2 Social Indicators for Managing Risk

Abstract Assessment and quantified analysis of risk are necessary to support and improve the quality of risk management decisions. We propose the use of social indicators for managing risk. There are several compound social indicators that quantify some aspects of human welfare, reflecting how well a society empowers people to lead the life they desire. The indicators also allow a comparison amongst nations and monitoring of the performance of a nation over time. The Life Quality Index (LQI), developed in this book, is the basis for the life quality method, primarily meant as a tool for managing risk. The LQI provides practical guidance for justification of expenditures on life safety and allows decision-makers a defendable basis for allocation of resources amongst competing claims.

2.1 Social Indicators

Social indicators are statistics that quantify some aspect of life in a society or group of individuals, conveying significant information about the quality of life. A social indicator can be accumulated into a time series. The gross domestic product (GDP) G per person and the life expectancy (LE) E are well-known examples of social indicators. They have been in use for half a century to express the wealth and health of a nation in numbers, and they are reliably measured.

In Article 55 of the Charter of the United Nations, an expert group was charged with the duty (UN 1954)

> to prepare a report on the most satisfactory methods of defining and measuring standards of living and changes therein in the various countries, having regard to the possibility of international comparisons.

The group identified the development of quantitative indicators of human welfare as being essential to the establishment of objective standards which could then be applied to analysis and comparison of the "level of living" in different countries. Expectation of life at birth, infant mortality rate, and the annual death rates were subsequently chosen (UN 1961) to serve as valid indicators of level of living in relation to health. The efforts toward the development of quantitative indicators for measurement of social well-being that began in the 1950s (UN 1954, 1961) is still ongoing and documented comprehensively in the Human Development Reports published by the UN annually.

The Life Quality Index (LQI) $L = E^K G$ is the compound social indicator we propose for

1. Assessing the rationale and effectiveness of public decisions affecting the management of risk to life, health and safety
2. Reflecting how well a nation, in its overall management of risk, meets the broad goals stated

A social indicator should pass some important tests (Lind 1992). The indicator should be:

- Objective
- Reliable
- Criterion-related
- Universally applicable
- Valid

The concept of what constitutes a good quality of life has been debated widely since it concerns basic human values and subjective responses. We cannot claim in the LQI to have the ultimate measure of the good life for all. However, there is an instructive analogy in the simple phenomenon of room temperature. If the thermometer reads 20 degrees Celsius, some will find it cold, others warm. Some will argue that temperature varies with location and orientation within the room, and that the thermometer reading is meaningless, humidity is important, and so on. But in spite of its many limitations, the thermometer reading is nevertheless useful because it is objective, reliable, relevant, and has validity. It says something about the state of the room air; what it says can be trusted, and can be used as a rough predictor of comfort for most people on the average, and the resolution of measurement is appropriate for the choice at hand (deciding whether to turn up the heat, to open the window, turn on the air conditioner, or do nothing). All indicators are imperfect but may nevertheless be useful.

2.1.1 The Human Development Index

A social indicator must, with some validity, reveal changes in the well-being that is a direct and valid statistical measure of the fundamental concern and it must be capable of monitoring the level and changes over time. Duration of life (expressed by life expectancy) and intensity through access to income (expressed by the GDP per person) are the two essential dimensions of life quality.

Further refinements and improvements to these basic dimensions are possible. However, we judge that an effective tool that can reliably measure the changes in national and international trends will provide better insights than a more comprehensive, perhaps theoretically elegant but less reliable indicator to which data do not exist. A social indicator is developed for a purpose, and it can serve well as an instrument of policy judged compatible with that purpose.

Human development (UNDP 1990) is about enlarging people's choices under the constraint of limited resources to ensure people are able to:

1. Lead a long and healthy life
2. Access resources for a decent standard of living
3. Have the knowledge necessary for cultural enrichment

Accordingly, the UN Human Development Index (HDI) compounds three basic indicators serving to reflect human development that include:

1. Life expectancy at birth
2. Real GDP per person, a measure of command over resources needed for a decent living
3. Education, incorporating adult literacy rates

The HDI is a simple average of a life expectancy index (0 to 1), an educational attainment index (0 to 1) and an adjusted GDP per capita index (0 to 1). Thus, the HDI is a normalized index that varies between zero and unity. Over the years the composition of the HDI has changed several times, reflecting changes in the implied meaning of "human development." Details of the construction of the HDI can be found in the UN Human Development Reports (UNDP 1990ff). As a simple normalized average, the HDI is at best only suited for the ranking of nations.

Compound social indicators can be viewed as refinements of the primary indicators and can be tailored to serve different policy objectives. By incorporating literacy, the Human Development Index seeks to reflect education as an aspect of culture that is important for the enjoyment of life and wealth, and particularly important for the kind of development that the UNDP seeks to promote. However, literacy is also difficult to define and measure (Lind 1992, 1993). We do not include literacy as a component of the LQI because our primary focus is on developing an indicator for the purpose of assessing life safety, health, and environmental policies, and providing guidance to decision-makers on allocation of resources.

2.2 The Life Quality Index

The Life Quality Index is developed for use in managing risk to public life safety. It is a function of two reliable and important measures of social development, *E*, and *G*. The quality of life or the total enjoyment of life may be thought of as having two dimensions: *intensity* and *duration*. The value, utility or enjoyment derived from wealth production, *G*, is the intensity. The duration refers to the (leisure or discretionary) time, *t,* available to a person outside the occupational activities that produce *G*.

The GDP per person is a measure of the wealth produced in the society. Part of this becomes invested capital, enhancing productivity for future consumption. Another part is collected as taxes and spent on behalf of the citizens to enhance the common welfare that includes the allocation to public health care or enhance the quality of life. The remainder is available to be spent by the households on whatever adds to their enjoyment of life.

The LQI also incorporates a parameter, *K*, derived from the economics of human welfare. *K* is determined to reflect the value that society places on a reduction of mortality in terms of economic expenditure and a measure of the health-related quality of life. In the LQI, life expectancy is the measure of life safety (quality-adjusted for health state if and when this is deemed an important factor) while the real GDP per person (adjusted, if necessary, for purchasing-power parity) is a surrogate measure of the wealth-related aspect of the quality of life.

The Life Quality Index can be viewed as either:

1. A measure of the GDP per person but with the duration and health-related quality of life factored in; or, conversely
2. The expected duration of life adjusted for the level of wealth and health to reflect the quality of life

The LQI is thus a function of mortality and economic productivity, reflecting a relative valuation of longevity with goods and services. The derivation of the LQI is described in Appendix A.

An important idea is that *available time and wealth are exchangeable*. One may freely substitute for the other over a lifetime to increase the total enjoyment of life. We expend a part of our lives working in order to create the income or wealth. We then expend a part of that wealth to extend our expectation of life in good health.

The first process is captured well under the measure of economic activity (the sum total of goods and services produced in an economy). The second process reflects safety and health and the trade-offs we make to enhance the duration or expectation of life. In both of these processes, we make a choice how to expend one kind of resource to obtain the other kind of good. Our choice broadly reflects the value we place on life in good health and thus we can deduce from these considerations the criteria for the economic value of safety provisions, health care, or any intervention designed to improve the quality of life.

Of course, there are other aspects of the enjoyment of life that are not captured by such simple representations, but they would be harder to draw into account. The economic equivalent of a lifetime in good health, however, is implied in *any* social indicator that has wealth and life expectancy as components. The present model may be simple, but we believe that it is a fair and reasonable representation of the aggregate value received by the individuals.

Table 2.1 Life Quality Index $L = E^5G$ in 2005 (normalized with respect to Canada LQI = 100) and the Human Development Index 2005 for selected countries

	LQI	HDI		LQI	HDI
Luxembourg	160	0.944	Germany	82	0.935
Norway	120	0.968	New Zealand	73	0.943
Iceland	118	0.968	Greece	64	0.926
Finland	112	0.952	Portugal	52	0.897
United States	108	0.951	Hungary	33	0.874
Japan	106	0.953	Chile	32	0.867
Ireland	102	0.959	Poland	30	0.87
Canada	100	0.961	Seychelles	29	0.843
Australia	99	0.962	Romania	16	0.813
Sweden	99	0.956	Brazil	14	0.8
Austria	95	0.948	China	12	0.777
United Kingdom	92	0.946	Philippines	8.3	0.771
Netherlands	91	0.953	Bangladesh	1.8	0.547
France	91	0.952	Chad	0.41	0.388
Denmark	87	0.949	Burkina Faso	0.39	0.37
Italy	86	0.941	Mozambique	0.16	0.384
Spain	82	0.949	Sierra Leone	0.09	0.336

When the purpose is to rank nations (or federations, provinces, or other economies or social groupings) the exponent K in the LQI must be the same for all countries or groupings. It is worth noting that there is considerable uncertainty in the LQI, primarily because of inaccurate and varying census practices, but also in the economic data. It is estimated that differences in LQI less than 5% can hardly be considered significant. Using $K =$

5.0 (see calibration for OECD 1976–2004 in Appendix C) gives $L = E^5G$. In Table 2.1, we have tabulated the 2005 values of this LQI for 34 nations, normalized by the value for Canada.

It is of note to compare the LQI and the HDI globally. A linearized social indicator can be formed as the logarithm of *L*:

$$\log L = K \log E + \log G. \qquad [2.1]$$

The Human Development Index is a function of *E*, *G,* and literacy. Insofar as it incorporates log *G*, and considering that log *E* over the range encountered in practice is almost linear in *E*, the HDI bears some resemblance to Eq. 2.1. The HDI is plotted against the logarithm of the LQI in Fig. 2.1, showing the nearly linear relation overall, particularly for the developed countries. There is a high correlation between the LQI and the HDI: high human development follows high overall life quality.

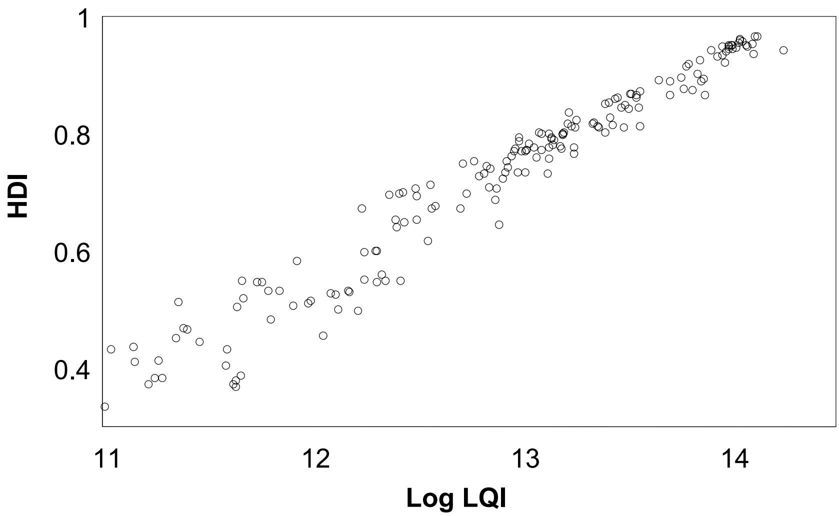

Fig. 2.1 Human Development Index vs. Life Quality Index for 173 countries in 2005 as reported by UNDP (http://hdrstats.undp.org/indicators/1.html)

With the value of *K* for OECD countries taken as 5.0 (Appendix C), Fig. 2.2 shows a contour plot of the LQI function *L*(*E,G*).

It is sometimes convenient to use a logarithmic plot. Curves of constant LQI are then straight lines with slope -1:*K*.

Fig. 2.2 shows, not surprisingly, a high correlation between the LQI's two components *E* and *G*. It is sometimes argued that such correlation weakens or invalidates an indicator. This argument is a fallacy. For example, consider the indicator $V = \pi r^2 h$ for the volume of cylindrical objects such as tin cans or barrels; this indicator is exact – even for wires and disks – the fact that for most cylindrical objects r and h are of similar magnitude, and thus correlated, is irrelevant.

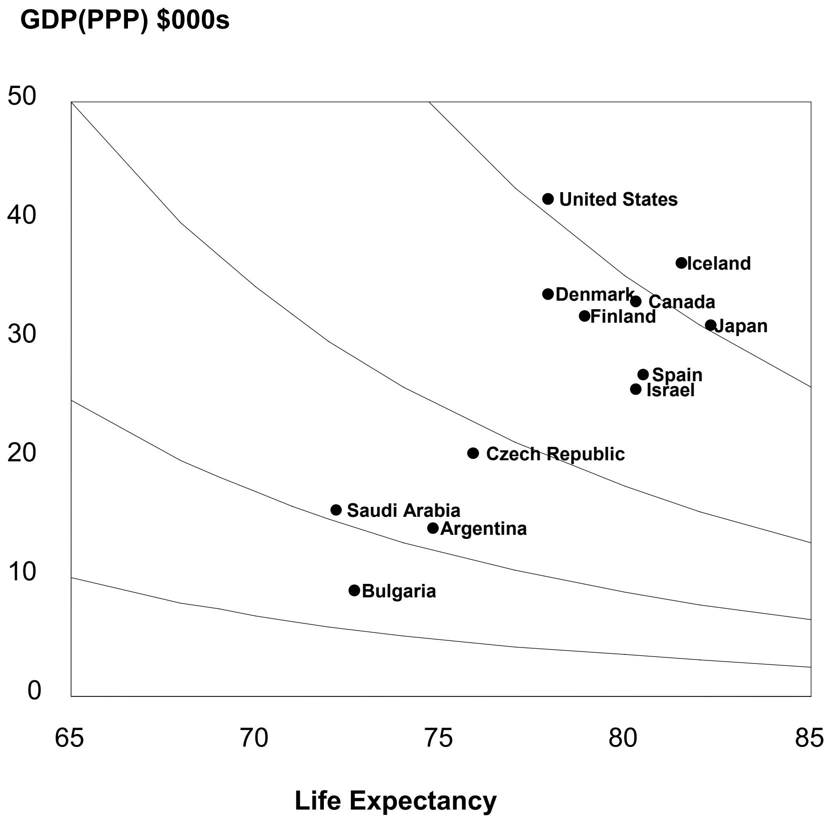

Fig. 2.2 Contours of the Life Quality Index and a few country-specific values (2005). (http://hdrstats.undp.org/buildtables/rc_report.cfm)

2.3 Rationale for Use of Life Expectancy and GDP

The rationale for the use of social indicators such as life expectancy and real GDP per person for the purpose of managing life safety risks derives from a consideration of the variables that are important in describing the process of human development.

Use of life expectancy as a principal indicator of human development rests on three considerations: the intrinsic value of longevity, its value in helping people pursue various goals and its association with other characteristics such as good health and nutrition.

For the purpose of making practical decisions, the measure to describe safety and improvements in safety must also be concise, relevant and constructed on the basis of available and reliable statistics. In addition, the universal application of such a measure is enhanced if it is suitable for comparisons both within and among countries. Life expectancy, based on mortality statistics of nations, "is a summary measure of the total mortality experience of a population which is little affected by any pattern of the age and sex pyramid, by the pattern of the birth rate or the history of migration" (WHO 1977).

Preston *et al.* (1972) state the case for life expectancy as a basic social indicator as follows:

> The circumstances under which men die are closely related to the conditions under which they live. The extent of violence, poverty, passivity, and ignorance in a population is reflected in the statistics of its causes and ages of death. Vigorous attempts to delay death are so universal that accurate mortality statistics provide a reliable touchstone of a population's level of social organization and technological sophistication. Not only do mortality conditions mirror those in the general society, but they also have their own important social implications....

Mortality improvements result from an intricate interplay of advances in income, nutrition, education, sanitation, and medicine, with the mix varying over age, period, cohort, place, and disease (Riley 2001). Trends in life expectancy gains provide critical information about the performance of a county against the global achievement or a judgment of its performance over time. World life expectancy more than doubled over the past two centuries, from roughly 25 years to about 65 for men and 70 for women (Riley 2001). For example, female life expectancy in the record-holding country has risen for 160 years at a steady pace of almost 3 months per year. In 1840 Swedish women lived on average a little more than 45 years; among nations today, the longest expectation of life – almost 85 years – is enjoyed by Japanese women. The four-decade increase in life expectancy in 16 decades is so extraordinarily linear [$r^2 = 0.992$] that it can be considered the most remarkable regularity of mass endeavor ever observed (Oeppen and Vaupel 2002).

The transformation of the duration of life has greatly enhanced the quantity and quality of people's lives, fueled enormous increases in economic output and in population size including the number of elderly (Fogel and Costa 1997, Martin and Preston 1994). The linear climb of record life expectancy suggests that reductions in mortality are not a disconnected sequence of unrepeatable revolutions but a regular stream of continuing progress (Lee and Carter 1992, Tuljapurkar *et al.* 2000) and the gap between the global record and the national level is a clear measure of how much better a nation might do given existing knowledge and practice.

The average total risk of death in a unit of time in a particular group or society at a particular time equals the *mortality*, i.e., the probability of death in a unit of time. The dimension of mortality is the reciprocal of time. It is small in developed parts of the world today. For example, the age-specific death rate for persons in the 30–34 age group is 0.00118 per year for Canada in 2005. The death rate is an observed statistic. In poorer countries, the mortality is higher, often by a factor of two across all age groups.

The probability of death varies between individuals, according to sex, age, present health status, occupation, residence location, wealth, social status, genetic factors, and so on. In less-developed countries infant mortality can be 100 times higher than in developed countries (Sect. 1.5). The annual risk of death from all causes rises exponentially after about age 45.

Discussion of risk mitigation in terms of the expected number of "lives saved" is common, but it is both imprecise and rough since predicting the death of particular individuals and precise timing is not possible. A life-saving intervention that prevents deaths among 5-year-olds has an impact higher, perhaps by an order of magnitude, than if it were applied to the 75 age group. Thus it is important to quantify the impacts on specific age groups to evaluate the effectiveness of interventions: the two can hardly be lumped into a single measure. In truth a life can only be extended (not "saved") and deaths can only be deferred. A rigorous statement would be "deaths deferred by N years" with a probability distribution $F_N(x)$. The group-specific change in mortality is the most expressive measure of changes, but it is difficult to interpret. Instead, the increase in life expectancy is both tractable and informative. In Chap. 3 and in Appendix D we show how the change in life expectancy is calculated from a change in mortality due to risk.

Regulation and risk reduction efforts in the control of technology have, as their primary focus, human life and health. Thus, a quantitative indicator of safety, such as *increase in life expectancy based on mortality statistics*, provides a reasonable test of the effectiveness of risk reduction efforts through regulation and control of technology.

Life expectancy, or the mean duration of life of a person of specified age and sex is an appropriate aggregate index of safety. Safety measures, policies, or programs do not usually save the lives of identified people but, if they reduce the number of deaths per unit of population time, then they increase the life expectancy in the group.

The interest of the individual member of society in regard to safety follows from this. It is simply that the person's expectation of life is determined by the general conditions of mortality present in the society. There are many advantages to using life expectancy (LE) as a surrogate measure for safety over other measures such as crude death rates. Life expectancy, which is an estimate of the average number of years of life left to each individual in a group, is calculated on the basis of observed age-specific mortality rates at any specific time for the group. It is therefore not influenced by the age pyramid of the population, allows a direct comparison of trends over time and among countries, and is relatively well understood.

> Life expectancy has the advantage of being measured in years of life – a concrete measurement that is meaningful in terms of individual experience …. Life expectancy also has certain characteristics that make it useful in the determination of the overall quality of life of a population. This is so because life expectancy depends not only, or even principally, on the quality of medical care available, but also on the standard of living and the quality of services received by the population ... (Wilkins 1980)

We make an important assumption that people generally want to live long and in good health. People are at some liberty to diminish their health or shorten their life but our focus is on how best to manage risk for the group. The basis for allocation of society's scarce resources for safety purposes can then be considered rational if it produces the greatest increase in life expectancy. This yields the greatest benefit to its members. The benefit of a safety measure can be expressed (in person-years) as the increase in life expectancy. This benefit, when weighed against the cost of the measure, provides an effective basis for managing the risk to society.

Life expectancy is in effect a broad social indicator encompassing a number of fundamental aspects of well-being that are basic to the overall quality of life experienced by a population (Wilkins 1980, Black *et al.* 2005, Heymann *et al.* 2006). When the requirement is for a broad quantitative measure that provides legitimate comparisons in time or location, then life expectancy calculated from life tables provides a firm basis for assessment. Reliable death rate data have been available for all countries for a major part of this century. Risk of death is adequately represented by mortality tables and then converted to loss of life expectancy.

2.4 Quality Adjustment of Life Expectancy: The Real GDP per Capita

We consider the quality of life to have two aspects, *health-related* and *wealth-related*. Depending on the context, either or both aspects may be important for the analysis and must be drawn into account.

The proposed safety objective is to maximize the total net benefit in terms of *quality-adjusted life years.* As a first (and occasionally sufficient) approximation in the risk management process, the evaluations can be performed using simply life years' expectancy as the common currency. Health-related quality-adjustment of the life years (QALYs) provides a refinement that is often necessary. An example is when the risk in question is not merely a question of survival or death, but also of a high incidence of permanent injury as from a traffic accident or long-term illness from exposure to pollution.

Wealth and health are linked, and our capacity to create wealth is also determined in part by the health status of the population. The fact is that wealth makes for health and longevity, while lack of wealth makes for sickness and short life (Kitigawa and Hauser 1973, Thompson 1975, Wilkins 1980, Hadley and Osei 1982, Wilkins and Adams 1983, Wilkins 1986, Wilkins *et al.* 1989, Black *et al.* 2005, Heymann *et al.* 2006). For this reason, it must be recognized that large expenditures of money, if expended on ineffective risk reduction *cost life* (Keeney 1994). Indeed, though wealth is not identical with health, it is so important a determinant of health that a society's capacity to improve the health status of the population can continue only if it has the wealth to do so.

National income (GDP per capita), is a summary measure of economic well-being. GDP per capita as a measure of individual human welfare has come under criticism because it can conceal widespread human deprivation if the distribution of income is skewed. Income, as a way of measuring welfare and well-being, was first developed by Pigou in the 1920s who described economic welfare as the measurable part of human welfare – the part that could be brought into a relationship with the "measuring rod of money." If the distribution of income is not grossly unequal, or when social programs for health and welfare provide adequate compensation, then the wealth-related real GDP per capita, corrected for purchasing power parity (PPP) is a reasonable surrogate measure of life quality.

2.5 The LQI as a Tool for Managing Risk

The use of QALYs as a measure of substantial value to society has been advocated by many researchers of public policy, health and safety (Zeckhauser and Shepard 1976, Vaupel 1976, 1981, Graham and Vaupel 1981, Colvez *et al*. 1987, Lind *et al*. 1991, JCHS 1993). The Life Quality Index (Nathwani *et al.* 1997) may be thought of as refinement of monetary measures commonly used in cost–benefit analysis. It is used as an objective function to provide guidance to a decision-maker for managing risk.

The objective in managing risk is to ensure that significant risks are identified and appropriate actions are taken to minimize these risks to a reasonably low level. Engineered safety is determined on the basis of a balance between the cost effectiveness of risk control and the benefits arising from the mitigation of risk. For the net benefit to be positive, whether it accrues to the organization or society at large, the management of risk entails a process of priority setting because there are limits on available resources.

The life quality method provides a new approach to managing risk that goes beyond the traditional focus of economic loss mitigation into an arena of risk to life and health (Pandey *et al.* 2006). The LQI is an ordinal utility function that quantifies the utility of income derived over the expected lifetime of a representative individual in the society (Fig. 2.3). It aggregates the economic, demographic, and life-safety aspects of a society (Rackwitz 2002, 2003, Rackwitz *et al.* 2005).

Here we show how the societal capacity to commit resources for risk reduction in a sustainable manner can be derived from the LQI. We further present the LQI-based benefit–cost analysis methods and clarify the underlying concepts' computational procedures.

2.6 How to Make Decisions About Life Risks

When there is a choice to be made we need to judge the risks. There are two kinds of situations. The choice could be whether to take a risk, to proceed with an activity or a project that will yield expected benefits but involves risk. Conversely, the choice may be to reduce a risk about taking an opportunity to improve health or safety, but at a cost. We treat the two cases in the same way.

The options may also involve significant environmental and social impacts. Where it is possible to quantify such effects in monetary terms, the treatment of environmental and social impacts can be handled explicitly in the analysis. Often, the environmental and social impacts are only partly quantifiable and difficult to draw into account, so they have to be considered separately.

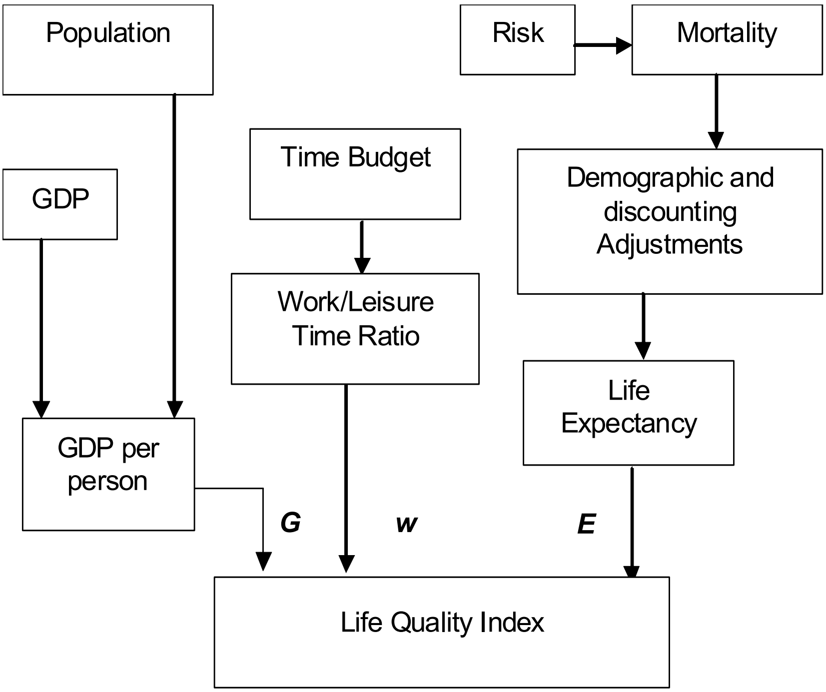

Fig. 2.3 Conceptual model of the components of the Life Quality Index

We present a framework for judging risk based on the Life Quality Index. The objective is to promote better allocation of scarce resources, both by reducing wasteful efforts on inefficient risk reduction and by supporting the implementation of efficient ones. The suggested format considers society's capacity to commit resources (SCCR), computed from a labor-demographic factor and the real gross domestic product, both nation-specific.

2.7 General Criterion of Acceptability

Any prospect (project, program, or regulation) that materially affects the public by risk and expenditure will have an impact on the relevant indicators. Thus, we derive acceptability by the requirement that the increment to the LQI, expressed as function of the variables affected, be positive.

Differentiation of $L = E^K G$ shows that a small change in the LQI due to an activity, a project, or a change in policy or regulation can be assessed as

$$dL/L = K\,dE/E + dG/G. \qquad [2.2]$$

In Eq. 2.2, dE is the change in life expectancy due to a change in the level of risk to the population, namely an increase in risk or a decrease in risk directly associated with the prospect, whereas dG may represent the monetary cost of implementing a regulation (dG negative) or the monetary benefits that arise from a project (dG positive) or activity. *The net benefit criterion* requires that dL be positive or

$$K\,dE/E + dG/G > 0. \qquad [2.3]$$

Note that the net benefit criterion is a function of dE and dG, which represent *changes* in expected risk to life and cost. The best option among several options is the one from which any change will reduce the LQI. This is in contrast to other criteria such as the ALARP or ALARA criterion (making risk "as low as reasonably practicable" or "achievable") which call for a comparison of risk to some fuzzy standard of practicality or feasibility. It is also in contrast to absolute probabilistic risk criteria such as "the probability of death shall not exceed 1/1,000,000 per year for the person most at risk."

Requiring that the first variation of the LQI be positive (Pandey *et al.* 2006) gives an optimality condition for a quantified risk encompassing life, limb, health, wealth, and income. The concept can be further extended to account for those quantifiable environmental impacts that can be mitigated by remedial actions (Ditlevsen and Friis-Hansen 2007).

2.8 Societal Capacity to Commit Resources

The central concept of this book is the societal capacity to commit resources (SCCR) to sustainable risk reduction, for which we use the symbol C. This capacity C is derived from the LQI and gives a direct and more convenient criterion (Pandey *et al.* 2006), an equivalent alternative to the LQI criterion in Eq. 2.3.

As shown in Appendix C, the LQI and the capacity C both vary considerably from country to country and vary over time. In recognition of this fact we write $L = L(i,t)$ and $C = C(i,t)$, where i is the country index and t is the year. However, it turns out that the ratio $D = K/E$ is more nearly constant over time for each country studied in Appendix C. Also, in applications the analysis is best carried out in local currency and using local interest rates. Therefore this approach is developed for practical use into a more nearly time-invariant format using the country-specific *labor-demographic factor* $D = D(i) = K/E$.

Following the LQI rationale (Pandey *et al.* 2006), a society's capacity to commit resources to reduce risk is not boundless, but reflects the empirical fact that the "average person's" ability to contribute effectively to wealth creation and well-being is influenced by exposure to multiple hazards. Any one, or any combination, of these hazards may eventually cause loss of life (years or days) in good health. Some of these hazards are *private*: It is largely up to the individual (by choice of lifestyle, etc.) to reduce the risk as much as desired. The remaining risks are *public*, in the sense that they are essentially controlled by legislation and public administration. It makes sense to maximize the person's life expectancy over the set of public options. Since this involves costs that must be paid for, you must subtract the time that the "average citizen" has to work to pay for public risk reductions. This time varies in time and varies from country to country, but it can be determined accurately from available national statistics. This is described below.

The derivation of the capacity C by the LQI rationale rests on three principles: (1) *the democratic principle* stating that public risks shall be managed equally with respect to all persons; (2) *the life measure principle* stating that all risks to life are measured by the expected loss of time in good health; and (3) *the time principle*, which states that time in good health lost and time spent in economic activity are marginally equivalent.

The capacity is derived directly from Eq. 2.3 by rewriting:

$$-dG/dE > KG/E = C. \qquad [2.4]$$

Thus, as described in detail by Pandey *et al.* (2006) and illustrated in Fig. 2.4, the SCCR C is a time series derived from six other time series of national statistics, viz., the gross domestic product per person, G; its contribution from labor (wages and salaries, etc.), G_w; Employment, M; the average number of hours worked per worker; the population P; and the expectancy of life in good health at birth, E. From these, five other national time series are calculated: the labor exponent, β; the work-time fraction, w; the LQI exponent, K; the labor-demographic factor $D = K/E$; and then the SCCR, $C = DG$.

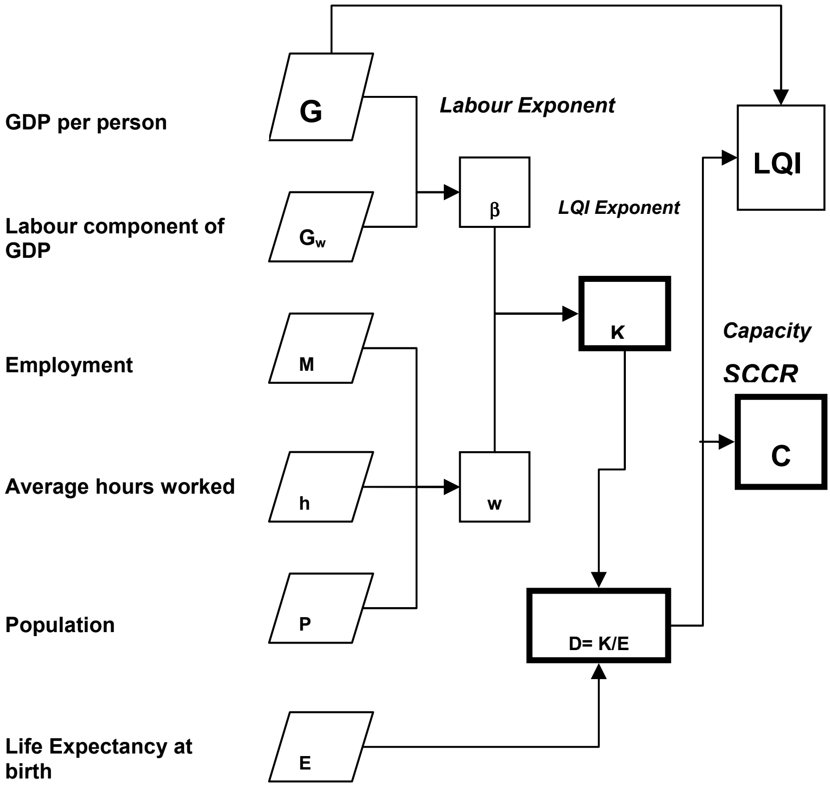

Fig. 2.4 Flow diagram of the calculations of LQI exponent *K*, the labor-demographic factor *D*, and the SCCR *C*

The calibration in Appendix C is based on statistical data for the period 1976–2004 for 27 OECD countries (OECD 2007). First, the work-time/total time population average *w* is determined from the population $P = P(i,t)$, the employment $M = M(i,t)$ and the average hours worked.

Next, the labor exponent β from the Cobb–Douglas production function $Y = AJ^{\alpha}W^{\beta}$ is determined. The preferred approach uses the return-to-scale condition $\alpha + \beta = 1$. The data for each country i, $i \in$ {Australia, . . ., USA}, then gives the values of $K = K(i,t)$.The value $K = 5.0$ is very close to the OECD average over the period 1976–2004. The trend is practically constant over the quarter-century, decreasing at a rate of 0.2% per year. The trend over the latest 10-year period, 1995–2004, decreases at the rate of about 2.5% per year. Projection of trend shows an average of $K = 5.00$ over the period from 1995 to 2015.

The labor-demographic factor $D(i,t)$ varies from 0.040 (Greece) to 0.086 (Germany), averaging 0.064. $D(i,t)$ is for each country i quite constant over time, with coefficients of variation averaging 5.6%. For decision-making practice in any of the OECD countries this means that the societal capacity can be determined as $C = DG$ quite accurately and should be known with sufficient confidence for risk management purposes. It is suggested to use the forecast value of $D(i,t)$ shown in Table C.4 in Appendix C together with the most recent forecast value of the GDP per person in local currency.

Just for illustration, suppose a life-saving intervention in Belgium is proposed for 2015. Assume that the real gross domestic product then equals G = 30,000 €. Table C.4 in Appendix C gives the factor $D(Belgium)$ = 0.075, so the SCCR equals $C = DG$ = 0.075(30,000 €) = 2,250 €. This amount is the maximum per person capacity for a prospect that is expected to deliver one year of life expectancy in good health. Most prospects in practice are considerably more involved to analyze, as illustrated in the following chapters.

2.9 Summary

Uncertainties and subjectivity of values will always be present when we have to make decisions about life safety under the constraint of limited resources. Still, our view is that the necessary quantitative social indicators are available for improving decision-making. The statistical data have sufficient universal applicability that they can be used for international comparisons and for monitoring the quality of decisions in practical contexts. The Life Quality Index reflects the economics of human welfare and is suited for this purpose. The Human Development Index, designed to reflect a broader concept of human well-being, is highly correlated with the LQI.

To judge whether a strategy for managing life safety risks is truly in the public interest requires an assessment of all the risks and benefits of all alternatives. The safety benefit is the gain in life expectancy, or life extension expected upon implementation. The associated costs must also be evaluated and drawn into account as impacts on the real gross domestic product per person. The LQI can be used directly to assess life-saving interventions, but a differential form, the societal capacity to commit resources, C, is more directly applicable. Simplest to apply in practice is the country-specific labor-demographic factor D. Applications are illustrated in the next chapter.

Ideally, with time and through public discourse, awareness of the costs of extending the expectancy and quality of life will increase. Informed debate and societal consensus can then form the basis for improvements to our risk management practices.

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