Special Issue Honouring Helias A. Udo de Haes: Broadening the Scope of LCA

The Integration of Economic and Social Aspects in Life Cycle Impact Assessment

Bo P. Weidema

2.-0 LCA consultants, Copenhagen, Denmark (bow@lca-net.com)

DOI: http://dx.doi.org/10.1065/lca2006.04.016

Abstract

Goal, Scope and Background. Although both cost-benefit analysis (CBA) and life cycle assessment (LCA) have developed from engineering practice, and have the same objective of a holistic ex-ante assessment of human activities, the techniques have until recently developed in relative isolation. This has resulted in a situation where much can be gained from an integration of the strong aspects of each technique. Such integration is now being prompted by the more widespread use of both CBA and LCA on the global arena, where also the issues of social responsibility are now in focus. Increasing availability of data on both biophysical and social impacts now allow the development of a truly holistic, quantitative environmental assessment technique that integrates economic, biophysical and social impact pathways in a structured and consistent way. The concept of impact pathways, linking biophysical and economic inventory results via midpoint impact indicators to final damage indicators, is well described in the LCA and CBA literature. Therefore, this paper places specific emphasis on how social aspects can be integrated in LCA.

Methods and Results. With a starting point in the conceptual structure and approach of life cycle impact assessment (LCIA), as developed by Helias Udo de Haes and the SETAC/UNEP Life Cycle Initiative, the paper identifies six damage categories under the general heading of human life and well-being. The paper proposes a comprehensive set of indicators, with units of measurement, and a first estimate of global normalisation values, based on incidence or prevalence data from statistical sources and severity scores from health state analogues. Examples are provided of impact chains linking social inventory indicators to impacts on both human well-being and productivity.

Recommendation and Perspective. It is suggested that human well-being measured in QALYs (Quality Adjusted Life Years) may provide an attractive single-score alternative to direct monetarisation.

Keywords: Areas of protection; child labour; cost-benefit analysis (CBA); human well-being; impact pathways; monetarisation; quality adjusted life years (QALY); single score; sustainability; well-being gap

1 Common Roots of CBA and LCA

Cost-benefit analysis (CBA) and life cycle assessment (LCA) share the objective to provide holistic, ex-ante assessments of human activities, and both techniques have developed from engineering practice. The origins of CBA is often ascribed to the U.S. Army Corps of Engineers, in response to the 1936 Flood Control Act, which contained the wording, "the Federal Government should improve or participate in the improvement of navigable waters or their tributaries, including watersheds thereof, for flood-control purposes if the benefits to whomsoever they may accrue are in excess of the estimated costs." The ad hoc methods developed by the U.S. Army Corps of Engineers were discovered by academic economists in the 1950's and improved into a rigorous system for the economic analysis of public investments (Watkins, s.a.). Early CBA was mainly concerned with the direct and indirect economic costs and benefits to different actors, and less with environmental externalities. It was not until the 1960's and early 1970's, with the background of rising environmental awareness, that the valuation of nature became an important issue in CBA (Krutilla 1967). At approximately the same time, the LCA technique was developed from energy analysis.

In spite of this common objective and the common roots, CBA and LCA have developed in relative isolation, independently adopting important contributions from economic science. The CBA technique has been improved by adopting advances in welfare theory and choice modelling (Bennet & Blamey 2001, Hanley et al. 2001), while the LCA technique has been adopting aspects of market theory (Weidema 2003) and the use of input-output matrices (Heijungs & Suh 2002).

This has resulted in a situation where much can be gained from an integration of the strong features of each technique. Such integration is now being prompted by the more widespread use of both CBA and LCA on the global arena, where also the issues of social responsibility are now in focus. Thus, it is time to sketch a common frame of understanding of environmental externalities. Such a common frame is provided by the conceptual structure of life cycle impact assessment (LCIA) developed by SETAC (Udo de Haes & Lindeijer 2002) and the SETAC/UNEP Life Cycle Initiative (Jolliet et al. 2004).

2 The SETAC/UNEP LCIA Framework

The framework of the SETAC/UNEP LCIA Definition study (Jolliet et al. 2004) was developed from the conceptual structure suggested in Udo de Haes & Lindeijer (2002), which resulted from a broad discussion in the SETAC Working Group on Life Cycle Impact Assessment, under the leadership of Helias Udo de Haes, as documented in 'the Areas of Protection debate' by Klöpffer (2002).

Table 1: Areas of protection in the SETAC/UNEP LCIA framework (slightly modified from Jolliet et al. 2004)

Objects considered: Endpoint value	Humans	Biotic environment (natural and man-made)	Abiotic environment (natural and man-made)
Intrinsic	Human health (and well-being)	Biodiversity (and well-being of animals in human care)	Natural and cultural heritage
Instrumental	Human productivity	Ecosystem productivity	Natural resources and man-made capital

The advantage of the SETAC/UNEP LCIA framework is that it provides a comprehensive classification for environmental externalities. It subdivides the environment in three compartments ('Humans', 'Non-human, biotic' and 'Non-human, a-biotic'), thus together covering the entire world. Part of these environmental compartments may then be designated as 'safeguard subjects', i.e. the things that we value and wish to safeguard within each environmental compartment. Safeguard subjects can be of both intrinsic and instrumental value (the latter called functional in Jolliet et al. 2004) so we obtain in total 6 overall 'areas of protection' (**Table 1**).

Jolliet et al. (2004) mention some examples of intrinsic values: Human health; Biodiversity for the non-human, biotic environment; Heritage values in the abiotic environment. The instrumental values have to do with things that give us the ability to obtain the intrinsic values, i.e. mainly issues regarding our productive capabilities. Human productivity is also affected by e.g. health impacts, which therefore have a value beyond the intrinsic loss of well-being. Similarly, we also value nature for its productive capacity, and the abiotic environment serves as capital stock (both man-made and natural resources). To complete the listing of Jolliet et al. (2004), well-being of humans and animals in human care have been added in Table 1.

It is interesting to note that the 6 areas of protection can be related to the three areas of the sustainability concept (People, Planet, Profit or Social, Biophysical and Economic sustainability). The resource and productivity aspects clearly relate to economic sustainability, while biophysical sustainability (often named ecological or even misnamed environmental sustainability) relates to the non-human, intrinsic areas of protection. Social sustainability obviously relates to the human, intrinsic area of protection.

3 Biophysical, Social and Economic Inventory Results

When investigating a human activity, be it a project (as typical for CBA), a single process, e.g. a factory site or an enterprise, or a product system (as in LCA), the exchanges between the human activity and its environment are recorded in what has become known in LCA as the 'inventory results'. In the same way as for the areas of protection, the inventory results may be related to the three areas of sustainability. The biophysical inventory results, which are the ones traditionally covered most comprehensively by LCA, are the emissions to air, water, soil, as well as energy emissions, biophysical aspects of occupational health, food contamination and physical disruption, e.g. from land use or release of alien species. The social inventory results cover a long list of indicators, which I shall return to in more detail in the following sections. The economic inventory results, which are traditionally covered by CBA, are the economic costs and benefits to different agents, as well as changes in capital stocks. Other issues that are sometimes included in CBA, but often neglected, are the influence of the activity on education and skills (the fact that we upgrade – or downgrade – our capabilities while we perform an activity), distributional issues, as well as influences on our time usage, e.g. the amount of time we spend commuting or on different household activities. Although belonging to the economic sphere, these issues are often covered by social impact assessment (van Schooten et al. 2003).

4 Integrating Social Aspects in Life Cycle Assessment

The concept of impact chains, linking biophysical and economic inventory results via midpoint impact indicators to final damage indicators, is well described in the LCA and CBA literature. In social impact assessment, the concept has only recently been introduced, and even when attempting to separate inventory results, midpoint indicators, and damage indicators, these are often confused (van Schooten et al. 2003). Therefore, in this paper, less emphasis is placed on describing biophysical and economic impact pathways, and more emphasis on how social aspects can be integrated in LCA.

When integrating into LCA all the different social aspects that are treated in the different basic texts on social impact assessment (as reviewed by e.g. van Schooten et al. 2003) it is essential to treat each aspect according its position on the impact pathways or in the different damage categories:

- Some aspects are inventory items (e.g. hours of child labour)
- Some aspects are midpoint indicators (e.g. the resulting lost education),
- Some aspects are damages to instrumental values (e.g. lost income),
- Some aspects are damages to intrinsic values, either to human health and well-being (e.g. autonomy infringements) or to objects with heritage value (e.g. language).

We can define indicators and units of measurement for each of these aspects, thus allowing quantification. A requirement for a good indicator is that it allows quantification of the extent (incidence or prevalence), the duration and the severity of the considered aspect. As examples of this, the damage categories under the general heading of human life and well-being are described below, with proposals for indicators, units of measurement, and a first estimate of global normalisation values. The damage categories are identified as the different aspects of human life that has intrinsic value:

- Life and longevity
- Health
- Autonomy
- Safety, security and tranquillity
- Equal opportunities
- Participation and influence

Life and longevity are intimately connected, since all humans die once – and only once – in a lifetime, so that the damage to life is in fact not additional deaths, but a change in the timing of deaths, i.e. loss of live-years through premature deaths.

Changes in the expected length of life are measured by the damage indicator Years of Life Lost (YLL). The current average life expectancy may be compared to the maximum life expectancy, to obtain a normalisation reference for the current total loss of life-years. Obviously, the maximum life expectancy is a somewhat disputed issue, which may vary among populations, depending mainly on genetic factors. The Global Burden of Disease study (Murray & Lopez 1996) suggested using the life expectancy of the population that currently have the largest longevity, namely the Japanese with life expectancies at birth fixed at 82.5 years for women and 80 years for men. It may be argued that it should be 82.5 years also for men, since the reason for the difference between the sexes are probably not genetic but rather based on the larger risks of male life-style.

The total amount of YLL for a population can be illustrated graphically in the form of the mortality gap, which is the area between the survivorship curve (**Fig. 1**) and the ideal situation where the entire population lives to the maximum life expectancy, i.e. area A in Fig. 1. The survivorship curve can be interpreted for a population as the proportion of the cohort that is still alive for each age along the x-axis. It may also be interpreted at the level of the individual, as the expectancy of being alive at different ages.

Non-fatal impacts on human health are measured in terms of the type of disability (disease or injury) and the duration of the condition. The unit of the damage indicator is therefore disability-years. To each form of disability, a severity may be assigned on a scale between 0 and 1, where 0 is equal to death. The resulting damage indicator is called healthy Years Lost due to Disability (YLD), and can be aggregated to the years of life lost (YLL), using the common unit of DALY (Disability Adjusted Life Years). For example, a disease with a disability weight of 0.5 and a duration of 1 year for 1 person will be recorded as a damage of 0.5 DALY, thus equal to 0.5 YLL, i.e. a reduction of life expectancy of 0.5 years for 1 person.

There are several ways of measuring severity weights (also known as disability weights), and improved severity weights are likely to appear over time (Murrey et al. 2002, Chapter 9). For example, rather than weighting each disability separately, it may be preferable to link disability states to more generic health states (expressed in terms of levels of mutually independent health attributes such as vision, hearing, speech, mobility, manual dexterity, anxiety/depression, cognition, and pain) and then weighting these attribute levels (Feeney 2002).

The advantage of expressing health states by such generic attributes is that when designed to be independent, the preference-weighted scores are additive. As we shall see, such attributes can also be used to measure, and thus assign weights to, autonomy infringements, and eventually to all aspects of well-being.

The total value of YLD for a population can be illustrated in **Fig. 2** by the area B, delineated by the lower curve which shows the health expectancy and the upper curve, which is the survivorship curve (compare to Fig. 1). The sum of A+B is known as the health gap. A similar curve could be drawn for an individual. The health expectancy is the sum of the years lived at full health (health state = 1) and the years lived with a health state lower than 1 (as expressed by the severity weights).

In analogy to the health impacts, other impacts on well-being (autonomy, safety, security and tranquillity, equal opportunities and participation and influence) require measures of incidence (number of persons affected) and duration of the impacts. As for health impacts, these other well-being impacts may be assigned a severity ('well-being weight') on a scale between 0 and 1, where 0 is equal to death. The

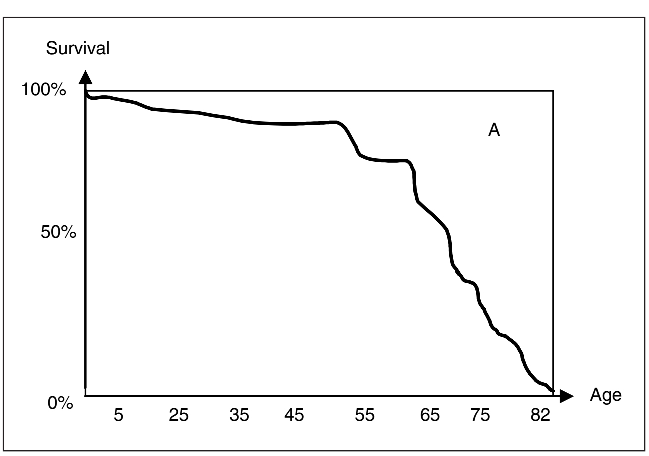

Fig. 1: The survivorship curve and the mortality gap (A). Shape of curve is for illustration only and does not refer to actual data

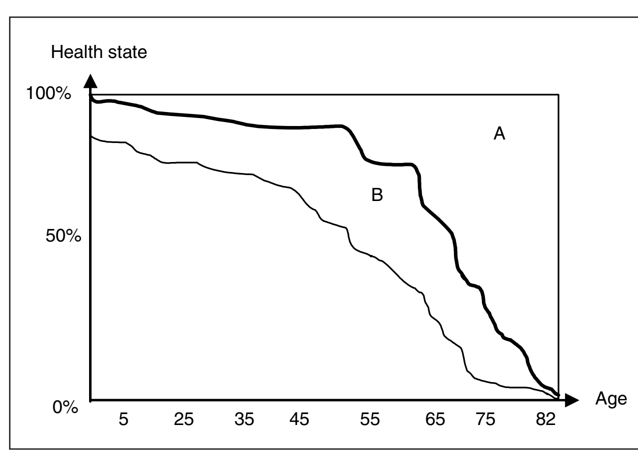

Fig. 2: The health gap (A+B). Shape of curves is for illustration only and does not refer to actual data

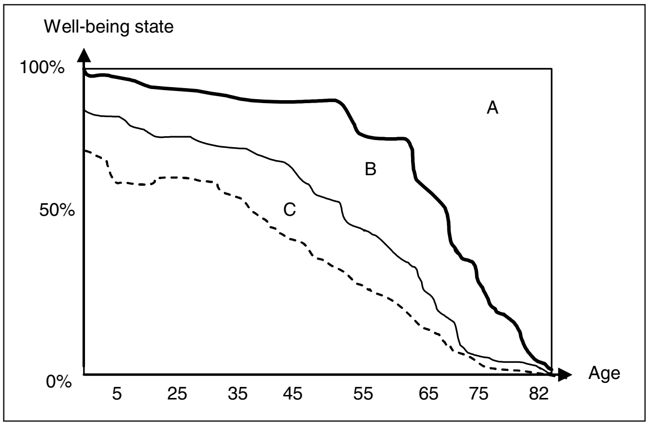

Fig. 3: The well-being gap (A+B+C). Shape of curves is for illustration only and does not refer to actual data

resulting damage indicator is Years of Well-being Loss (YWL) and is comparable to Years Lost due to Disability (YLD) and years of life lost (YLL), using the common unit of QALY (Quality Adjusted Life Years), where a well-being impact with a severity weight of 0.5 and a duration of 1 year for 1 person will be recorded as a damage of 0.5 QALY, thus equal to 0.5 YLL, i.e. a reduction of life expectancy of 0.5 years for 1 person.

This makes it possible to illustrate the total value of non-health related well-being for a population by the area C in **Fig. 3**, delineated by the lower curve which shows the well-being expectancy and the middle curve, which is the health expectancy (compare to Fig. 2). The sum of A+B+C we may call the well-being gap. The well-being expectancy is the sum of the years lived with full autonomy (well-being state = 1) and the years lived with a well-being state lower than 1 (as expressed by the severity weights). This concept is equivalent to the concept of 'Happy Life Expectancy' suggested by Kunst et al. (1990) and Veenhoven (1996).

Ideally, the same methods should be applied for soliciting disability weights and well-being weights. However, non-health impacts have not been as popular a subject of comparison and quantification as have disabilities. Until an adequate number of such studies are available, initial assessments will therefore have to rely on more rough assessments based on analogies to conditions with known severity weights, i.e. disability weights. This would imply that infringements on autonomous expressions (e.g. physical confinement and mental torture) be assessed in terms of the degree of deviation from autonomous (voluntary) behaviour, and compared to the restrictions caused by physical and mental disabilities.

A first attempt at measuring the global burden of well-being in this way can be found in **Table 2**.

I am aware of the hesitation to make e.g. human rights violations relative through quantification, since any violation is in principle unacceptable. However, since these violations do occur, and arguably are of different severity, the only thing we obtain by refraining from quantification is that we limit our ability to prioritise our resources in the battle against these violations. What is not measured is often placed at zero value, even by people that recognize that this should not be so. I therefore suggest that we have much to gain, and little to loose, by seeking to quantify these social impacts.

Table 2: A first estimate of the global burden of well-being impacts, year 2002

Impact	Total damage [E+6 QALY]	% of full wellbeing
Value of full well-being before impacts	6230	100%
Mortality[a]	–1700	–27%
Non-lethal health impacts[a]	–960	–15%
Autonomy infringements[b]	–930	–15%
Anxiety[c]	–300	–5%
Unequal opportunities[d]	–160	–3%
Participation restrictions[e]	–380	–6%
Current level of well-being	1800	29%

[a] WHO publish data on the health gap with their annual World Health Reports. In 2002, the health gap, without age weighting and discounting, was 2660 E+06 DALY, out of which approx. 2/3 was due to mortality. If age weighting and discounting is applied, mortality receives relatively less weight.
[b] See Table 3.
[c] See Table 4.
[d] Estimated that the most disadvantaged ¼ of the global population (1.6 E+9 people) is affected at 0.1 QALY per person. It should be noted that it is only to a lesser extent that unequal opportunities has a direct influence on well-being, which is measured by this value. The main impact is in the damage category of human productivity.
[e] Estimated from a severity weight of 0.1 QALY per person affected, and a prevalence of 54% of the adult population (which is 72% of the total population), i.e. 2.4 E+9 people, derived as a scaled population weighted average of the Freedom House index on political rights (Piano & Puddington 2004), plus a severity weight of 0.05 for union rights applied to a prevalence of 2.7 E+9 adults affected, derived as a population weighted average of the rescaled inverse Kucera index of trade union rights (Kucera 2004).

Autonomy comes from being in control of one-self and one's resources (beyond health). In fact, health impacts may be seen as just one specific kind of impact on autonomy, i.e. reducing the victim's ability to control the different aspects of autonomous behaviour.

As autonomy comes from being in control, impacts on this damage category are infringements on this self-control. These infringements may be both passive (restrictions on autonomous behaviour) and active (forced behaviour).

More systematically, autonomy infringements may be grouped according to the nature of the infringement:

- Infringements that completely dominate voluntary behaviour, such as slavery (forced labour), arrest and imprisonment, and working hours so excessive that little or no free time is left for voluntary behaviour. Child labour also falls in this category when it limits the ability of the child to follow school and other activities necessary for full physical and mental development.
- Infringements of bodily or mental integrity, such as torture, mutilations, cruel, inhuman or degrading treatment or punishment, restrictions on personal sexuality and fertility (including planning the timing and number of births). These infringements have important health as-

Table 3: A first estimate of the global burden of autonomy infringements

Infringement	Capita affected annually, E+6	Short term damage, annual, QALY per capita affected	Long term damage, annual, QALY per capita affected	Average age of victim	Total short term damage, E+6 QALY	Total long term damage, E+6 QALY	Total damage, E+6 QALY
	A	B	C	D [a]	E=A*B	F [a]	E+F
Bonded labour [b]	20	0.4	0.15	30	8	7	15
Child labour [b]	180	0.4	0.15	12	72	162	234
Trafficking [c]	3.7	0.8	0.15	21	3	14	17
Incarceration [d]	9	0.8	0	n.r.	7	0	7
Excessive work [e]	1,000	0.2	0	n.r.	200	0	200
Torture [f]	0.1	1.4	0.15	21	3	14	17
Genital mutilations, female [g]	2	0.3	0.2	12	1	14	15
Genital mutilations, male [g]	13	0.3	0	n.r.	4	0	4
Interpersonal or communal violence [h]	26	0.2	0	n.r.	5	0	5
	10% of which	0.2	0.15	20	1	11	11
Crime victim compensation [h]	4	-0.1	0	n.r.	–0.4	0	–0.4
No access to contraceptives [i]	200 (women)	0.1	0	n.r.	20	0	20
Unwanted pregnancies [i]	60	0.2	0.1	24	12	90	102
Refugees or internally displaced [j]	37	0.3	0	n.r.	11	0	11
Warehoused refugees (> 5 years) [j]	8	1.5	0.2	20	12	35	47
Infringement of freedom of expression [k]	2,400	0.1	0	n.r.	240	0	240
Sum					596	334	929

[a] Average age of victim (column D) is only relevant for the calculation of long-term damage, which does not apply to all types of infringements. F is calculated as A/t*C*(47-t-D), i.e. by multiplying the prevalence (A/t), the severity (C) and the remaining lifetime (47-t-D). The duration (t) of the incidences is measured in years and generally set to 1, but for bonded labour, child labour and warehousing, a duration of 5 years per incidence is assumed, the prevalence therefore being 5 times lower than number of persons affected annually. The assumed average life expectancy of victims is 47 years, as already reduced due to the separately measured general health impacts (the health gap in Fig. 2).
[b] Source: <www.antislavery.org>. The value covers only the worst forms of child labour.
[c] 700,000 people annually are trafficked across national borders (USDJ 2004), and an additional 3 million women annually are trafficked internally (UNFPA 2000).
[d] 9 million people are in prison (Walmsley 2003). As for the other items, this is a neutral observation, and no moral judgement is implied.
[e] 1,000 million people have excessive work hours <www.ilo.org>.
[f] 100,000 people are received annually by torture rehabilitation centres <www.hiltonfoundation.org>
[g] <www.noharmm.org/HGMstats.htm>
[h] Author's estimate of violence victims, based on Krug et al. (2002). Only 4 million out of these victims of violence have access to a crime compensation programme (Calculated from combining the national assault statistics with data from the International Crime Victim Compensation Program Directory <www.ojp.usdoj.gov/ovc/intdir/>).
[i] Vlassoff et al. (2004)
[j] <www.refugees.org>
[k] The global population weighted prevalence of infringements of freedom of expression is 53% (calculated from Karlekar 2004), assumed to relate only to the adult 72% of the population.

pects, but have additional components of defamation, which are not covered by the health impacts alone.

- Infringements related to specific aspects of voluntary behaviour, such as settlement and migration (within national borders, leaving and returning to one's native country, deportation), choice of life companion (forced marriages), freedom of personal opinion (speech and publication), freedom to express personal religion, moral rules, rituals, language and dress.

A first attempt at measuring the global burden of autonomy infringements can found in **Table 3**. The intention has not been to describe and discuss each data source in detail, but rather to demonstrate the feasibility of the procedure. Improvements in statistics should be made in the years to come.

The tentative severity weights in Table 3 have been derived by estimating the short-term and long-term damage caused by the respective infringements in terms of their health state equivalents, scored on the EuroQol scale[1] and translated into QALYs by using the N3 tariff of Dolan et al. (1995). All short-term effects have been estimated to have a duration of 1 year, except refugee warehousing, which has a duration of 5 years. Only some of the infringements are estimated to have long-term effects, but overall these effects nevertheless add up to more than half of the overall short-term effects.

It should be noted that the effects assessed in Table 3 are in addition to any health effects that may accompany the au-

[1] The EuroQol scale has five health attributes (mobility, self-care, usual activities, pain/discomfort, anxiety/depression) and scores of 1, 2 or 3 for each attribute. As an example, the severity weight of 0.4 for bonded labour has been derived from a EuroQol score of 2-0-2-2-2, signifying a moderate severity (2) on four out of the five attributes. Each of these scores of 2 is translated into a severity weight between 0 and 1 (the additive severity weights for the four attributes are 0.069, 0.036, 0.123, and 0.071, respectively, using the N3 tariff of Dolan et al. 1995). Adding a constant severity weight of 0.081 for any impact at all, these severity weights add up to the total of 0.069+0.036+0.123+0.071+0.081=0.38 (rounded to 0.4).

Table 4: A first estimate of the global burden of non-clínical anxiety

Impact	Capita affected annually, E+6	Damage, QALY per capita affected [a]	Total damage, E+6 QALY
Inadequate access to health care [b]	1,600	0.09	140
Inadequate access to pensions or social security [c]	680	0.09	61
Threats of violence or other contact crimes [d]	130	0.09	12
Burglary or attempted burglary [e]	220	0.09	20
Threatening or traumatic traffic situations [f]	140	0.09	13
Stressful working conditions [g]	600	0.09	54
Sum			300

[a] Each of the mentioned conditions is assumed to be an independent cause of an anxiety rated at 0.1 QALY. To account for anxiety already covered as a health issue, 10% of the value has been subtracted.
[b] According to WHO Global Atlas of the Health Workforce <www.who.int/GlobalAtlas/home.asp>, 2600E+6 people live in countries with less than 1 physician per 1,000 people. The value of 1600E+6 is obtained by weighting the population of each of these countries with the relative availability of physicians (where 1 = 1 per 1,000). This value does not give a measure of the access to treatment for specific groups within each country, i.e. some groups in countries with more than 1 physician per 1,000 people may still have limited access. However, the national averages can be seen as the currently best available estimate of the share of the global population that has inadequate access to health care.
[c] Calculated as the number of people living in countries without recorded programmes for old age pension, sickness benefits and unemployment benefits according to the Social Security Administration's assessment 'Social Security Programmes Throughout the World' <ssa.gov/policy/docs/progdesc/ssptw/>, but divided by 3, so that a person that lacks access to all three types of programmes is counted only once.
[d] Per incidence of violence (see Table 3), 5 times as many are assumed to be exposed to threats of violence or other contact crimes.
[e] Rough estimate based on the UN International Crime Victims Survey.
[f] Per incidence of road traffic injuries, 5 times as many are assumed to experience threatening or traumatic traffic situations.
[g] 20% of the global labour force, based on the UK estimate of Smith et al. (2000).

tonomy infringements, since these health effects are already accounted for in the health gap.

The damage categories Safety (freedom from threats to personal health), Security (freedom from threats to personal property) and Tranquillity (freedom from excessive stress) cover the psychological feeling of being unsafe, insecure and/or stressed. Besides this direct anxiety, it may also involve changes in behaviour, restricting ones freedom, such as refraining from participating in certain activities, from going to certain places, or from leaving one's property. Lack of safety and security may also involve less efficient preventive behaviour, such as having more children to ensure survival of some to care for the family later. There exist two mainstream models, which link workplace stress to conditions of high demands in combination with either low autonomy (Karasek & Theorell 1990) or threats to, or violations of, legitimate rewards (Siegrist 1996). The autonomy and reward paradigms may possibly be seen as complementary explanations. Both models can be extended to cover situations outside the workplace (Knesebeck & Siegrist 2003, Siegrist et al. 2004).

While the actual anxiety or change in behaviour would provide the most direct measure of impact on the three damage categories, there exist few epidemiological studies of anxiety. Anxiety as a disease (general anxiety disorder) has a prevalence of 3.4% in the USA, workplace stress as a disease has a prevalence of 1.3% in the UK workforce (Jones et al. 2003), while 20% of the workforce is exposed to stressful conditions (Smith et al. 2000).

Lacking more comprehensive studies, we may apply a model that predicts the prevalence of anxiety from the combination of, on the one hand, exposure to threats to health, property and workplace autonomy, and on the other hand, inadequate access to care systems that can prevent, remedy or compensate the potential impacts.

A first rough estimate of the number of people affected by anxiety is provided in **Table 4**.

5 Impact Pathways for Social Inventory Indicators

Having listed and quantified the damage categories, the next challenge is to model the social impact pathways from the social inventory results to the damage indicators. Although many relationships are still only scarcely researched, there is a growing body of knowledge that seeks to explain the causal links of social sustainability, and it is therefore my suggestion that such a quantitative modelling – at least at a very rough level – is already possible based on existing research and data.

As with the biophysical environment, the modelling can be done both from bottom-up, i.e. from inventory results to damage indicators, or from top-down, i.e. starting from the damage categories. I would suggest that modelling from the top-down is more efficient, since once we have identified the main causes for health problems, autonomy violations, unsafe and insecure conditions, inequality and exclusion, then we can concentrate on these most important impact pathways, thus avoiding spending disproportionate efforts on impact pathways of minor importance.

Some impact pathways are quite straightforward, such as the relationship between the inventory indicator 'hours of child labour' and the impact indicator 'autonomy infringements' measured in QALY. Assuming that the inventory indicator includes only serious forms of child labour, which limits the child's ability to follow normal school and other activities necessary for full physical and mental development, it is reasonable to assume a linear relationship between hours of child work and the impact in QALY (1.3 QALY per year of child labour, including the long-term impacts; see Table 3, which translates to 6.5 E-4 QALY per hour of child labour, if a working year is set to 2000 hours). Besides this direct impact on autonomy, child labour also affects human productivity negatively, since the lack of education (and possible other abuse) leads to lower productivity of the affected individual. Based on OECD (2004) and Fields et al.

(1998), a rough estimate of the size of this impact is that per year of lost education, the victim's production is reduced by 10% of the average wage in the country of incidence. Since this applies to the rest of the victim's productive life (estimated at 30 years, cf. Table 3, note [a]), this translates to a loss for each hour of child labour of 3 times the average hourly wage of the country, i.e. a significant loss both for the victim and for the society in which he/she lives.

Other impact pathways are more complex, such as those related to trade union rights. Kucera (2004) lists 37 types of violations of trade union rights, with severity weights between 1 and 2. Each violation contributes to a national score, which is distributed on a scale spanned by the countries with fewest and most violations. Some of the 37 types of violations relate to legislation and the behaviour of authorities, while others could serve as indicators of the behaviour of individual employers. This applies at least to the two indicators with largest occurrence: dismissal due to union activities and prevention of the right to strike. Kucera recorded 1351 violations in 169 countries over a 5-year period. In Table 2, note [e], this is translated to a prevalence of violations of union rights for 2.7 E+9 people, i.e. 2 E+6 people per incidence. The justification for using Kucera's index as a damage indicator for the general prevalence of violations of human rights is that one incidence of violation may in itself have far-reaching effects for the general strength of unions, while also being an indication of other unregistered incidents. This implies that if violations are recorded systematically in an enterprise, each recorded incidence should be regarded as having a much larger effect than only on the workers of that particular enterprise. However, it is obvious that a more systematic recording of incidences may also reveal more incidences than recorded by Kucera, therefore implying that a lower prevalence should be estimated per incidence. Also, better modelling of the actual consequences of different violations would be welcomed, seeing the overall importance of this damage category. The recommendations of the National Research Council (2004) may be helpful in this respect.

Fortunately, many of the social inventory indicators are of the kind where the impact pathway is relatively straightforward:

- Occupational health and safety is mainly recorded in terms of diseases and injuries per working hour, which translate straight into health damages. Stress measurements can easily be converted to damages in terms of anxiety and disease.
- The educational value of an employment or other activity can be measured as the resulting lifetime increases in income for the labourer relative to the average lifetime wage, and thus summed as a human productivity impact.
- Forced labour and incarceration follows the same logic as child labour described above.
- Unemployment has well-documented health impacts and impacts on human productivity, which both can be related to the hours of unemployment.

More complex impact pathways relate to:

- Lacking access to social security, which, besides its immediate impact on the damage category security, has a long-term distributional effect (especially affecting the poor and keeping them in poverty). The distributional effects on human health, well-being and productivity is one of the more complex (and controversial) impact pathways.
- Use of indigenous resources, another distributional issue where it is relatively complex to model the impact of deviations between the market value of the resources and the value actually paid.
- Equal opportunities, where the challenge is also to estimate the income foregone and model the impacts of the resulting distributional bias.
- Restrictions on participation and influence, another area where we have very little guidance for modelling the impacts of specific restrictions.
- Migration (both permanent, daily, weekly, seasonal as well as tourism), another issue with complex impact pathways, sometimes also affecting the impact category of cultural heritage.

In spite of the difficulties for some impact pathways, it is obvious that with the current state of knowledge we can do much better than to set these impacts to zero.

As can be seen from the above list, one of the key difficulties for a complete impact modelling is the distributional issue, i.e. that impacts do not affect all groups in society equally, and especially that disadvantaged groups may be affected disproportionately. In CBA, the issue has largely been ignored, partly because the analysis is often carried out from a specific point of view, where the target population of concern, the 'agents with standing', is defined at the outset of the analysis, partly because of the widespread acceptance of the Kaldor-Hicks criterion that an activity is beneficial as long as those who loose from it *could* be compensated, i.e. not requiring that they actually *are* compensated. In a similar vein, CBAs are often been carried out with a national viewpoint, thus ignoring impacts abroad.

In contrast, LCA has nearly always had a global scope, which is also more defendable when used in a sustainability context. However, a global scope does not preclude that the assessment results can be sub-divided to yield information on the share of the impact that falls on different agents, be it nations, regions, income strata, or specific disadvantaged groups. The difficulty pointed to above is rather to carry such results further in terms of what uncompensated inequality in impacts means in the longer term for human well-being. It is well known that an income increase in low-income strata yields more well-being than a similar income increase in high-income strata. A simple assessment of this, which is sometimes used in CBA, is to weight income changes to a group with the inverse of its income level relative to the societal average. A more advanced modelling, in line with the concepts of choice modelling used to solicit severity weights, would require that a relationship between income and well-being be established, thus providing a true social welfare function.

6 Assessment Results in Environmental Impacts, Well-being or Money?

One of the main historical differences between CBA and LCA is that CBA requires that all impacts can be monetarised (translated into money terms) while LCA has typically refrained from arriving at a single score, but has rather delivered results 'at midpoint', i.e. in terms of environmental damages such as global warming, recorded in physical units such as CO_2-equivalents. The more recent development in LCA, envisaged in Udo de Haes et al. (2002) and Jolliet et al. (2004) has been to extend the impact modelling to 'endpoints' or damage categories, such as those listed in Table 1.

The six damage categories in Table 1 can be seen as a first step towards a single-score indicator for LCA. This lies implicitly in the acceptance of choice modelling approaches in the weighting of disabilities, as in the WHO Global Burden of Disease approach, which is now applied both in the Ecoindicator 99 and the IMPACT2002+ methodologies (Goedkoop & Spriensma 1999, Jolliet et al. 2003), and which has been extended to cover general well-being in the approach to social impacts outlined above. When choice modelling can be applied to trade-offs between mortality, different diseases and autonomy infringements, it is natural to propose that also the impacts on the biophysical damage categories (biodiversity, animals in human care, natural and cultural heritage) could be measured in terms of their importance to human well-being, and by the same procedure. This is also facilitated by the more detailed data now available for biophysical impacts, e.g. from the Millenium Ecosystem Assessment (http://www.MAweb.org). The three instrumental damage categories (human and ecosystem productivity, natural resources and man-made capital) are – by definition - already midpoints relative to the intrinsic values, and although complex, the final modelling from productivity to well-being should not be controversial.

This procedure, which converts all impacts into the QALY measure of well-being, provides an attractive alternative to direct monetarisation, since money is only an instrumental value, while QALY is a measure of the ultimate intrinsic value. With this development, we avoid the doubtful monetarisations of impacts on the biophysical damage categories, while still maintaining the option of expressing impacts in monetary terms (since the LCA single-score in QALY's and the CBA single-score in monetary units in principle measure the same thing, it is straightforward to establish a 'conversion rate' between them, by applying the overall budget constraint to both measures).

References

Bennet J, Blamey R (2001): The choice modelling approach to environmental valuation. Cheltenham, Edward Elgar

Dolan P, Gudex C, Kind P, Williams A (1995): A social tariff for EuroQoL: Results from a UK general population survey. University of York, Centre for Health Economics (Discussion paper 138)

Feeny D (2002): Health-status classification systems for summary measures of population health. In: Murrey et al. (2002), pp 329–342

Fields G S, Leary J B, López-Calva L F, Pérez-de-Rada E (1998): Education's crucial role in explaining labor income inequality in urban Bolivia. Cambridge, MA, Harvard University Institute for International Development. (Development Discussion Paper No. 658)

Goedkoop M, Spriensma R (1999): The Ecoindicator 99. A damage oriented method for life cycle impact assessment. Amersfort, PRé consultants

Hanley N, Mourato S, Wright RE (2001): Choice modelling approaches: A superior alternative for environmental valuation? Journal of Economic Surveys 15(3) 435–462

Heijungs R, Suh S (2002): The computational structure of life cycle assessment. Dordrecht, Kluwer Academic Publishers

Jolliet O, Mueller-Wenk R, Bare J, Alan Brent A, Goedkoop M, Heijungs R, Itsubo N, Peña C, Pennington D, Potting J, Rebitzer G, Stewart M, Udo de Haes HA, Weidema B (2004): The Life Cycle Impact Assessment framework of the UNEP-SETAC Life Cycle Initiative. Int J LCA 9 (6) 394–404

Jolliet O, Margni M, Charles R, Humbert S, Payet J, Rebitzer G, Rosenbaum R (2003): IMPACT 2002+: A new life cycle impact assessment methodology. Int J LCA 8 (6) 324–330

Jones JR, Huxtable CS, Hodgson JT, Price MJ (2003): Self-reported work-related illness in 2001/02: Results from a household survey, 2003. Published on the Internet at <www.hse.gov.uk/statistics/causdis/swi0102.pdf>

Karasek K, Theorell T (1990): Healthy work, stress, productivity and the reconstruction of working life. New York, Basic Books

Karlekar KD (ed) (2004): Freedom of the press 2004. Lanham: Rowland & Littlefield

Klöpffer W (ed) (2002): The Area of Protections debate. Gate to EHS: Global LCA Village March 2002:1–43. <http://www.scientificjournals.com/sj/lca_village/Pdf/aId/ 4844>

Knesebeck O, Siegrist J (2003): Reported non-reciprocity of social exchange and depressive symptoms: Extending the model of effort-reward imbalance beyond work. Journal of Psychosomatic Research 55, 209–214

Krug EG, Dahlberg LL, Mercy JA (2002): World report on violence and health. Geneva, World Health Organization

Krutilla JV (1967): Conservation reconsidered. American Economic Review 57, 777–786

Kucera D (2004): Measuring trade union rights: A country-level indicator constructed from coding violations recorded in textual sources. Geneva, International Labour Office (Working Paper 50)

Kunst AE, Okma-VanKeulen PT, Veenhoven R (1994): Happy life expectancy in 5 European countries. Presentation for the XIII World Congress of Sociology, Bielefeld, 1994–07

Murray CJL, Lopez AD (eds) (1996): The global burden of disease: A comprehensive assessment of mortality and disability from diseases, injuries and risk factors in 1990 and projected to 2020. Global Burden of disease and Injury Series, Vol. 1. Cambridge, Harvard University Press

Murrey CJL, Salomon JA, Mathers CD, Lopez AD (eds) (2002): Summary measures of population health. Geneva, World Health Organization

National Research Council (2004): Monitoring International Labor Standards: Techniques and Sources of Information. Committee on Monitoring International Labor Standards. Center for Education, Division of Behavioral and Social Sciences and Education and Policy and Global Affairs Division. Washington, DC, The National Academies Press

OECD (2004): Education at a glance: OECD indicators. Paris, Organisation for Economic Co-operation and Development

Piano A, Puddington A (eds) (2004): Freedom in the World 2004. Lanham, Rowland & Littlefield

van Schooten M, Vanclay F, Slootweg R (2003): Conceptualizing social change processes and social impacts. In: Becker & Vanclay (eds), The International handbook of social impact assessment. Cheltenham, Edward Elgar, pp 74–91

Siegrist J (1996): Adverse health effects of high effort – Low reward conditions at work. Journal of Occupational Health Psychology 1, 27–43

Siegrist J, Pollack CE, Knesebeck O (2004): Social productivity and well-being of older people: A sociological exploration. Social Theory and Health 2, 1–17

Smith A, Wadsworth E, Johal SS, Smith GD, Peters T (2000): The scale of occupational stress: The Bristol stress and health at work study. Sudbury, HSE Books

Udo de Haes HA, Finnveden F, Goedkoop M, Hauschild M, Hertwich EG, Hofstetter P, Jolliet O, Klöpffer W, Krewitt W, Lindeijer E, Müller-Wenk R, Olsen SI, Pennington DW, Potting J, Steen B (eds) (2002): Life-cycle impact assessment: Striving towards best practice. Pensacola, SETAC

Udo de Haes HA, Lindeijer E (2002): The conceptual structure of life cycle impact assessment. Chapter 8 in Udo de Haes HA et al. (eds), Life-cycle impact assessment: Striving towards best practice

UNFPA (2000): State of World population 2000. New York, United Nations Population Fund

USDJ (2004): Estimated global trafficking victims by age, sex, type of exploitation, and region. Washington DC: United States Department of Justice

Veenhoven R (1996): Happy life-expectancy – A comprehensive measure of quality-of-life in nations. Social Indicators Research 39, 1–58

Vlassoff M, Singh S, Darroch JE, Carbone E, Bernstein S (2004): Assessing Costs and Benefits Of Sexual and Reproductive Health Interventions. New York, Alan Guttmacher Institute (Occasional Report No. 11)

Walmsley R (2003): World prison population index. 4th edition. London, Home Office (Findings 188)

Watkins T (s.a.): Introduction to Cost Benefit Analysis. <http://www2.sjsu.edu/faculty/watkins/cba.htm> accessed 2004-09-07

Weidema BP (2003): Market information in life cycle assessment. Copenhagen: Danish Environmental Protection Agency. (Environmental Project no. 863). <http://www.mst.dk/udgiv/publications/2003/87-7972-991-6/pdf/87-7972-992-4.pdf>

Received: October 14th, 2005
Accepted: December 5th, 2005
OnlineFirst: December 6th, 2005