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THE RATIONAL IMPERATIVE OF PROFESSIONAL RISK MANAGEMENT

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Abstract. The conundrum of *modern post-industrial societies is extraordinary level of overall social well-being punctuated by concerns over multiple risks to which our management responses are ill-adapted. Risks are mostly foreseen but uncertain and often dreadful, but some risks are unforeseen in their likelihood and can have disastrous consequences. The public's trust in the capabilities of professionals to manage the risks is often a matter of contention but, in our view, the primary obligation of risk regulators and professional risk managers is to make paramount the duty to serve the public interest. Risks must therefore be assessed scientifically and quantified: "Numbers, not adjectives" must guide decisions. Relative valuation of what is at risk and what can be sacrificed to reduce the risk is fundamental.*

Societal preferences about longevity vs. prosperity is expressed by a social indicator, the Life Quality Index LQI. The LQI reflects fundamental human life values and allows explicit balancing of risk with life benefits. It is derived from the economics of human welfare to give a clear guide to risk evaluation. We summarize the derivation of the LQI and derive a paradigm for consistent management of risks in all areas of public exposure to risk. The literature gives many examples that have been implemented in structural engineering and disaster management.

It is concluded that the LQI together with the marginal life saving principle provides a reliable and rational approach to quantify, judge and manage public risks with transparency.

1 INTRODUCTION

For millennia structural design has relied solely on judgment based on experience. During the last few centuries we have been judging the extreme actions upon a structure over its projected service life in order to calculate the stresses and deflections. Further, during the last few decades we have become able to calculate the probabilities of extreme structural states (including collapse) and compared them to specified limits – these limits, too, have been based on judgment.

Professional judgment remains fundamental to structural engineering, but history shows how professional practice has been moving towards the ideal of scientific objectivity and accountability. To this end it is imperative not just to guess but to have a *measure* of risk and of safety. During much of the past 100 years we have developed probabilistic structural analysis, but until recently probabilistic standards of acceptable risk have been based on guesswork and calibration to resemble past practice. Accountability to society that the safety levels are optimal has not yet been served. 'Judgment' may be just a nice euphemism for guesswork.

An objective quantification of 'acceptably safe', derived from revealed preferences by the economics of human welfare, is described here to provide an answer. Risk and of safety both require clear definition – "*numbers, not adjectives*." The 'scientific' meaning of *risk* is a set of events over a specified future period, each with a probability of occurring.

How safe is safe enough? This innocent question makes safety into a quantity and is germane in the development of engineering codes and standards, just as it is in the risk regulations in many other areas. The question of appropriate safety concerns the designer of every structure. It is essential in regulation, whether of design codes, consumer products, medical devices or procedures, and so on.

The safety question is universally important, but there is wide room for divergent opinion: Just what do we mean by "safe"? What do we mean by "risk"? The professional engineer, the regulatory authority, the general public and those exposed all see risk very differently. The engineer has a professional obligation to serve the clients' best interest, and so must judge safety objectively and dispassionately. Also, life safety is about surviving a long time in good health, so engineering risk management must harmonize with societal risk management in general. Engineering risk management should be rational and justifiable in the public interest.

In developed society safety concerns every person – is it safe enough to walk alone at night? The popular notion of risk is very different -- fear and dread. This might not normally matter much, but the difference can be extremely important. When the population in L'Aquila, Italy in 2009 suffered a disastrous earthquake that killed some 300 persons, there was anger and disappointment directed at the six scientists and civil protection officials who just a week prior had sensibly recommended against evacuation. In 2012 a local court convicted them of manslaughter and sentenced them to jail and payment of compensation [1]. Such misunderstandings of risk and the limits of our professional capacity to predict future events must be avoided. Communication about risks to non-specialists should and can be improved, e.g., by following a specified standard protocol as has just been proposed [2]. Meanwhile, we serve the public best by dispassionate risk assessment.

The rational imperative of professional risk management is to quantify risk and risk acceptability.

2 ALARA

Widely cited in risk regulation is the so-called *As Low As Reasonably Achievable or Possible/Practicable (ALARA or ALARP) principle.* Risks are classified by estimate or convention as either negligible, tolerable or non-acceptable. What is “reasonably” possible, practicable or achievable depends on who and when, and may well be decided by the feelings of a few people sitting around a table, as if ‘possible’ meant the same as ‘practicable’. If risks are deemed negligible (sometimes *de minimis*) they need no regulation. Otherwise risks are considered with regards to how efficiently they may be reduced. According to the ALARA principle these risks shall be reduced until the costs associated with further reductions become disproportionate to the risk reductions and the risks are called ‘tolerable’.

Moreover, much risk regulation also exhibits *risk aversion*. A risk-averse attitude implies that the loss of many lives in individual accidents is less important that the loss of just as many lives in one single accident. Risk aversion is clearly problematic as it does not provide equity in the societal regulation of risk [3, 4].

The scientific study of risks is well advanced. We can calculate the probability of any set of events that is worth studying, using available measured data. There is a problem: uncertainty – data and hence risks are never certain. However, Bayesian processing of data allows us to assign probabilities in a transparent manner, incorporating uncertainty and supporting decisions while satisfying the demands of objectivity and accountability. Thus, quantifying a particular risk is not the problem.

Rather, the main problem is twofold: (1) assessing the *disutility* (for the want of a better word) of sets of multi-dimensional outcomes (loss of life, health, assets, production . . .) and (2) choosing a standard of what their associated risks are worth, whether tolerable, acceptable or optimal.

Risk is intrinsic to life itself. Any activity that we undertake to secure a benefit has some associated risk that varies with context and can be changed, but this changes the net benefit and leads to a problem of prioritization: (3) How shall limited resources be allocated for life-saving purposes for the collective benefit of society? (4) It is important to ensure transparency of the decision-making process and (5) maintain respect for societal values. The LQI paradigm described below addresses these five issues. It is also compatible with the ALARA convention.

3 FUNDAMENTAL PRINCIPLES OF RATIONAL RISK MANAGEMENT

Nathwani et al. [5] presented four principles for managing risks to the public:

Accountability: Decisions for the public in regards to health and safety must be open, quantified, defensible, consistent and apply across the complete range of hazards to life;

Benefit: Risks shall be managed to maximize the total expected net benefit to society;

Measure: The measure of health and safety benefit is the expectancy of life in good health; and

Kaldor-Hicks Compensation: A policy is to be judged socially beneficial if the gainers receive enough benefits that they can compensate the losers fully and still have some net gain left over [6].

These principles are fundamental and explicitly satisfied in the application of the LQI paradigm.

4 THE LQI RATIONALE

The control of risk takes resources and thus presents a problem in resource allocation, an issue of broad societal importance. How much life safety can we afford from a societal perspective, what is the societal capacity to commit resources to safety? Phrased in this way, the “safe enough?” question becomes one of *sustainable resource allocation*. It is also important for communication between administration, industry and the public on how priorities are set in sharing common resources for the purpose of risk management. Professional engineering ethics in this context demands that risks and costs be balanced transparently and justifiably.

The governing principle in health economics for supporting decisions on health and life safety management is the *marginal life saving cost (MLS) principle*, see e.g. [4, 7]. The basic idea behind this principle is that investments into activities that affect health and life safety must be pursued until the costs associated with saving one more life year in good health exceeds a certain amount, the *marginal life savings cost limit*. The assessment of this amount has been subject to some scientific debate and various proposals, with significant variability in the amounts and philosophical basis that have been suggested in the literature. We suggest that the LQI provides the best way to satisfy the quality requirements of risk assessment because of its derivation and accurate calibration.

In conjunction with the marginal life saving cost principle the LQI has found application into a wide range of practical contexts in both public and industrial health and life safety management [8, 9, 10]. Presently this framework is being implemented in the new edition of ISO 2394 “General Principles on Reliability of Structures” and will thus form the fundamental rationale on how and how much societies shall invest into structures for what concerns risk reduction with respect to, e.g., natural disasters, safety against terrorist attacks, industrial disasters, and effects of climate change, safety of nuclear power, offshore and marine activities.

5 THE LQI FORMULATION

The gross national product per person (GNP) and the life expectancy at birth are aggregate descriptors of what one may loosely call the total average quality of life per person and use as utility function. The utility of wealth production is a positive monotonic function $h(g)$ of g, the GNP per person while the time to enjoy it can be taken as a positive monotonic function $f(e)$ of the expectancy at birth, e, of life in good health. Each enhances the other, so the appropriate measure is a product of the two. Averaged over society, the utility per person can be written as the life product $f(e)h(g)$.

Lind et al. [11] describe how separation of the variables shows that $f(.)$ and $g(.)$ should be powers of e and g respectively, leading to the life product index format $L = g^b e^c$ where b and c are positive constants. Since the utility is invariant under a monotonic transformation, this expression can be simplified to $L = g^a e$.

Further, it is observed that people produce wealth by assigning some of their life to the task of work. People’s choice of how much of their life they give to work thus shows how much life-value they attribute to the GDP per person.

The societal capacity to commit resources to risk reduction is derived from the LQI by setting the first variation of L equal to zero: $dL/L=adg/g+de/e$. Any project or regulation that produces small changes dg and de to g and e respectively, contributes positively (negatively) to the Life Quality Index utility if and only if de/dg is greater (less) than $S=ae/g$. S is a statistical time series that represents the societal capacity to commit resources sustainably. In risk assessment S is a yardstick for assessing life risks, applied just like the “societal value of a statistical life“ or the “societal willingness to pay“ found in the literature; both have shortcomings. We propose an alternative terminology, based on the fact that S is the limit between interventions that are beneficial and those that consume too many resources for the benefit they deliver. S is called the *limit of benefit* to risk reduction.

R. Rackwitz has given a lucid argument for optimization based on the LQI when there is risk to life, deriving from principles of human rights and equality that are found in all modern, democratic constitutions and the 1948 United Nations’ Universal Declaration of Human Rights. Rackwitz also illustrated several applications in the assessment of structural safety, proposing a social benefit rate for public interventions close to the long term growth rate of the GDP (around 2% for developed countries). Correspondingly, the interest rate used in evaluating projected time sequences of cash flow and risk flow should be slightly smaller. Further, Rackwitz concluded broadly that optimal structures are almost always also acceptable, but that just acceptable structures are almost always suboptimal [12].

The exponent *a* reflects the relative value of duration of life and economic benefit. There have been several calibrations of *a* from observed human preference. Pandey and Nathwani [13] provided a rigorous approach to this calibration, deriving the exponent parameter from the economics of human welfare [6]. Using a Cobb-Douglas formulation of GDP they derived *a* as $a=wb^{-1}(1-w)^{-1}$, where b is the Cobb-Douglas labour exponent [13]. With this formulation, using economic data for each of 27 developed OECD countries over the period 1976-2004, Nathwani et al. [8] found *a* to be practically constant, established the LQI in the form $L=eg^{0.2}$ and the limit of benefit as $5e/g$.

Lind et al. [11] showed that parameter *a* in practice need not be very precise. They considered a wide selection of 26 implemented risk reducing regulations in the USA analyzed by Morrall [14]. The cost to prevent [i.e., postpone] a death ranged from $100,000 to $132 million; the expected number of lives saved ranged from 0.06 to 1850 per year, and the annual cost ranged from 840,000 to $8.9 billion. 14 of the 26 regulations were found to have an expected benefit above the limit, i.e. were cost-effective, with $a = 1/6$; the rest were not. The same result would be obtained with any value of *a* between 0.102 and 0.25, in particular the preferred value $a = 0.2$. This standard value is now widely used; it should be generally applicable for developed countries for a long time in the future.

Thomas and Stupples [15] developed the LQI approach further, introducing the J-value of a risk-mitigation pair, a dimensionless ratio of cost per QALY to $1/S$. A series of more than twenty publications by P. Thomas and his collaborators describe multiple applications to a broad range of life- health- and environmental mitigation, e.g., [16].

6 APPLICATIONS

The applications of the LQI are of two kinds. Conventionally, such social indicators are used to rank countries or other social groupings. More important, the LQI implies a relative valuation of longevity and the production of goods, services and capital. In applications it is generally convenient to normalize *e* and *g* with respect to a country, date or currency, etc.

The dimensionless $L = EG^{0.2}$, may be considered the standard or *canonical form of the LQI*, in which $E = e/e^*$ and $G = g/g^*$ respectively denote values of *e* and *g* normalized with respect to specified constant reference values e^* and g^* respectively.

More than 200 publications apply the LQI or have developed it further. With a few exceptions the applications address practical problems of acceptable risk in various areas of technology or public health.

The MLS-LQI paradigm thus provides the basis for decisions involving all health and life safety investments nationally and even globally [17] if calibrated accordingly. This framework, in contrast to much present practice, accounts for rational societal preferences for investments into health and life safety improvements and thus greatly enhances sustainable societal development.

Safety or health provisions taken at present have economic and life-saving consequences that extend into the future, and so it is in general necessary to take discounting into account. For details see the expositions by Faber et al. [7, 17].

7 CONCLUSIONS

- It is imperative that risks to the public be managed rationally and dispassionately in the exclusive interest of the public. This entails that resources committed to risk mitigation be distributed rationally.
- The overriding goal in risk regulation is to preserve life in good health and resources.
- Engineers and other professionals who manage these risks are subject to professional ethics. This requires the risks to be analyzed scientifically and quantified.
- The measure of value in life risk is the expected duration of life in good health.
- The marginal life saving cost (MLS) principle requires that risk reduction measures be quantified and that the effective measures be preferred to ineffective ones.
- The Life Quality Index (LQI) reflects the compound societal valuation of disposable time and economic activity. Maximizing the contribution of a life risk reduction to the LQI is a reliable objective of regulation to reduce risk.
- The relative reduction of a risk to life in good health by x% is justified if the cost is less than 5x% of the GDP per capita in a developed country.
- Many examples in the literature and summarized in the Bibliography [10] illustrate the practical application of the MLS-LQI paradigm.

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