The importance of judgemental factors in environmentally sensitive design

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Abstract
At Brunel University we have been teaching Environmentally Sensitive Design to final year students. Initially we expected that the techniques of Life Cycle analysis (LCA) would provide a reliable tool in this work. However, the more we examined this tool, the more we became convinced that the apparent numerical accuracy of LCA is spurious and misleading.

The Designer is left with many judgemental questions and we have developed a number of tools to assist the designer in making these judgements. These include streamlined LCA; an Environmental Design Review and a comprehensive check list.

We also report our approach to the aggregation of pollution data in a number of different categories.

Brunel University, through its departments of Design and of Manufacturing and Engineering Systems, has some experience in the presentation of established bodies of scientific knowledge to relatively naive groups of end users. The department of Design started to explore the ideas of Life Cycle Analysis (LCA) with a view to presenting them in a form accessible to Designers.

During this work it became clear that the tools of Life Cycle Analysis are themselves, far from being clearly defined and this paper explores some of the reasons why LCA does not give robust answers to environmental problems and describes a number of developments that have proved both practical and useful to Design students at Brunel.

During the '50s and '60s a number of rather public episodes began to persuade the public that science and technology are not always benign activities:

- Nuclear Bombs
- London Smog
- Detergent Foams on Rivers
- Pesticide Build up (Rachel Carson's "Silent Spring")
- Oil Spills (Torry Cannyon)

At this stage, in most people's minds, things had not moved beyond a general unease; the transition to a feeling that there was an environmental crisis was crystallised for many by the so called "ozone hole". Partly because the scientific background was not easy to understand, partly because the risk was of skin cancer, this phenomenon became an icon for a whole range of environmental issues.

The following list of topics indicates many of the areas of current concern:

- Exhaustion of fossil fuels
- Exhaustion of mineral resources
- Greenhouse effect
- Acid rain
- Ozone hole
- Photochemical smog
- Toxic waste
- Radioactive waste
- Using animals for testing chemicals
- Species extinction/loss of biodiversity
- Increased noise pollution
- Lead in Petrol
- Water shortages
- Loss of Rain forest
- Human population growth

For many environmentalists the issues of greatest concern are those with global impact, particularly if the human race might be affected! On this basis some of the issues on the list are not perhaps matters of environmental concern; using animals for testing chemicals would seem to be mainly an ethical issue and noise pollution could be a matter of local consumer choice. Neither is likely to be planet threatening in isolation. Nonetheless, the issues are many and complex. Each of us has our own view of which problems are the most serious. The author considers that global warming and loss of biodiversity are the most threatening problems.

For some decades now, workers such as Ian Bowsted have been developing the techniques of Life Cycle Analysis (LCA), and many environmentalists consider this to be the key tool in an approach to Environmentally Sensitive Design. In its most straightforward form, LCA tracks a product from Cradle to Grave identifying the environmental inputs at each stage.

Extraction → Manufacture → Distribution → Use → Disposal

At Brunel University, the Department of Design was exploring the most effective ways of communicating the techniques of LCA to undergraduate students, and, somewhat to our surprise, we realised that the apparent numerical accuracy offered by LCA was in many cases an illusion.

In some cases, for example, the study of washing machines by PA consultants[1], a single phase of the life cycle will be orders of magnitude more damaging than all the other phases. In the case of washing machines this is the "use" phase. [Fig 1] In these cases a designer has a clear guide for further work. More often, for example, in the hair spray study by Chem Sys[2], the damage is spread over all stages of the Life Cycle and over many different categories. [Fig 2]

More worrying still when a single product is examined by different groups, the numerical values obtained can vary by more than an order of magnitude: for example, a number of groups have compared disposable and Terry nappies[3] with no clear outcome. [Fig 3]

Clearly consideration of the entire Life Cycle is a necessary condition for any valid analysis, but on its own it is not sufficient to guarantee meaningful results.

In many ways we should not be surprised at this failure of LCA to deliver hard numbers. Throughout the process the user has to supply judgemental information. To mention briefly three such areas of judgement.

1 Uncertainty in drawing the system boundary: the system boundary should include all the known and potential environmental damage associated with the product. [Fig 4]

  Unfortunately, while hard data is relatively easy to obtain during Manufacture and Distribution, data becomes very unreliable in the Extraction and Disposal phases.

  For example, it is common to draw the system boundary to exclude leachate from landfill since this may occur in tens or hundreds of years or never. However, this leachate, of heavy metals or PCBs, may in the end be very significant.

2 Split production: where two or three products are produced in a fixed proportion it is often difficult to know how to divide the pollution between them. For example, in the production of chlorine by the electrolysis of brine with a movingmercury cathode, sodium hydroxide and hydrogen form valuable by products. [Fig 5]

3 Aggregation of data: This is the problem of comparing chalk with cheese. How does one compare Sulphur Dioxide emission with emission of Lead? The method of critical volumes is often used: where legislation sets a maximum concentration of pollutant, the volume of water (or air) required to dilute the pollution to the legislative maximum is taken as the index of pollution. Clearly this method can only apply to pollutants controlled by law, and in any case parliamentary legislation is hardly to be considered a reliable indicator of pollution hazard.

All of this evidence suggests that individual (or collective) judgement must play a large role in any assessment of environmental impact, and a number of tools have been developed that reduce the work required to come to practical decisions.

Streamlined LCA This is a widely known approach that, by making various simplifying assumptions, significantly reduces the time and cost of Life Cycle Analysis. In the context of the inherent uncertainty in some aspect of LCA, the additional errors introduced by these assumptions can be made quite small. For example, with the streamlined LCA, it is common to ignore components that make up less than 5 or 10% of the product; generic data is used rather than plant specific data etc.

Design Checklists At Brunel, we have developed a comprehensive check list[4] that can be used by a designer as an aide memoir to ensure that no important opportunity for enhancing the environmental sensitivity of a design is missed.

Design Environmental Review For the past two years, at Brunel University, students have carried out what we call a Design Environmental Review on some of their projects. This combines elements of a streamlined LCA with elements of a checklist but also prompts consideration of more fundamental questions about the appropriateness of the design solution. [Fig 6]

This technique is sufficiently straightforward that it could easily be adapted for use in schools by concentrating primarily on the energy inputs into the LCA and using one of the public domain databases such as the Proctor and Gamble LC1

Spreadsheet[5].

Data Aggregation This problem has been mentioned earlier, and at Brunel we propose the following approach to the aggregation of different classes of pollution.

1 For each class of pollutant, estimate the amount of pollution per product by, for example, streamlined LCA. Calculate the amount of pollution, P, that would be produced if the entire production of this group of products moved to this technology.

2 Identify for each class of pollutant the total global release (T).

3 Decide on the relative importance of the different forms of pollution (J), either as an individual, by gathering together opinions from panels of experts.

4 Calculate the individual pollution indices, I:

$$I = \frac{P \times J}{T}$$

This data can be aggregated in a number of different ways; we have found that a diagrammatic representation marking each index along the axis of a star graph is often helpful. [Fig 7 & 8] Alternatively the individual indices can be combined to give a single overall pollution index that can be used to compare different designs.

Even allowing for the role of judgemental factors it is difficult to see how to quantify loss of biodiversity and habitat. It is evident from the geological record that new species are constantly emerging at the same time old species become extinct. It is evident from the geological record that new species appear to have been constantly emerging while other species became extinct. It is believed by most scientists that this process continues at the present and it is possible to make some estimate of the normal rates of speciation and extinction. These estimates suggest that the destruction of rainforest has a very profound impact on biodiversity although we are well short of being able to form an accurate picture of the possible long term effects.

References

1 Environmental Labelling of Washing Machines. PA Consulting Group, Cambridge Laboratory, 1991.

2 Report of Working Group on the Eco labelling of Hair sprays, UK Eco labelling Board, Chem Systems, 1992.

3 A review of Proctor & Gamble's Environmental Balances for Disposable and Re–usable Nappies: a report commissioned by the Women's Environmental Network, 1991.

4 Report for the European Foundation, Dublin Yorick Benjamin 1992.

5 Life Cycle Inventory for consumer goods packages, Proctor and Gamble, European technical Centre, 1992.

6 Environmental Science – living within the system of nature, C E Kupchella & M C Hyland, Allyn & Bacon 1986, pp107.

Fig 1

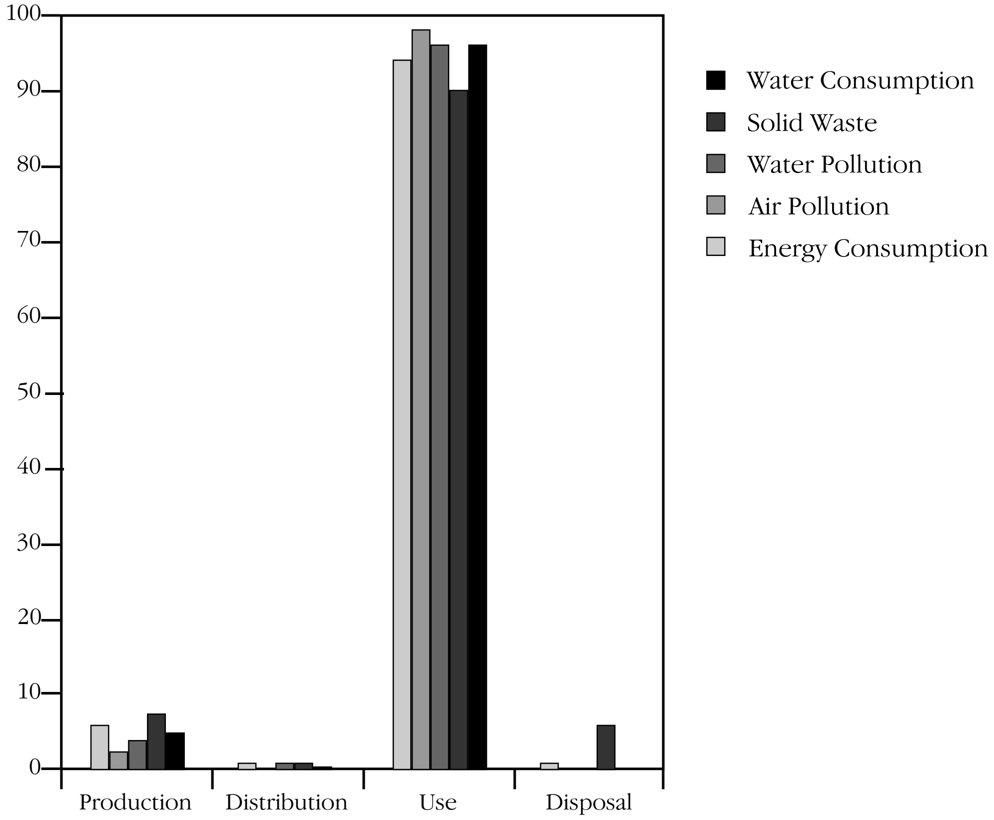


Fig 2 - Pump Life Cycle Impacts: contributions to total

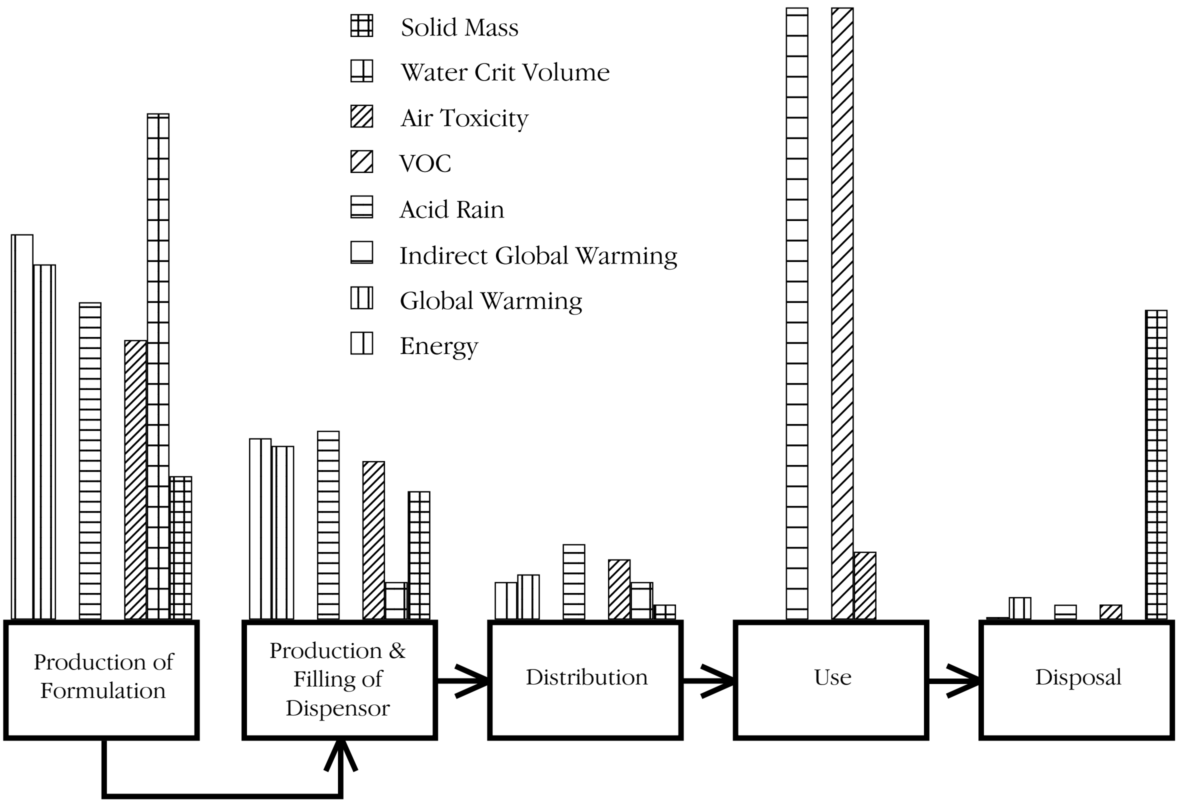


Fig 3 - Standardised results for the Lentz and Little studies (per infant, per annum)

	Lentz		Little		Landbank[a]	
	Disposable	Cloth	Disposable	Cloth	Disposable	Cloth
Energy (MJ)	8900	6700	1300	4300	9600	1800
Raw materials (kg)	224	55	598	85	569	29
(non-regenerable	64	52	87	76	208	25)
(renewable	160	3	511	9	361[b]	4[c])
Air emissions (kg)	3	4	2	20	-	-
Waste water effluent						
volume (m^3)	28	25	5	28	28	9
pollutant index (kg)	15	32	0.3	3	-	-
Domestic solid waste (kg)	224	3	524	6	240	4

a Observations based on Lentz study (- indicates insufficient raw data)
b Wood, requiring an average of 4.8 km^2 per annum for cultivation
c Cotton seed (1kg), plus wood (3kg) for cardboard detergent boxes, requiring cultivated area of 0.5 km^2 per annum

Fig 4 - Confidence limits of life cycle data

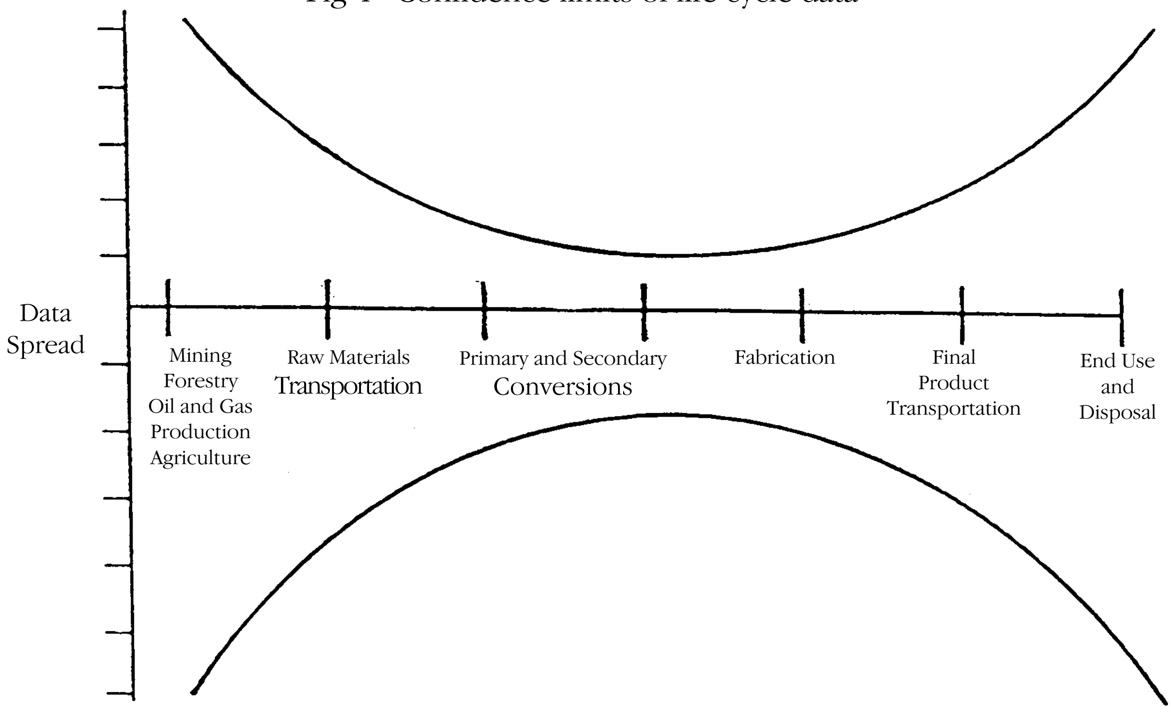
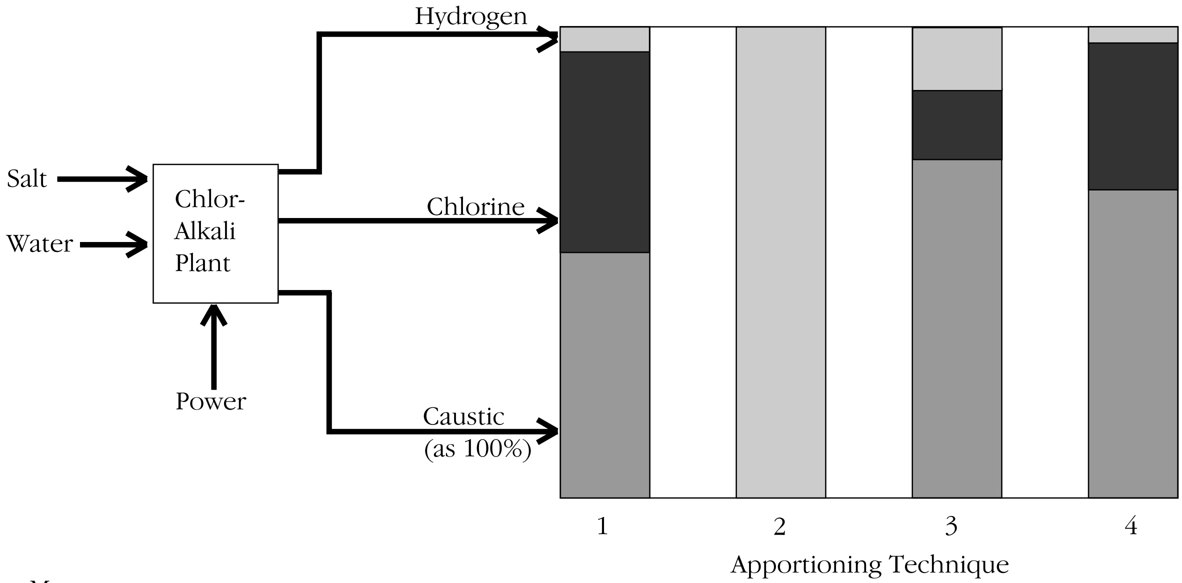


Fig 5 - Chlor-Alkali Plant



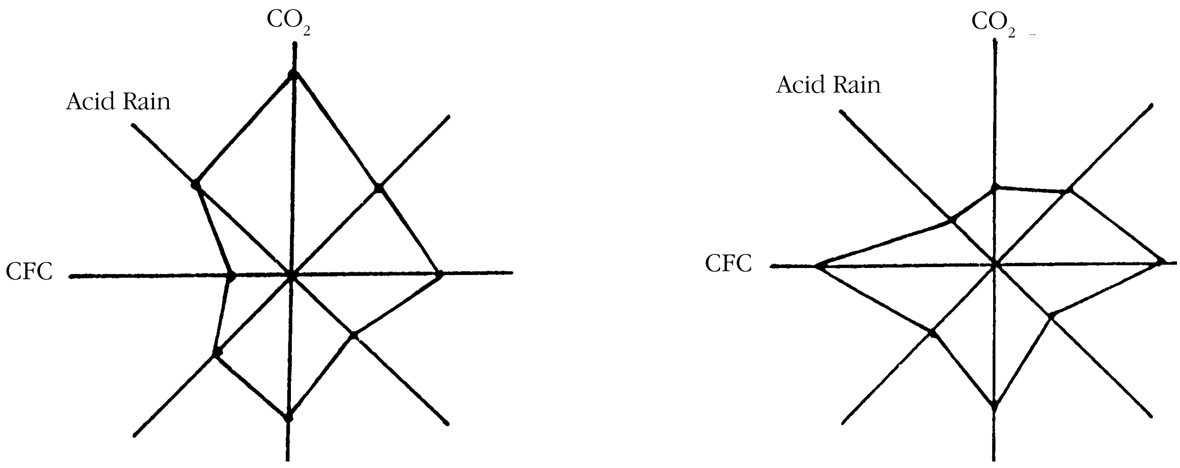
- Mass
- Energy content
- By-products given alternative production credit
- Market value

Fig 6 - Streamlined LCA

Design Environmental Review

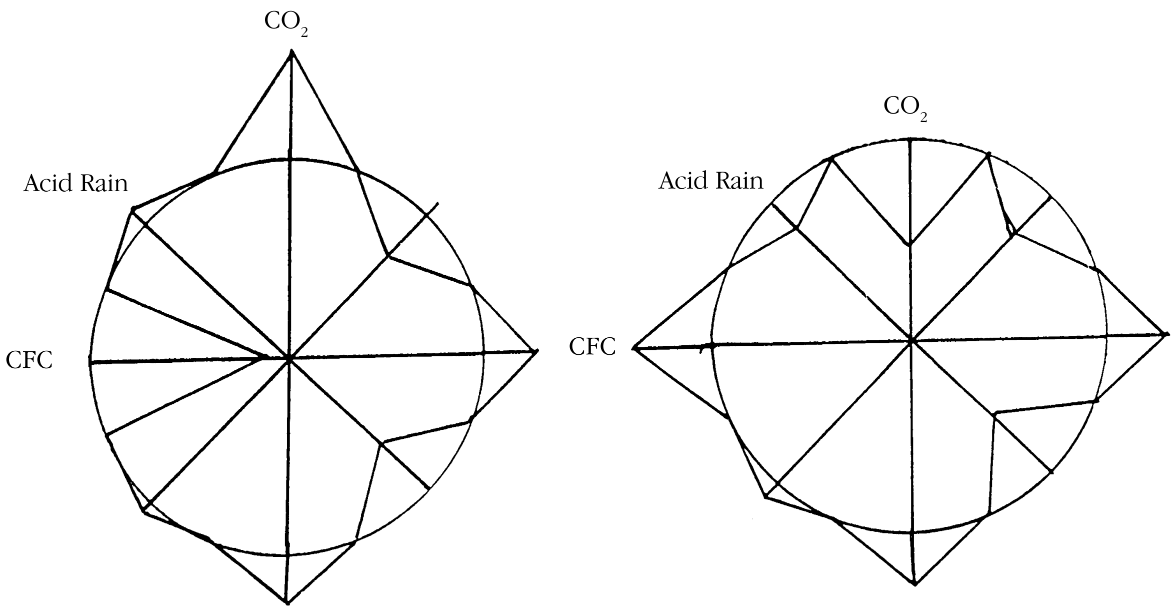
- Is this the right solution to the need?
- Identify main components - no need to be too specific (ignore <10%)
- Check for material incompatabilities
- Check for toxics
- See if Eco-label exists
- Use generic data to: identify major energy inputs, material use, polution etc
- Identify the major issues
- Consider whether or not design changes can be made that retain functionality while reducing the major impacts
- Is this the right solution to the need

Fig 7



CO_2
Acid Rain
CFC
CO_2
Acid Rain
CFC

Fig 8



CO_2
Acid Rain
CFC
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CFC