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## Life quality index for the estimation of societal willingness-to-pay for safety

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### Abstract

The engineering and management of human safety is an important societal objective that includes extensive efforts by governments, both legislative and administrative, to enhance the health and safety of the public. Although the achievement of safety goals depend primarily on individuals and organizations responsible for safety, much support is drawn from expertise in diverse scientific and engineering disciplines. The activities range from structural safety (dams, tunnels, bridges to tall buildings) to safe operation of hazardous industrial installations (energy generation facilities, LNG terminals, petrochemical plants) to transportation systems (airline, rail, car safety) to technologies designed to minimize adverse impacts on the environment. All these activities are crucially concerned with *risk*: with the likelihood and the probable effects of various measures on life and health. We have developed a unified rationale and a clear basis for effective strategic management of risk across diverse sectors. Safety is an important objective in society but it is not the only one. The allocation of society's resources devoted to safety must be continually appraised in light of competing needs, because there is a limit on the resources that can be expended to extend life. The paper presents the Life Quality Index (LQI) as a tool for the assessment of risk reduction initiatives that would support the public interest and enhance safety and quality of life. The paper provides an intuitive reformulation of the LQI as equivalent to a valid utility function that is consistent with the principles of rational decision analysis. The LQI is further refined to consider the issues of discounting of life years, competing background risks, and population age and mortality distribution. The LQI is applied to quantify the societal willingness-to-pay, which is an acceptable level of public expenditure in exchange for a reduction in the risk of death that results in improved life-quality.

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## 1. Introduction

Risks can always be reduced but at some cost. However, demands for absolute safety, implying zero risk, can do more harm than good. If the costs of risk reduction are disproportionate to the benefits derived, then it diverts societal resources away from critical areas such as health care, education and social services that also enhance the quality of life. As aptly noted by Henry David Thoreau (1852):

the cost of a thing is the amount of what I will call life which is required to be exchanged for it, immediately or in the long run.

The need to strike a balance between the benefits of improved safety (i.e. life extension), risk (potential for loss of life) and cost of risk reduction (i.e. enhancement of quality of life) is compelling. The balancing of impacts on the quality of life and health against economic costs of risk reduction, although controversial, is an essential professional obligation. Our ability to “save lives” is finite and limited by our capacity to create wealth. Thus, the central problem in managing risk, in effect, translates into our ability to allocate a scarce resource wisely.

Our work has been partly motivated by developments in Canada in the early 1990s and, in particular, the recommendation of the Government of Canada’s Regulatory Policy which requires comprehensive social and economic impact analysis for setting regulatory standards [1]. The goals of the policy are to ensure that the benefits of regulatory interventions must clearly outweigh the costs to Canadians. This is as true for policies that relate to safety and risk reduction initiatives as they do for other areas of concern.

When faced with risk, we are attempting to answer, intuitively, three related questions: (i) Is it safe? (ii) Is it a big and important risk? and if so, (iii) At what cost and level of effort would a life-saving proposition be worthwhile to reduce risk? In this context, we have proposed the use of the Life Quality Index (LQI), described elsewhere [2], as a tool for assessing the rationale and effectiveness of decisions affecting the management of risk to life, health and safety. Good risk management not only requires a strategy for selecting risks (separating the important and consequential from the trivial risks), but also a consistent framework of reasoning as described below.

The Life Quality Index is a social indicator derived to reflect the expected length of life in good health and the quality of life enhanced by wealth. It rests on the premise that helping individuals achieve a long life in good health is a fundamental value and therefore, it is ethical and reasonable to pursue this as a primary objective for risk management.

The Life Quality Index gives an account of how well that objective is being met. Risk control and mitigation initiatives that do not increase the chance of longer life in good health detract from that objective and their justification remains tenuous. The LQI can help us choose appropriate strategies for managing risk. Applications of LQI to safety of structures and other technical facilities have been illustrated in [3–5].

The LQI combines societal wealth and longevity in the following function form:  $LQI = G^w e^{1-w}$ , where  $G$  is the real gross domestic product (\$/year/person),  $e$  is the life expectancy at birth, and  $w$  is a constant that reflects the proportion of time spent in producing  $G$ . In the original derivation, LQI was presented as a mathematical construct [2], which requires additional explanation and justification. It has been observed by researchers and critiques that there is no clear expla-

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