perceive risk in our own individual and collective decision making – how our attitudes towards different risks can be swayed by our experience, culture, worldviews, and group associations – and the effect this has on how we attempt to manage risk. The paper examines how we all individually use a series of mental shortcuts (heuristics) to evaluate the potential risks we face, how these inform our considerations of precaution on the one hand and risk-taking on the other, and thus inform our decisions. The paper also considers how the media, and social media in particular, can have significant influences on the perceptions of risk – even where there is a scientific consensus on societal issues for which there may still be much values-driven public debate. Finally, the paper describes the varying interpretations of precaution and how this influences our ability to address future challenges and risks.

The final paper (Part 3) in the series will be published early in 2017 and will consider how governments continually make risk-related decisions on our behalf. It will provide an overview of the New Zealand risk landscape and ways to think about how societal risks might best be managed. It will specifically address the role of government in risk management, and how decisions are made in the face of uncertainty and when a range of societal values and different worldviews must be considered.

Introduction

Confronting risk and uncertainty is unavoidable in our daily lives, and in planning for the future. We can be absolutely certain about very little; in fact nearly all of our decisions are made in the face of either recognized or unrecognized uncertainty. Our personal confidence in particular 'truths' stems from complex interactions between our knowledge, experience, inherent biases and values, and from perceptions gained from others in our society. We might think we start with an 'objective' approach to weigh up choices and make decisions based on calculations of costs and benefits, but what we see as a cost or a benefit depends heavily on our values, biases and past experiences. And because of the different values people place on outcomes, our ability to calculate risks collectively – even using scientific methods – has its limits.

Any risk assessment process considers which risks merit the most attention, how large the risks are, and whether certain risks are acceptable given the antipicated benefits. Part 1 of this series (Gluckman, 2016) described how scientists approach the 'rational' calculation of risk by putting a numerical value on risk consequences and probabilities. However, it also pointed out the considerable limitations of such actuarial approaches. And the decisions we take over many matters are made subconsciously rather than by any formal and conscious analysis – for example, when we decide to cross the road at a dangerous spot or ignore the odds stacked against us when buying a lotto ticket.

Indeed, we know that many potential risks are hard to quantify, and involve subjective judgments of value. Weighing different classes of risk based on numerical calculations of consequences can be criticised as 'comparing apples and oranges' because our value judgments will differ for almost any type of risk. Nevertheless, we all have to make decisions – and individuals, societies and those we entrust to make decisions on our behalf need a way to evaluate the options, the balance of risks and benefits, and the possible trade-offs of mitigating one risk at the expense of another.

This paper focuses on the individual and societal factors that shape our risk perceptions in different situations – by seeming to amplify some risks while attenuating others, thereby influencing decisions about what constitutes acceptable or unacceptable risk, both in relation to our own decision-making and that of others.

1. What is an 'acceptable' risk?

The question of what degree of risk is 'acceptable' is at the core of many of the decisions we make. The first paper in this series described the range of approaches we use to determine this, from formal methods of risk assessment, to the frequent, unconscious and informal decisions we all make in the face of uncertainty.

One approach used to determine the level of risk that might be 'acceptable' is cost-benefit analysis, which weighs a risk against the cost of reducing it. This approach questions whether the risk is big enough (costly enough) to warrant the cost of its reduction. If the benefits of risk reduction do not outweigh the costs, then the risk may be deemed 'acceptable'. In some cases mitigation activities can reduce the risk to a point where it is considered to be practically and essentially "negligible" (a fairly objective measure – see Part 1 (Gluckman, 2016)) Aircraft design requires that this level of risk reduction is achieved – the risk of failure has to be close to zero for it to pass safety tests required by regulatory authorities.

Aiming for negligible risk is not, however, the most common kind of risk assessment we make. More often we consider what is 'tolerable' – a level of risk that we are prepared to live with in order to derive benefits, while accepting that there may be some costs. For instance to reduce risks to our national power supply, extra capacity (and redundancy) is built into the grid, to the point where the risk of failure is remote but not impossible. The utility companies have judged that further redundancy is not cost-effective, and as general consumers of electricity we tolerate the risk of occasional power failure in order to keep costs down. However even greater protection is judged necessary in a hospital, so they have extensive back-up power systems installed.

Similarly, most of us tolerate some risks to our privacy in order to enjoy the benefits of digital technologies. The risks can be reduced by limiting some of our activities online, but we would forego the benefits of many useful apps and websites if we did not agree to their access terms. We give away a degree of privacy every time we search something on Google or buy something off the web.

Numerical risk scores or the use of metrics such as potential numbers of fatalities, injuries, etc. can also provide comparisons, and thus a gauge of acceptability or tolerability when comparing newly determined risks with other, already known and tolerated risks. Yet while such numerical methods are useful, individuals, and society in general, tend to view risk rather more subjectively when deciding what level of risk (or kind of risk) is acceptable or needs mitigation.

Our personal perceptions of risk are related to our awareness and knowledge of hazards [see Part 1] (Gluckman, 2016), but also involve our individual and societal values and beliefs about the desirability of different outcomes. In many situations our lack of relevant prior experience of the hazard and a lack of interpretable technical data, means our decisions are influenced by our values, culture, worldview an innate biases, and from the perceptions of others we respect or are influenced by. As a result, the judgments we make about risk acceptability are often at odds with the results of more scientific risk appraisal.

2. Risk perception, biases and value judgments

Our innate biases frequently confound our evaluation of relative risk. We can be fearful of risks that expert evaluation suggests are insignificant, just as we can be apathetic about risks that should command our attention. We often end up focusing on small risks arising from frequently encountered hazards at the expense of looking at the big picture – ignoring risks that are more difficult to quantify. We may worry much more about our child playing sport and getting injured than the long-term risks associated with not getting enough exercise.

But we also may become fixated on risks that are rare and remote if they appear to have very large consequences. This is because we view the risks through the lens of emotions and intuitive reactions, rather than technical or rational assessments of likelihood. For example, the dramatic nature of airplane crashes, compounded in recent years by the fear of terrorist hijacking, make air travel seem more dangerous than road travel, despite the actual risk of death being much greater for traveling by car.

2.1 Emotions and 'outrage factors'

Our views on risk are influenced by a number of so-called 'outrage factors' (Sandman, 1989); emotion-based perceptions that bear upon risk acceptability (see Table 1). Risks that are seen to be imposed on us involuntarily can provoke substantial outrage, whether or not the risks are actually significant. We have seen this in some of the responses to the recommendation to fluoridate community water supplies.

Table 1. Outrage factors that negatively influence the acceptability of risk. (Sandman, 1989)

Factor	Example
Lack of control We cannot take personal precautions to protect ourselves against the risk. Control is in the hands of an institution (e.g. corporation or government)	Risks of food or water contamination, or accidents caused by industrial processes are less acceptable than risks from activities we control ourselves (e.g. choosing to eat unhealthy food, driving a car)
Involuntary exposure Exposure to risk is not chosen by those exposed	Involuntary exposure to chemicals or radiation from industrial sources is less acceptable than voluntary exposure to cigarette smoke or UV irradiation while sunbathing
Unfairness Risk and consequences are inequitably distributed in society	Risks that are borne unequally in communities (e.g. as a result of siting of industrial waste dumps or factories) are less acceptable than those that are borne equally (e.g. vaccinations)
Man-made hazard Human technology based rather than natural	Industrial accidents (chemical spills, etc) caused by human error are less acceptable than natural hazard events such as severe storms or floods
Dread Hazard exposure evokes fear - may cause hidden and irreversible damage which may result in disease many years later	Exposures that may cause cancer (e.g. radiation, asbestos) or events with potential for severe harm are less acceptable than exposures leading to common diseases or household accidents
Event focused in time and space Single events that kill many people at once are less accepted than hazards that kill fewer people at once, but kill more often	Airline accidents are less acceptable than car crashes. Terrorist incidents or mass shootings are less acceptable than homicides.
Unfamiliarity Risks taken in everyday life are tolerated more than new unfamiliar risks	Exposure to unfamiliar chemicals from industry is less acceptable than exposure to household chemicals

Risks arising from natural hazards seem more acceptable than those that are man-made. Any human-induced risk (e.g. those generated by industries (chemical or oil spills, biological contaminants, pollution) or government action (failed regulations or policies), may cause outrage because of a feeling that it is imposed, unnatural, and/or out of our control.

We also consider how much trust we have in those who are imposing or communicating the risks, and whether the exposures and consequences, as well as the benefits, are evenly distributed. Outrage is likely if those creating and imposing the risks do not bear the burden of the potential negative consequences, and/or if those who are imposed upon do not reap the benefits associated with the risk-taking activity. For example, if an industrial activity might cause pollution in the local community, and the profits are not distributed within that community, outrage is likely to make the pollution risk seem greater, and the risk less acceptable.

Some hazards that can harm or kill a relatively small number of people in a single incident (e.g. an industrial accident, acute chemical exposure) are viewed as less tolerable than those that can harm or kill many people over time (e.g. smoking, poor diets), even if the overall number of fatalities is the same. This is in part because incidents with a large number of fatalities or injuries receive more media attention, alarming the public and keeping the risk in the foreground of public consciousness. Playing on emotions can clearly shift the balance against the objective evidence about the relative level of risk.

Outrage also springs from the unknown. ‘Dreaded risks’ are those that we gravely fear because of deep uncertainty about their possible impact, or the fear that exposure to the hazard will lead to hidden, long-term, and/or irreversible damage. Public perceptions of the risks surrounding nuclear energy and genetic modification provide enduring examples.

There are also risks that also confound expert analysis. So-called 'black swan events' have no historical record or precedent of occurrence, and take us by surprise – such as the terrorist attacks on the World Trade Center and the Pentagon in the US. There are also extremely rare hazard events (shocks) for which a probability cannot be calculated, but which have consequences that are potentially catastrophic. These may be foreseen by some experts, but because of deep uncertainty about the timing of their occurrence, they may be essentially ignored. (Moller & Wikman-Svahn, 2011).

For example, it is currently not possible to predict the timing of a volcanic 'super eruption' like that which occurred at Krakatoa in what is now Indonesia, in 1883, killing around 40,000 people. (Thornton, 1997) Lake Taupo was formed by such an eruption some 26,000 years ago. Although we now have monitoring systems on all volcanoes in New Zealand, they only provide short-term warnings (and much uncertainty) and would leave minimal time to prepare for potential widespread destruction if such an eruption were to occur. Black swan risks can affect not only human lives, but the critical systems that underpin national – and potentially global – social and economic viability. Such risks are unacceptable, but if we can't calculate their probability, what expense do we go to in order to mitigate them when resources are limited and many other threats may be imminent?

One of the most important questions that arises for society is whether we should invest in technologies that will reduce our vulnerabilities and increase our resilience

Outrage factors, whether based on real or perceived risks, are important to consider when understanding our own individual decision-making processes and the societal responses to decisions made by others. One of the most important questions that arises for society is whether we should invest in technologies that will reduce our vulnerabilities and increase our resilience – for example adding chlorine to water to reduce the risk of bacterial contamination, or fluoride to reduce the societal burden of dental decay. In these two cases we know that the risks are negligible, but what if the risks of the evolving technologies themselves are uncertain? What about the possibility of using synthetic bacteria to clean up oil spills, or gene editing to stop Kauri dieback? The benefits could be great, but the full spectrum of possible consequences is not known, and because of this the use of the technologies may be resisted.

Even when risks are well characterised, outrage factors can override the available evidence and expert evaluation of the risk severity, leading to public rejection of the technology or the science. This happened in the public responses to positioning cell-phone towers near schools. When such perceptions become a barrier to the introduction of a technology or industrial activity it is referred to as a withholding of 'social license to operate'. Industries with (either perceived or real) potential detrimental social or environmental impacts are therefore given standards to meet including demonstrating continual risk monitoring and management. The challenges that arise when new technologies are considered will be discussed further in Part 3 of this series.

2.2 Cognitive biases and the interpretation of risk

Our assessment of risk and the decisions that follow do not always involve conscious thought. But even when we do decide consciously, most often we rely on "rule of thumb" (or heuristic) reasoning and on mental recall rather than any formal calculation of risk. We generally estimate the relative seriousness of a risk based on its prominence in our consciousness, and how easily we can envisage harmful consequences or recall negative experiences. (Kahan, 2007) This intuitive approach to decision making is what we do when we are '*thinking fast'*, in contrast to reasoning through rules of logic and evidence (e.g. probability theory) in a rational, deliberative, and analytical manner, when we are '*thinking slow*'. (Kahneman, 2011) Innate biases in our reasoning ('*cognitive biases'*) come into play when processing information quickly and intuitively. Some of the different types of cognitive bias are described below.

2.2.1 Risks we won't take: Loss aversion and *status quo* bias

Although the appetite for taking risk varies among individuals (and across our lives), and between different cultures and segments of society, there is a general tendency for people to care more about avoiding potential losses than achieving potential gains. No one likes to lose. Perceptions can be strongly influenced by wording choices ('framing') that highlight either negative (loss) or positive (gain) aspects of the same decision. (Kahneman & Tversky, 1979) For most of us, a 75% chance of losing sounds much worse than a 1 in 4 chance of winning. In public health messaging to communicate risks and benefits of medical screening, 'loss' framing (e.g. the potential loss from not having a mammogram – a cancer diagnosis might be missed) influences screening uptake more than "gain" framing (the personal benefit of finding out if you are free or not free from breast cancer) (Edwards et al., 2001)

The common bias towards 'loss aversion' (avoiding loss) leads us to stick with previous decisions – holding onto what we've got and maintaining the *status quo* – rather than risk losing it by trying something new. (Kahneman & Tversky, 1982) In the face of uncertainty we tend to favour inaction over action, because we feel more regret for bad outcomes that result from taking action (and more feelings of responsibility), than for harm that comes from doing nothing. We might regret advising a close friend or family member to invest in shares that subsequently lost all of their value more than we would regret *not* advising them to invest in shares that later soared in price.

However this also leads us to underestimate the risk of inaction, which may be greater than the risks of action. An action with great potential for mitigating one risk, and a small potential for creating another, might not be taken – essentially creating increased risk. For example, some parents avoid immunization because they fear the rare and generally mild side effects of the vaccine, and thereby take on a much greater risk to their child and other children – the spread of (sometimes deadly) infectious disease.

Whether we are taking risks or avoiding them, we learn from previous decisions we have made – and the outcome of such decisions can bias our future thinking. If a past decision has led to a good outcome, we are likely to make the same decision again in similar situations. In this way, over-cautious or risk-averse choices can be reinforcing – giving a perception of having avoided a 'disaster', which reinforces the avoidance behavior.

2.2.2 What we hear is what we know: Information availability and familiarity bias

One of the most common sources of biased thinking is that of information *availability,* or ease of recall. Risks are generally perceived to be higher if their negative effects can be readily brought to mind. This can be greatly influenced by exposure to media messages about the risk (see Section 4). Individual and collective responses and perception may be based on singular memorable events and their relation to them, rather than on a rational view of the probability of such an event occurring. For example, if a bolt of lightning once struck the house of a close friend or relative, you may view the risk of a lightning strike to be higher than it actually is. This phenomenon is well demonstrated by the general view that the risks of being killed in a terrorist attack or in a plane crash are much higher than they really are.

The ease of recall of shocking (but mostly rare) negative consequences differs from the issue of *familiarity* with common risks, which tends to *decrease* our estimates of risk magnitude – for example we rarely think about the real – and everyday – risk of driving or riding in a car. Likewise, employees over time become familiar with what can be significant workplace risks, to the point where they may fail to take advised precautions. These old or frequently encountered hazards are viewed as less worrisome and are treated more leniently than new ones because they are well understood, and we are desensitised to them. This also applies to old, but familiar technologies that are known to be hazardous, such as the use of some chemicals for pest or weed control, which are accepted more readily than new, but less well understood genetic technologies that may be substantially safer. It is an attitude of "better the devil you know".

These attitudes are reflected in the regulations that governments develop, which tends to favour existing technologies over new ones where the risks are potentially more uncertain. Regulators also find it more difficult to remove or regulate an existing technology that, while potentially hazardous, is also associated with known and tangible benefits. An obvious example is our use of fossil fuels – while the hazards to the environment are becoming ever more apparent, society is finding it very difficult to move away from the industries and the automobiles that rely on fossil fuel extraction and consumption. It is easier to regulate against new hazards for which the benefits are not yet so tangible or the societal habits entrenched, such as nanotechnology or genetic modification. Regulations that make trialing new technologies more costly or difficult will result in fewer changes to current practice, even if that practice is itself risky.

This bias reinforces our inclination as a society to maintain the *status quo*, and also operates on the individual level. Most of us are more likely to adopt new technologies if they improve on an existing habit, rather than forcing us to break a habit or adopt a completely new one. The generation that has grown up using mobile phones is more likely to communicate via social media and take up new communication technologies – and also see them as less risky – than older generations for which such communication streams are less familiar and not habitual. One generation might deny and the other might exaggerate either the potential benefits or the potential costs. In general, we require strong evidence of potential gains to relinquish entrenched habits or beliefs.

'Disruptive' innovation – that which radically changes societal habits – can be seen as upsetting the social structure, presenting an uncertain future that may be feared, and leading to perceptions of loss of a particular way of life that is, if not perfect, at least familiar. How do we decide on the balance between the potential long-term benefits or costs of innovation (e.g. communally-owned, self-driving vehicles) and the short-term costs and benefits of maintaining the *status quo*? We shall return to this question in Part 3 of this series.

2.2.3 Protecting our beliefs: Confirmation bias and cultural worldviews

> ***"A man hears what he wants to hear and disregards the rest."*** *– Simon and Garfunkel, The Boxer*

People are often unconcerned about risks that evidence and experts have shown to be significant. Sometimes this is because to recognise something as a hazard would threaten a set of values or beliefs (e.g. climate change, risks to beachfront/clifftop properties of coastal hazards and erosion). On the other hand, some risks that are the subject of significant public concern are considered minor by scientific risk assessment (e.g. health effects from radiofrequency fields or of fluoridation or chlorination of water supplies). Strongly-held beliefs related to one's culture and value system (their 'worldview') can lead people to evaluate risks and related evidence selectively, in ways that reinforce their beliefs. (Kahan & Braman, 2006) This is reflected in a tendency to accept at face value the conclusions of scientific studies that support prior opinions, and to reject conflicting studies as invalid. (Lord et al., 1979) Some vocal advocates for veganism, for example, will highlight any study that hints at negative effects of eating dairy or other animal products, ignoring numerous valid studies that demonstrate benefits of such protein in the diet. It is common to view an argument as valid if we believe in its conclusions, rather than considering the argument's logic (or lack thereof). (Evans & Curtis-Holmes, 2005)

In fact the evidence shows that people often *actively* seek out information that supports their own opinions and beliefs about themselves and the world. (Festinger, 1957) Such 'confirmation bias' occurs because it is human nature to dislike questioning our own beliefs – we tend to seek consistency and avoid conflict between our beliefs and behaviours, and our 'knowledge'. When there is potential conflict, it might be alleviated by changing the belief or the behaviour to fit with the new knowledge, but more often, people in such situations will downplay the significance of the conflicting knowledge and cherry-pick those bits of information that confirm their prior views. Thus, individuals can claim their view to be based on facts and logic, yet draw radically different conclusions from the selected 'facts'.

In many such cases, rather than shedding beliefs, science and facts will be rejected. For example, people who do not want to believe that their lifestyles are possibly harmful to the planet are more likely to reject the science supporting human-induced climate change. Yet paradoxically they might be more likely to accept the science of genetic engineering, and vice versa. Such rejection of science is often associated with conspiracy theories. (Lewandowsky et al., 2013) But providing more evidence with the intention of changing this kind of thinking often only strengthens the position of the believer – it is turned around and used as evidence of a conspiracy or cover-up, thus strengthening the original beliefs.

Unfortunately, the internet and social media can create situations where confirmation bias becomes even more likely. There are so many opportunities now available to pick and choose the kind of information we want, and with media and advertising now delivered based on preferences, personal profiles, and search histories, most people find little to challenge their beliefs.

2.2.4 Going with the flow: Group think bias

> ***"Once a course of action has gathered support within a group, those not yet on board tend to suppress their objections—however valid—and fall in line."*** (Kaplan and Mikes 2012. *Managing risks: A new framework*. Harvard Business Review)

Our preference for consistency and certainty in our own beliefs and behaviours leads us to seek out the company of people who reaffirm, rather than challenge those beliefs. One important function of social groups is to provide social validation of one's attitudes and worldview. Aligning with a group that shares an ideology can diffuse an individual's responsibility for the contradictions that the ideology may pose between personal beliefs, behaviours and/or knowledge. The more cohesive the group, the easier it is to feel that decisions being made must be ok – or at least you alone are not responsible for making them. The comfort of such 'collective rationalization' thus motivates people (usually unconsciously) to interpret technical information in ways that reinforce their group connections.

This is particularly well demonstrated by a new form of group that has emerged – the 'echo chambers' of social media – where people tend to connect only to people of like mind. Discussions occurring within such social media groups reinforce the very views that led those people to form a group in the first place, and lead individuals to overestimate the prevalence of their own opinion amongst the general population. (Leviston et al., 2013) The echo effect of social media can give license for views that individuals might otherwise have been inclined to question – potentially driving the whole group toward more extreme views.

Where strongly opposing views exist, providing more scientifically robust information can thus polarize the differing groups further, rather than bringing them closer together. This is because people construe and assimilate information in opposing ways to *reinforce* their prior perceptions of risk. Regarding the risks of nanotechnology for example, perceptions of risk for people with the same initial and low level of familiarity with the technology, but with differing cultural worldviews, diverge dramatically with increasing exposure to technical information. In an experimental study, those initially opposing the technology became more opposed, and those supporting it became more supportive (Kahan et al., 2009). This suggests that it is a person's worldview that affects the interpretation of information and not the factual nature of the information itself, because people became more, not less, divided when exposed to balanced information.

Similar observations have been made with respect to climate change. Once views have been formed, providing more information just tends to push people further apart, entrenching opposing views rather than fostering societal consensus. Attitudes to many other technologies (e.g. genetic modification) and societal interventions (e.g.

decriminalization of drugs; supervised sites for injection by opiate addicts, etc.) appear to follow a similar trend.

Within groups, traditions, beliefs and ideologies are continuously reinforced in order to maintain cohesion and identity. Group solidarity is often magnified by labels that are applied to describe the group's ideology, whether by the group itself or by outsiders. In the climate change debate, for example, the opposing groups have been labeled as 'supporters' and 'deniers' (or 'skeptics'), which serves to emphasise group identity and homogeneity. Assigning such labels, however, fails to represent more subtle differences in opinions that are not extreme, and incites more combative debate. It also tends to limit the careful examination of individual claims, which are often disregarded because they are perceived simply as coming from the opposing group's viewpoint. In this situation, group labels encourage the protection of group ideology and belonging over thoughtful analysis of evidence. (Howarth & Sharman, 2015)

3. A meeting of science and values

As risks have become more complex and technological, society has come to increasingly depend on experts and expert institutions for their interpretation. The mechanisms of the scientific process are designed to provide useful information to guide decisions and regulate risks, and have helped keep us safe from many possible harms. But science and technology can also generate new risks (often technological, and either perceived or real) that need to be considered.

"Facts alone literally have no meaning until our emotions and instincts and experiences and life circumstances give rise to how we feel about those facts." (Ropeik, D. 2014 *Feelings matter more than facts alone: A challenge and opportunity for science advisers*)

In fact, all technologies since the discovery of fire have provided benefits but have also had negative aspects and consequences and there are always some uncertainties created when new technologies are adopted. Human history is largely determined by how technologies have been adopted, used and misused. Increasing awareness of the possible negative impacts of the very rapid technological progress of recent years has sown doubt in the public consciousness about the balance between benefits and harms. For some there is a growing distrust in the ability of science to provide assurances of safety. Indeed, on highly contentious issues, scientific/statistical risk assessment alone can no longer calm public anxiety and can even contribute to a growing distrust in expert institutions. (Fischer, 2000) Most concern until recently has focused on genetic, environmental and public health issues [Box 1] but increasingly issues of cyber-security, loss of privacy, and autonomy are leading to concerns about many other forms of technology.

Box 1

Uncertain harms, corporate science and environmental advocacy – the glyphosate story

Glyphosate is the active ingredient in the world's most commonly used weed killers. Glyphosate-based herbicides (GBHs) have been used widely in New Zealand orchards, vineyards, pastures, roadways, sports fields, and home gardens since 1976. Glyphosate replaced more dangerous chemicals, and allowed a reduction in tillage of soil for weed control, which reduces soil erosion and CO_2 emissions.

Initial risk assessments of glyphosate considered it to be relatively safe for human exposure, because it inhibits an enzyme that is found only in plants. However, concerns have been raised over its increasing use, and recent suggestions of its potential toxicity in mammals (and possibly humans) because of its possible endocrine-disrupting effects and carcinogenicity. (Myers et al., 2016) GBHs from agriculture can contaminate water supplies and leave residues on food crops when sprayed shortly before harvesting, which can be detected in human tissue.

These concerns led the International Agency for Research on Cancer (IARC) to examine the current animal and epidemiological data, and to re-classify glyphosate as 'probably carcinogenic to humans' (Group 2A) in 2015. (Guyton et al., 2015). Other agencies also reviewed the same evidence, and came to different conclusions. The European Food Safety Authority (EFSA) assessment concluded that glyphosate is unlikely to pose a carcinogenic hazard to humans. (European Food Safety Authority, 2015) In response to outrage from some quarters over the apparent contradiction with the IARC assessment, EFSA noted that the IARC programme evaluates cancer hazards *but not the risks associated with exposure* (and it is likely that levels of exposure do matter). The U.S. Environmental Protection Agency's risk assessment of GBHs is ongoing, but preliminary documents state that a causal relationship between glyphosate and cancer is not supported by the existing evidence base. (EPA Cancer Assessment Review Committee, 2015) Likewise, the NZ Environmental Protection Authority recently concluded that no reclassification of glyphosate as a carcinogen or mutagen was required under the Hazardous Substances and New Organisms (HSNO) act. As with other chemicals with uncertain risks, glyphosate is being actively monitored, and if significant new information becomes available, a reassessment will be initiated. (Temple, 2016)

The uncertainties in the risk assessments around glyphosate further stoked an already raging controversy - not only over human health risks, but over effects on pollinators such as the monarch butterfly and honeybee populations, as their preferred foraging foods were killed off by glyphosate. (Haughton et al., 2003) But societal outrage went further, because risks were perceived as being imposed involuntarily and unfairly by the agrichemical industry, and in particular by its main player, Monsanto, the developer of the first, and still the most extensively used GBH commercial product, Roundup. After cornering the GBH market in the U.S., Monsanto developed genetically-modified, glyphosate-resistant crops — allowing even more Roundup to be used. Outrage over GMOs, and the perception that human and environmental health were suffering at the hands of a corporate giant, has kept advocates busy on both sides of the debate.

Environmentalists opposed to GMOs and pesticides have tended to reject the science on glyphosate safety as being biased, and ignore the potential environmental benefits (reduced tillage, higher yields on less land). But bias goes both ways. Funding from big organic food companies who would benefit from the vilification of Roundup and GM crops provided financial backing to vocal academic critics of conventional agriculture, (New York Times, 2015) in order to promote a credible 'voice of authority' to support their claims of risk, and essentially turning science, or perhaps pseudo-science, into advocacy. (Ropeik, 2016) The real risks in this situation remain uncertain – and mired in the controversy.

3.1 Believing the experts

In forming their views and assimilating information, most people follow the lead of credible experts – but they define and choose 'experts' based on whom they perceive as sharing their values. Experts are not immune to bias, and, as explained in Part 1 of this series, (Gluckman, 2016) the actuarial approach itself is not free from value judgments. Biases and values are inherent in the risk assessment process, beginning with what we recognise as a hazard. They can influence the priority given to the study of specific risks and thereby generate data necessary to promote action on those risks.

Scientists are human, with their own biases and values. But modern science has largely evolved as a set of internationally recognized processes designed to minimize such biases, at least in the collection and analysis of the data. A core value judgment that remains in the processes of science is in the evaluation of the sufficiency of evidence on which to draw a conclusion. Because this judgment can be subject to bias, it is important to have independent replication and aggregation of scientific evidence from different studies and sources in order to reach a scientific consensus. [Box 2] Public trust in science and scientists may be becoming increasingly tenuous as the issues become ever more complex and contested. Scientists must find better ways to interact with decision makers and the public in order to bolster confidence in the authority of their expertise and the legitimacy of the advice that they provide.

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3.2 Loss of trust

The complex nature of our societal risks and how they have been dealt with previously has led to the emergence of what has been termed 'post-trust' society, (Lofstedt, 2005) characterized by a generalised public loss of trust in policymakers, regulators, industries, and scientists as 'experts'. A number of factors contribute to the erosion of trust, not least being the chain of highly publicized regulatory scandals internationally around exposure to hazards (e.g. food safety, contaminated blood, asbestos), drug safety, or threats to the natural environment, as well as documented manipulation of science by the tobacco industry. (Bero et al., 2006) There is often a perception of lack of impartiality and fairness in important decisions, mainly stemming from the perceived impact of interest groups on collective decision making.

New Zealand has not been immune to controversial issues that stir public distrust. For instance, concerns around health (fluoridation of water), new technologies (energy technologies, biotechnology), over-exploitation of natural resources (fisheries vs conservation of the marine estate, fresh water quality), and preserving biodiversity (using 1080 against invasive species) have all been and continue to be the subject of vigorous debate. [Box 3] The increasing diversity of scientific and expert views portrayed in the media, and the media's own practice of trying to create debate even when it does not really exist among scientists (see section 4), leads to confusing messages and the impression that science can no longer provide useful responses to important policy-relevant questions. As debates become polarized, motivations and values are questioned, and the science is increasingly contested. In such situations, scientists and experts need to step up their efforts to behave as 'honest brokers' of expert knowledge and evidence and acknowledge their own biases and values. (Pielke, 2007).

Even though there may be much that is unknown, science has an essential and critical role to play for both publics and policy makers in assisting the risk assessment process. But this requires that scientists do their best to minimize biases, and that science communicators present to publics and policy makers not only what is known, but what is not known, and how the scientific consensus has been reached (if there is one). This is the 'brokerage model" of science communication which tries to minimize rather than play on preexisting biases of individuals and societies.

Box 2

What science can (and cannot) tell us

Science is a set of processes for producing knowledge – ways of observing, thinking, experimenting and evaluating that has allowed us to achieve an increasingly comprehensive understanding of ourselves and our environment. The scientific method is based on fundamental principles of logic and reasoning – linking ideas with evidence to form conclusions.

Science relies on evidence – the accumulation of observations, historical data, and experimental findings that leads to the formulation of theories to explain natural phenomena. The process of science involves ongoing efforts to test these theories and make revisions based on the outcomes of the tests.

Karl Popper's philosophy of science asserts that scientific theories must be 'falsifiable' – that is, able to be disproved by testing or further observation. If a falsifiable hypothesis is repeatedly tested and the results are statistically significant, it can be accepted as scientific 'truth' - but truths can still be falsified when more knowledge is gained.

Science is therefore always contingent – it holds the possibility of arriving at different explanations for observed phenomena. New observations may challenge the prevailing theories, prompting their revision. But science generally progresses through the modification of ideas, rather than outright rejection – there are few true scientific revolutions. A lone experiment, or a single publication, will not provide a new truth. The progress is towards scientific consensus, building from the consistency, coherence, and volume of evidence. While the complete and absolute 'truth' may be elusive, scientific methods allow increasingly accurate approximations and predictions to be made.

It is important for scientific theories, and the 'truths' they uncover, to be continually challenged and adapted – especially if they impact on important decisions, policies, and regulations that affect society. But it is equally important to recognise the questions that cannot be addressed in the scientific process – those that cannot be proved or disproved because they are about beliefs and values. Even in some cases where science can provide some answers, the scientific approach may be rejected as irrelevant if it confronts strongly held beliefs. Uncertainty may be exploited or manufactured in order to discredit the science. But uncertainty is inherent in science, which strives to test a theory against the evidence in order to reduce the uncertainty.

3.3 When science can't solve it

Even if science cannot be definitive, it provides essential understandings to our individual and collective decisions about risk. Science has an essential role to help characterize hazards, determine levels of risk, forecast likelihoods, and understand potential consequences. But as our risks become ever more complex and interconnected, science can only offer answers in terms of probabilities, and arguably with less certainty. In assessing highly complex risks involving deep uncertainties, the 'normal' scientific method, though necessary, is not sufficient to guide decision-making especially when ethical, social and ecological issues come into play. Science doesn't have all the answers, and claimed scientific facts can be controversial. Such situations – where the "*facts are uncertain, stakes are high, decisions are urgent*" – have created a need for 'post normal' scientific thinking. (Ravetz, 2004)This way of thinking about science questions the view of perfect objectivity and certainty that has been the ideal of traditional, applied science – i.e. that which is carried out when uncertainties are low ('normal' science (Kuhn, 1962)). It recognizes that scientific findings need to be interpreted in the light of individual and community values. But when these values are disputed, the complexities of science may be used to stir pseudo-scientific debate when the real debate is one of values. For example, one reason for some of those objecting to fluoridation of water or universal vaccination has nothing to do with science but relates to their view that it is forced medicalization. [Box 4] In addressing such issues, a post-normal scientific approach may involve engagement of a wider 'extended peer community' to assess information from a perspective that is beyond what is found in peer-reviewed scientific literature. (Ravetz, 2004; Gluckman, 2012) This type of work sets 'scientifically robust' information in the context of 'socially robust' processes for using that information. In a sense this is what policymakers do when they incorporate science into their advice to politicians within a democratic system. This will be further elaborated in Part 3 of this series.

3.3.1 The post-normal perspective: Evidence and contested values

Much of the contention around risk assessment of a new technology or some other activity (e.g. use of 1080 for pest control) relates to the sometimes problematic interaction between disputed social values and how science is adopted to support one view or another. In the case of climate change, much of the debate that led to a slow acceptance of human causes was not the complex science but rather the contested views regarding the

Box 3

Spraying poison from the sky – A necessary evil?

New Zealand is known for its natural assets and very high biodiversity. Evolving in the absence of land mammals, a large number of endemic bird and plant species that are unique to New Zealand have no natural defences against predators. The arrival of humans in the 13th century, and the introduction of a number of non-native mammalian predators since that time has brought on one of the highest extinction rates in the modern world. However massive extinction rates, particularly of megafauna, also accompanied the arrival of humans in both Australia and the Americas much earlier. It is a recognized problem of human invasion, without a comfortable solution.

The pesticide 1080 (sodium fluoroacetate) is used in New Zealand to control mammalian pests (rabbits, possums, rats and stoats) that threaten the survival of our native plants and animals. Possums are also the main carrier of bovine tuberculosis, a significant threat to our agricultural economy. These alien invaders are currently uncontrolled on most areas of conservation land, and contribute to ongoing biodiversity decline.

Aerial spraying of the pesticide is much more cost-effective than ground control, and in reality the only practical approach for many regions. However, dispersing a poison over large tracts of land is an emotionally evocative concept that arouses strong negative responses. Opposition is understandable. Understandable too is the equally emotional desire to preserve our native forests and birds from destruction by invasive pests.

On the surface, there may appear to be reasonable arguments on both sides. Hunters and animal rights activists alike oppose 1080 at high doses as an inhumane killer of dogs and deer, and a risk to the food chain and environment. Conservationists, farmers, and government believe that it is the best available solution to mitigate the risk of catastrophic loss of the unique New Zealand natural habitat and bird species living in it, and to prevent the spread of disease to livestock via possums. What is to be done when two such understandable goals are in direct conflict?

Digging a little deeper, it is clear that science favours one side of the debate. The 2011 independent review by the Parliamentary Commissioner for the Environment (Wright, 2011) put sentiments aside and examined the evidence and the practicalities of critical pest control and found that 1080 spraying was the most effective, cost-effective and lowest risk option currently available for halting the devastating effects of possums, rats and stoats on native plants and birds, and for halting the spread of bovine tuberculosis by possums.

There is no doubt that 1080 is a poison - that is why it is an effective pesticide. However, the controlled spraying regimens now used in New Zealand have been shown to pose very low risk to humans and larger mammals such as dogs and deer. 1080 is biodegradable and therefore is not a persistent pollutant. A more universally acceptable weapon against these pests is surely desirable, but we have none. In the future biotechnological solutions such as gene editing may emerge, but these too might create public debate. A choice must be made. Claims of hidden agendas and issues of trust about how pest control is managed have interfered with acceptance of the 1080 aerial spraying policy. Increased transparency and community engagement are needed to support social licence for implementation of this currently necessary strategy.

economic implications of addressing the challenge. The inevitable scientific uncertainties around projections for global warming and the contribution of greenhouse gases have been used or exaggerated by some to rationalise not taking action that would conflict with certain worldviews, sociopolitical perspectives or entrenched habits. In reality the questions have been less about science than about how and why one generation should incur costs for the benefit of later generations, or why countries that had not contributed massively to greenhouse gas production should incur costs because of the activities of other countries.

Similarly, the debate over genetic modification of crops to produce foods is often placed in the context of science, but the evidence for the safety of such foods is very robust. (Nicolia et al., 2014; Panchin & Tuzhikov, 2016) The underlying debates are those of economics, philosophy, attitudes to corporate control over food production, views on the manipulation of nature, and so forth, which in turn have been incorporated into various political agendas. It is not the place of science to resolve such largely irreconcilable worldviews – indeed it cannot do so. Rather science can inform discussion by society over such values, which become reflected in how any particular situation is perceived.

4. Media messages and risk perception

When the risk relates to complex – and often poorly communicated – science and technology, resistance can stem from fear of 'unknowable' future consequences. Achieving societal consensus on such risks is difficult; with little or no personal experience with the risks, people are dependent on news and social media for information.

Conventional mass media and social media have enormous influences on the public's perceptions of risk, because this is where most people obtain their information. Public risk perception depends far more on what is portrayed via television, radio, the internet and social media than it does on expert opinion. Media can be a very effective tool to increase awareness of hazards and risks, but at times it can also disseminate incorrect or biased information, which can reduce trust and support in decision-making processes.

Conventional journalism still has a responsibility to maintain journalistic integrity and ensure factual reporting. It is critical that news media address the scientific validity of claims to which they give airtime. However, news coverage of science often omits caveats and limitations that are conveyed in the original scientific literature and by scientists themselves, presenting stories based on preliminary evidence as if the data were conclusive. Decreasing budgets for science journalism, compounded by a need to cater to audiences that see news as a form of entertainment, further compromise the quality of coverage. Vivid or horrific incidents are more likely to be aired than other less gruesome but more common accidents or harmful events. Similarly, rare but catastrophic technological failures are reported more frequently than the everyday benefits these technologies bring.

In some cases fears can be magnified by advocates of particular positions. Celebrity advocates may act through the mainstream or social media and can perpetuate misleading messages – for example much of the negative publicity about vaccines continues to be based on the debunked myth linking vaccines to autism, despite their being absolutely no evidence to justify such a link. [Box 4]

Box 4

Vaccine opposition – how did it arise, and how does it persist?

In 1998, the medical journal *The Lancet* published a paper that suggested a link between the MMR vaccine (a combined vaccine against measles, mumps and rubella), and the development of bowel inflammation and autism spectrum disorders. (Wakefield et al., 1998) It reported on twelve boys, of whom 8, according to their parents' or physicians' recollections, developed symptoms of a developmental disorder soon after immunisation. Small and insignificant, the study nevertheless instigated a controversy considering the safety and effects of the vaccine. At its height in the early 2000s, the confidence in the vaccine fell not only among the parents of children with autism but also among public leaders and even physicians. Despite media inquiries, the then British Prime Minister Tony Blair failed to disclose the vaccination status of his infant son. In some communities and countries the rates of vaccination fell below the threshold required to secure herd immunity and outbreaks of measles appeared; in 2008, for the first time in 14 years, measles was declared endemic in England and Wales. (Godlee et al., 2011) And yet, after this article Wakefield published no new data and multiple large epidemiological studies found no link between MMR vaccine and autism. In 2004, 10 out of 11 Wakefield's co-authors retracted the interpretations of the data. In the following years it was found that not only was the research problematic but that the data had been manipulated and Wakefield had received payments from solicitors involved in a legal case against vaccine manufacturers. The Lancet finally retracted the paper in 2010 and Wakefield was sanctioned by the Medical Council and lost his medical registration, but the opposition to MMR vaccine did not disappear.

There are several explanations for this controversy and its persistence against scientific evidence. The parents were comparing two risks: of measles and of autism. By the early 2000s, thanks to immunisation, many had never seen measles; by contrast, many had personally seen or at least read about cases of autism, a spectrum of neurodevelopmental disorders that appears to be on the rise across the developed world. While some of the increase is linked to changed diagnostic criteria and practices, there may be environmental causative agents at play. The fear of autism vs the perceived innocuity of a 'rash' and ignorance of the severe effects of measles may explain such individual risk assessments.

This explanation for why the risk of measles was judged more acceptable than the non-existent risk of autism, and the preference for the small study on 12 children (which was exposed as fraudulent and misleading) over large epidemiological ones, may be found in confirmation bias. In the nineteenth century, resistance to the mandatory smallpox vaccination was widespread despite the huge risk that this disease posed. (Durbach, 2004) While some of the resistance was caused by the (real) potential risk of the vaccine, many objected on principle. For some, the vaccine, and in particular attempts to make it compulsory, went against assumptions about the limits of State intervention in personal life. Finally, vaccination conflicted with cultural ideas about the body, whereby health depended on preserving the bodily integrity and preventing the introduction of any foreign matter. Traces of this idea may be found among 'anti-vaxxers' who often also support the idea of 'natural healing' with minimal recourse to medication, through eating organic food, and boosting immunity 'naturally'. Some celebrities have been coopted to the anti-vaccine argument and their views are often considered by their audience more authoritative than expert opinion. Conspiracy theories involving the medical experts have been invoked. The article against MMR vaccine was thus eagerly received . This misleading and damaging societal meme has proved to be most persistent.

4.1 Striving for balance: Questioning consensus

In attempting to present an unbiased portrayal of a controversial issue, the mass media may convey a misleading sense of balance of opposing scientific views, giving a false impression that the weight of evidence is equal on both sides. For example, media debates on climate change or water fluoridation tend to pit a single expert against another opposing expert, suggesting that views on the issue are evenly divided, even though in reality the weight of evidence heavily favours one side of the argument. Sometimes pitching a marginal or maverick argument against the mainstream scientific consensus is done to create debate and entertainment, but is essentially a form of bias itself – it has been termed 'balance as bias'. True scientific consensus can often be completely overshadowed by such false balance in reporting, though some responsible news media outlets have begun to establish standards against this practice. (Jones & BBC Trust, 2011)

Scientific consensus is generally arrived at by careful evaluation of evidence from a large collection of consistent findings. It is a process by which the science community reaches a conclusion about what constitutes evidence, and about what the evidence demonstrates. [Box 2] The consensus need not be constant and will evolve as new knowledge accumulates – indeed that willingness to evolve conclusions is core to the culture of science.

Despite sometimes overwhelming agreement of scientific views, there may some scientists who disagree with the majority, and can make technical arguments about the shortcomings of the available data and the 'mainstream' scientific consensus. They can make their voices heard, and, if given ample exposure, can sow seeds of doubt in the minds of the public. The media, by giving outlying, and often scientifically questionable ideas equal airtime allows social controversy to appear (and indeed become) larger than it would otherwise be.

When it comes to environmental or public health risks, minority voices claiming that a particular risk is high often get disproportional attention compared with a scientific majority that sees the risk as much lower (Kortenkamp & Basten, 2015) (e.g. as in the fluoride debate). In such cases, even a small group of dissenting voices claiming high risk can sway public perception. If controversy is presented without context that explains majority vs minority scientific opinions, people are likely to perceive the science as uncertain. Uncertainty, whether real or constructed, can be exploited to advance a particular cause or agenda, obstructing the development of policy informed by scientific evidence.

It also can be difficult to distinguish between those scientists who are speaking outside of the consensus (and potentially misinterpreting or misrepresenting the science) for their own agenda, and those who are speaking outside of the consensus responsibly and who genuinely represent an emerging, valid view. While the former can be very damaging, the latter can be vital in certain situations. The history of views on plate tectonics is a prime example of a radical shift in understanding that was first seen as maverick: when first introduced, the theory of plate tectonics was 'against the consensus', but has now been proven correct. The challenge is identifying and distinguishing between these, and how they affect the public trust in science. Conversely the argument that HIV-AIDs was not caused by a virus was promoted by one maverick scientist who had the ear of power – and delayed the introduction of effective intervention in South Africa, with tragic consequences. (Cohen, 1994; Nattrass, 2008)

4.2 Going viral: The social media effect

Social media can provide communities with a sense of connection and stability during crisis situations, providing updates, instruction and reassurance where needed. Its two-way nature helps authorities understand public concerns. But social media can also rapidly spread fears that are at odds with the evidence. Exchanges on social media are often emotional and very subjective – and can be transmitted essentially like a virus. On the way, communication chains can distort the message. Preconceptions affect what information is transmitted (people single out information that fits their preconceptions) – and in turn influence the perceptions of the receiver. (Moussaid et al., 2015)

Mainstream and social media effectively now work in tandem, with editors seeking out stories that will get clicks or that are inspired by viral stories. Mainstream media picking up social media's viral stories or looking to 'listener/reader' feedback as significant content is increasingly how stories are developed.

4.3 Risk communication: Sending the right messages

Risk communication is the process of providing people, communities and decision makers with the information needed to make sound choices. Good risk communication provides a balanced evidence-based summary of risks and harms – it should help to answer pertinent questions, such as '*what does the science say about the level of risk*?', '*what is known and what is not known*', '*what are the implications?*' and '*what can be done about it?*' However facts and numbers are not what most people respond to when it comes to risky decisions. Risk assessments made by the public are almost always framed in qualitative, rather than quantitative terms, and a wide range of values-based criteria are applied to the same set of 'facts'.

Risk communication strategies that only provide information about the output of scientific risk analysis and the probabilistic thinking of risk experts are inappropriate and insulting to both the democratic process and to the empowerment of individuals. Such one-way communication about risk is destined to fail – especially for technological risks, and is outdated in today's digitally-aware social environment where rapid messaging has diffused the influence of technical experts as principal information sources.

4.3.1 Pressure for certainty

Nonetheless, experts must still be called on to provide information about risks, and are often pressured by either media or decision makers toward expressing certainty. Although most people recognize that certainty is an illusion, it is a natural preference to seek it, despite the impossibility of the task. We tend to hear, remember and report what communicators say as being more certain than it was, and yet we punish communicators who sound certain but are found to be wrong – for example the scientists who were put on trial following false assurances of safety before the deadly earthquake in Aquila, Italy in 2009. Both overconfident false alarms and overconfident false reassurances lead to lost credibility.

Neither risk communicators nor the public can wait for certainty, because it will never come. Absolute proof of zero risk is impossible. How long should they wait, and how much evidence is needed, in order to make a judgment call? If an engineer noted warning signs of a possible bridge collapse, should she allow people to keep going over it until there is more evidence? Or if a doctor receives a cancer test result that might very well be false positive, should he warn the patient? We might say yes in both of these cases, but what if there's a chance of irreparable harm in taking action? It is usually better to provide information on risk, but to clearly convey levels of uncertainty or confidence, because the price of failure to warn is often higher than price of a false alarm. The current dilemma over prostate cancer testing using blood tests highlights these issues for many men (see Part 1 of this series (Gluckman, 2016)).

Acknowledging uncertainty admits a degree of subjectivity, and this needs to be handled in a clear and transparent manner, explaining where the uncertainties lie, how they are handled in the risk assessment, and what steps are being taken to reduce them. How the 'goals' of risk assessment or safety margins are selected should be elaborated through open dialogue, wherein the public can engage in a social learning process to come to mutual understanding of the issues. Risk-related behaviour is more likely to change when risks are understood and collectively shared by the community.

4.3.2 Understanding values and establishing trust

In reality there is no value-free way of framing a risk issue. Clearly, the source of the information affects how audiences interpret and respond to it. The communicator first needs to be trustworthy and credible, but also 'likeable', and viewed as sharing values with the receiver of the information. Because people often care more about trust, credibility, competence, fairness and empathy than about statistics and details, focusing on presentation of technical facts will not necessarily provide audiences with what they want to know. Public sentiment, values, and concerns first need to be addressed. Acknowledging the validity of people's starting views and emotions is key to engaging them in meaningful discourse about risks.

Thus, a key to effective risk communication is understanding how risk is perceived, and what is required for people to be concerned enough (but not unduly anxious) in order to take appropriate mitigating action. While many solutions to risk problems lie within the realm of science, it is not enough to know what risk-reducing actions may be effective. Even when the message is clear, there may be other barriers (e.g. insufficient economic or social resources) that limit the response. The messages need to consider both the willingness and the ability of the audience to respond.

5. Making the decisions: Dealing with risks and uncertainty

To this point, we have considered the complex factors that influence how we think about risk and uncertainty both consciously and unconsciously, and on both an individual and collective level. We utilize this thinking in order to manage the many risks that we encounter frequently, and others that might confront us rarely. Decisions have to be made.

5.1 Trade-offs

Decision-making inevitably involves some level of uncertainty, but uncertainty is not always about negatives. There are two sides to the risk coin: risk can be viewed as a burden – the possibility of loss – or an opportunity – the possibility of gain, and its management necessarily involves trade-offs between these, on both individual and societal levels. By making a choice between two alternatives that both have advantages and disadvantages, we dismiss the opportunity to enjoy the advantages of the unchosen alternative, and accept whatever disadvantages exist for the chosen one.

In managing the uncertainties and risks we inevitably face, trade-offs must almost always be made. Very few decisions are made in a vacuum – there are always other consequences (intended or otherwise) and spillovers to other activities. When we decide to speed down the road we are weighing the advantage of getting somewhere faster against the risks of being caught and fined, or even losing our driver's license. But we are likely to be ignoring the fact that we have increased the probability of being in a road accident that might harm us or others, with all the consequences that would then follow. When we take out a mortgage we weigh up the benefits of having a house versus the costs of the mortgage, and think about all the tradeoffs that follow from having less discretionary spending for things we might enjoy. We may or may not weigh up the consequences of massive interest rate rises in 5 years' time, or a fall in house prices, and how we rate these risks may influence the size of the mortgage we take out.

We make such trade-offs in our every-day decision making. When we spend resources to reduce some risks it may be at the expense of accepting others. We may also make trade-offs between paying for speculative long-term benefits over other immediate, tangible benefits, or likewise, between mitigating potentially catastrophic future risks over current small risks. Should we put away money for retirement or pay for insurance to guard against possible future losses, or spend it now on what seem like urgent needs – like a holiday or a new car?

Similar questions exist at the heart of government decision-making. At a societal level, actions taken to reduce the potential for harm could restrict development of a technology or utilisation of a resource, and the loss of benefits from these, just as choosing not to invest money in promising shares for fear of loss obligates individuals to forego the potential benefits.

Should dairy intensification be limited to protect water quality even if there might be immediate fiscal costs for farmers, the structure of rural communities, and for the economy as a whole? Should we consider gene editing as a way of dealing with mammalian pests? Should we decriminalize or legalize the social use of marijuana? Should we build more motorways to deal with traffic jams? Should we massively increase access to very expensive pharmaceuticals? Should we have free tertiary education? Should we reduce the number of prisoners by changing the criteria for imprisonment, because of the cost of prisons and the social costs of incarceration? All these and many other issues have an evidence base to support decisions, but all have many uncertainties and different perceptions of the risks, the costs, and the benefits involved. All involve high values components and these values are very much in dispute across our society. Yet decisions in every case have to be made, and whatever decision is made involves tradeoffs and some degree of risk. And in every case there is a danger of the evidence being drowned out by rhetoric.

Reducing risk involves both costs and benefits, and decisions as to what risks are acceptable and which are not. We must consider the cost effectiveness (whether financial, emotional or reputational) of mitigating or preparing for a risk with that of coping with its consequences. The cost of risk reduction becomes prohibitive below a certain level of risk. But there are also situations where inaction generates its own risks, as is clearly the case with some natural hazards. In general we do not try for 'no risk', but rather decide on a residual level at which cost of mitigation does not exceed the value of the benefit received from the mitigation activity [see Part 1]. (Gluckman, 2016)

5.2 Complex risks and precaution

The risks we face as a society are becoming ever more complex because of an interconnected range of causal factors, mainly resulting from human action and invention. Interdependencies between the built environment, transport, communication and lifeline utilities can cause cascading failures that amplify the consequences of a single natural or human-induced event or a series of interrelated circumstances. Such risks often have no clear boundaries. The nature and extent of the risk is hard to define and different stakeholder views – none of which are verifiably right or wrong – make decision-making even more challenging.

An anticipatory approach is generally used to confront complex risks – by focusing on enhancing resilience and preparedness through the appropriate use of precaution. Sometimes, however, attempts to address the risks can lead to unforeseen consequences – whether the risk is from a natural hazard on one hand or human activity and innovation on the other. For example, precautions against erosion using 'hardened' defenses such as seawalls in one area can contribute to unnatural erosion or sedimentation elsewhere.

Conversely, uncritically applied extreme precaution can lead to paralysis and inaction, making innovation virtually impossible. Prohibition of an activity or technology because of perceived risks, even if these are remote, can create risks elsewhere in society or in the economy. The nature of our species is one of serial innovation, yet we face some difficult choices about the introduction of new technologies to address many global challenges.

Effective approaches to addressing risk and uncertainty will require adaptive policies to cope with a range of scenarios that can and should be revised when the context changes and/or new information is available. The policies and actions must be robust – not just designed for the most likely outcomes, as this can increase vulnerability to less likely, but more catastrophic events by creating a false sense of security. For example, structures designed to avoid flooding in 'standard' high rain or tide conditions can result in higher flood damages in extreme storm conditions because of a lack of preparation or anticipation of the rarer but possible severe events.

The need to cope with scientific uncertainties around potentially catastrophic risks led to the emergence of the frequently misunderstood 'precautionary principle'. This will be discussed in Part 3 of this series.

6. Moving forward: Risk-taking and innovation

Innovation, whether social or technology-based, is inherent to our human nature and is important for our continued wellbeing as a society – providing better human and environmental health, sustainable cities and industries, improved efficiencies and our quality of life. Innovation will be essential in the face of increasing pressures on natural resources and to address the sustainable development goals that every nation has agreed to. But innovation is inherently a risk-taking activity, as there is always some degree of uncertainty involved. As a society we need to think about how to embrace new and potentially disruptive technologies that may carry risks but could ultimately lead to much greater benefits. But equally we need to be prepared to limit the use of such technologies if they are found to do more harm than good. Of course there are, and should be, strong values-based debates about these decisions. [Box 5]

New Zealand is a technologically advanced nation that is rightfully proud of its history of inventiveness and innovation – both technological (e.g. navigation aids, dish-drawer dishwashers) and social (e.g. world-leading suffrage laws). Both technological and social innovation are viewed as important for the future of our society. But we also place great value on our natural resources, our cultural heriatge, and our health and wellbeing, and by definition will always have incomplete knowledge of the risks that new technologies may impose on them.

Some technologies touch public sensitivities more acutely than others; for example nuclear power, genetic modification, nanotechnology, and hydraulic fracturing (fracking). The public may feel that rules and regulations are not keeping pace with new scientific developments (Chalmers & Nicol, 2004) and indeed for some advanced technologies, such as artificial intelligence, we have little or no experience from which to draw lessons for policy. This enters in a complex area of the interaction between technological development and society, which will be addressed in Part 3 of this series. We will discuss how societal decisions involving risk are made in a democracy and how social license can be negotiated and maintained in order for society to be comfortable with many innovations. And we will discuss how governments must make many, if not all, decisions in the face of uncertainty and how they undertake their primary role of protecting their citizens, assets and environment from a broad range of risks.

Box 5

Societal cognitive biases and disruptive innovation

The same cognitive biases that affect our own decision-making also affect how we act as a society. Consider two distinct disruptive technologies of the last three decades – genetic modification of agricultural crops and the development of social media. The use of genetic modification to manipulate agricultural production has had a mixed reaction in different societies. Some have embraced it readily, other have rejected it. Initially there was justified concern over safety, and some countries, including New Zealand, adopted very stringent precautionary approaches. Others did not, and now the safety of genetically modified (GM) food is no longer in doubt, at least in the minds of major scientific academies that have reviewed the evidence. The claims of adverse health consequences have been shown to be totally unfounded, although this does not stop some advocates of a total ban on this technology continuing to claim that such evidence exists.

Cognitive biases and outrage factors at least partially explain why a history of safety has not translated into universal acceptance of GM crops by societies. The way GM organisms were introduced into agriculture meant that the benefits accrued very narrowly to agribusiness and were not spread across society. Others have felt uncomfortable that putting genes from one species into another species was 'playing god' and therefore inherently distasteful. Slogans like "Franken-foods" were used to influence public impressions, sometimes for political or marketing purposes.

Yet consider another disruptive technology - the introduction of internet-based social media. Society has never actively engaged in a discussion about its adoption because the personal benefits were obvious and accessible to every user of it – better communication and the democratization of formerly closed-shop institutions such as publishing or journalism. But social media is not without serious social consequences – the rise in cyber-bulling, *ad hominem* but anonymous attacks that impact on many people quite adversely, the loss of personal space and privacy, and the trivialisation of serious discussion that may be impacting on democracy itself.

Looking back on how we have or have not accepted these technologies, we might consider these hypothetical scenarios:

- What if GM crops had been developed by a government lab to produce foods that prevented the development of diabetes, and the intellectual property was not protected so all could benefit?
- What if the first use of social media had been by a terrorist group for propaganda, and had been directly implicated in major terrorist events?

Perhaps then the positioning of social licence for these two technologies would have been reversed.

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Glossary

Ambiguity
Situations where the likelihood (probability) of each outcome is unknown (see 'decisions under uncertainty)

Bias
A particular tendency, trend, inclination, feeling, or opinion, especially one that is preconceived or unreasoned. *Cognitive biases* can cause us to make decisions or reach conclusions that do not align with facts and logic.

Consequence
In risk assessment terms, consequence is the outcome of an event that has an effect (positive or negative) on people and/or assets

Decisions under risk/decisions under uncertainty
These two terms are used in some sectors: 'decisions under risk' assumes that the probabilities of outcomes are knowable to some extent, whereas 'decisions under uncertainty' occur when the probabilities, and possibly the outcomes themselves, are unknowable.

Event
An event could be one occurrence, several occurrences, or even a nonoccurrence (when something doesn't happen that was supposed to happen). It can also be a change in circumstances. Events are sometimes referred to as incidents or accidents.

Exposure
People, property, systems, or other assets present in hazard zones or exposed to hazards that are thereby subject to potential losses.

Hazard
An intrinsic capacity to cause harm.
A hazard can be an event, entity, phenomenon or human activity, and can be single, sequential or combined with other hazards in its origin and effects. Each hazard is characterised by its timing, location, intensity and probability.

The origin of hazards can be natural (geological, hydro-meteorological and biological) or induced by human activity (environmental degradation and technological hazards), and include latent conditions or trends that may represent future threats.

Probability (Likelihood)
Probability is defined as the likelihood of a hazard occurring or the chance of a hazard happening. Probability is usually described quantitatively as a ratio (e.g. 1 in 10), percentage (e.g. 10%) or value between 0 and 1 (e.g. 0.1), or qualitatively using defined and agreed terms such as unlikely, almost certain, possible etc.

Risk
Risk is defined as the likelihood and consequences of a hazard. Risk can also be described as the effect of uncertainty on objectives (Risk Management Standard ISO31000

Risk assessment
The process of evaluating the likelihood and consequence of a hazardous event. Risk assessment involves hazard identification, risk characterization, likelihood/probability estimation, and consequence analysis.

Risk attitude
A person's or organisation's general approach to risk, influences how risks are assessed and addressed (i.e. whether or not risks are taken, tolerated, reduced or avoided).

Risk reduction
Risk reduction refers to efforts to decrease in risk through risk avoidance, risk control, or risk transfer – this can be accomplished by reducing vulnerability and/or consequences

Residual risk
The risk that remains after risk treatment has been applied to reduce the potential consequences.

Resilience
Resilience means being shock-ready, and having the ability to resist, survive, adapt and/or even thrive in response to shocks and stresses. Resilience can be defined in terms of societal, economic, infrastructure, environmental, cultural capital, social capital, and/or governance components.

Shock
The term 'shock' is usedto denote a sudden, disruptive event with an important and often negative impact on a system/s and its assets.

Social license
'Social license to operate' generally refers to the acceptance or approval by a local community of a company's project or ongoing presence in an area. It is increasingly recognized by various stakeholders and communities as a prerequisite to development. The need to gain and maintain social license compels industries with potential detrimental social or environmental impacts to prove they will act responsibly in order to avoid challenge.

Stress
A stress is a long term, chronic issue with an important and often negative impact on a system/s and its parts.

System
A system is defined as set of things working together as parts of an interconnecting network; a complex whole e.g. society (individual, community, nation), the environment and physical entities (e.g. infrastructure).

Threat
A threat is a potentially damaging physical event, phenomenon or activity of an intentional/malicious character. It is a man-made occurrence, individual, entity, or action that has the potential to harm life, information, operations, the environment, and/or property

Vulnerability
The characteristics and circumstances of an asset (populations, systems, communities, the built domain, the natural domain, economic activities and services, trust and reputation) that make it susceptible to, or protected from, the impacts of a hazard

Worldview
The overall perspective from which one sees and interprets the world. A particular philosophy (collection of beliefs) on life held by an individual or a group.