SUSTAINABLE PROJECT LIFE CYCLE MANAGEMENT: CRITERIA FOR THE SOUTH AFRICAN PROCESS INDUSTRY

by

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"Nature is neutral.

Man has wrested from nature

the power to make the world a desert

or to make deserts bloom.

There is no evil in the atom; only in men's souls."

\- Adlai Ewing Stevenson, 1952.

Dissertation Summary

Sustainable project life cycle management: Criteria for the South African process industry

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Sustainable development aims to meet present needs without compromising the ability of future generations to meet their own needs. The concept has three definite objectives namely social equity, economic efficiency and environmental efficiency. Sustainability criteria are becoming factors within international trade agreements and governments worldwide are introducing more stringent legislation with regards to environmental issues in order to address sustainability. Business sustainability is thus becoming a prerequisite for global competitiveness and companies worldwide are adapting core competencies, policies, culture, business processes and decision-making processes to incorporate the objectives of sustainable development. Project management, as a core competency, must therefore incorporate planning, execution and implementation procedures within the broader sustainability framework.

The strategic importance of project management drives the integration of environmental and social objectives into a life-cycle project management framework, since economic aspects of sustainability are effectively considered in current project appraisal procedures. The aim of this dissertation is to develop a decision-making framework for projects in the South African process industry that incorporates **environmental sustainability**. Social aspects are not

considered at first because the incorporation of sustainability into businesses traditionally start by focussing on environmental aspects only.

The necessary environmental management tools and approaches to address environmental sustainability do exist, although all of the tools are not utilized in the current project life cycle management framework. The dissertation therefore proposes the promotion of other environmental management tools within this framework. An Environmental Evaluation Matrix (EEM) tool has been developed as part of the dissertation. The EEM tool is proposed as a strategic tool that can bridge the gap between decision-makers and designers, while simultaneously providing key environmental information for decision-making purposes and prompting designers to consider environmental aspects often ignored. A case study identified strengths and weaknesses of the tool. It is evident that the concept can be effective but the scoring guidelines of the tool will have to be adapted to be company specific.

Environmental information can be incorporated into the decision-making process by either expressing it in financial terms or by expressing it separately and using multi criteria decision analysis techniques to weigh environmental and economic aspects against each other. At each evaluation point within the project life cycle one of the techniques, or a combination thereof, can be used.

The implementation of the proposals to incorporate environmental sustainability criteria into a project life cycle management framework requires a paradigm shift at all levels within the company. However, due support from top management is a necessity to ensure that environmental aspects are adequately supported by management practices.

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List of Abbreviations

AIChE:	The American Institute of Chemical Engineers
BSC:	Balanced Scorecard
CORE:	Coalition for Environmentally Responsible Economics
CWRT:	Centre for Waste Reduction Technologies
EEM:	Environmental Evaluation Matrix
EIA:	Environmental Impact Assessment
EIO:	Economic Input-Output
EMS:	Environmental Management System
EPA:	Environmental Protection Agency (United States)
ERA:	Environmental Risk Assessment
IEED:	International Institute for Environment and Development
IEF:	Industrial Environmental Forum
IEM:	Integrated Environmental Management
IISD:	International Institute for Sustainable Development
ISIC:	International Standard Industrial Classification of all Economic Activities
ISO:	International Organization for Standardization
IUCN:	International Union for the Conservation of Nature/ World Conservation Union
GDP:	Gross Domestic Product
GRI:	Global Reporting Initiative
LCA:	Life Cycle Assessment
LCC:	Life Cycle Cost
LCCA:	Life Cycle Cost Analysis
LCE:	Life Cycle Engineering
NEPA:	National Environmental Policy Act
OECD:	Organisation for Economic Co-Operation and Development
SANF:	Southern African Nature Foundation
SEA:	Strategic Environmental Assessment
SIA:	Social Impact Assessment
SIC:	Standard Industrial Classification of all Economic Activities
TCAM:	Total Cost Assessment Methodology
UNDP:	United Nations Development Program
UNEP:	United Nations Environmental Program
WBCSD:	World Business Council for Sustainable Development
WCED:	World Commission on Environment and Development
WRI:	World Resource Institute
WSSD:	World Summit on Sustainable Development
WWF:	World Wildlife Fund/ Worldwide Fund for Nature

Chapter 1: Introduction to Sustainability

1.1 International History of Sustainable Development

1.1.1 Environmentalism

"*It is entirely possible that when the history of the twentieth century is finally written, the single most important social movement of the period will be judged to be environmentalism*" (Nisbet, 1982).

The enlightenment period of the eighteenth century emphasised the importance of the individual, his freedom as well as his liberation. In this spirit of rationality, individualism, naturalism and utilitarianism Adam Smith (1723-1790) wrote a very important and influential economic textbook *An Inquiry into the nature and causes of wealth of nations* (Blignaut, 1995).

Smith showed a propulsive force that would put society on an upward growth path and a self-correcting mechanism that will keep it there (Heilbroner as cited in Blignaut, 1995). Smith's model is often referred to as an economic growth model that leads to the belief that economic growth will provide prosperity and answers to the quest of humanity.

The goal of economic growth was further enhanced by the experimental philosophy of the late 1800's that the engines of human progress were scientific rationality and social utilitarianism. Bacon added the perspective that knowledge is a means, not an end and should be expressed and applied in technology to provide the means by which humans can assume power over the material world (Jones as cited in Rees, 1988).

In this spirit the industrial revolution of the nineteenth century took place. In Britain this revolution caused an early consciousness of the effect of industrialism on the human environment and in 1863 the first environmental protection legislation was tabled in the UK, namely the Alkali Act of 1863. The Great London Smog incident in 1952 also resulted in a stream of public health and other legislation, e.g. the Clean Air Act of 1956 (Lichfield, 1988).

After the second World War, decision makers at government level realized that available planning tools were not sufficient to address the environmental and social problems that were starting to emerge: Acid rain, global climate change, ozone depletion, species extinctions, pollution, urbanisation etc. Nonetheless, the goal of economic growth remained. This goal has mainly been pursued by means of industrialism; regardless of whether the economic system is capitalism or communism, or however devastating the effects on the environment or human health (Porrit and Barbier as cited in Blignaut, 1995).

By the mid-twentieth century a minority started to realize the interconnections between the environment, economy and social well-being. The publication of Rachel Carson's "Silent Spring" in 1962 is considered as a turning point in the understanding of the importance of these interconnections. This publication was in line with the wave of environmental concern that the USA was experiencing in the 1960's and various non-government organisations were formed in that decade to promote environmental awareness.

Since the mid-1960's analysts warned that there was a consistent shift in public preference towards a greater emphasis on environmental protection and qualification of environmental quality (Inglehart as cited in Caldwell, 1989). The USA came to the realisation that a piecemeal approach to environmental legislation was no longer sufficient and this led to the USA's *National Environmental Policy Act (NEPA) of 1969* (Glavovic, 1984).

Although the USA and many other countries had environmental legislation dealing with various effects in place by 1969, NEPA represented the fist comprehensive commitment of any modern state towards the responsible custody of its environment. NEPA was nevertheless widely criticised by scientists as " *a dishonest or distorted use of science"* (Caldwell, 1989).

Mechanisms to protect the environment became a worldwide phenomenon and 1971 saw the introduction of the "Polluter Pays" principle by the Organisation for Economic Co-operation and Development (OECD) Council. In the same year the International Institute for Environment and Development (IEED) was established in Britain and more emphasis was placed on economic development that does not destroy the environmental resource base.

In 1972 the United Nations held a Conference on the Human Environment in Stockholm. At this conference it was decided that, *"although states have a right to exploit their own resources pursuant to their own environmental policies, they nevertheless have a responsibility to ensure that activities within their borders do not cause damage to the environment of other states or areas beyond their limits of national jurisdiction" (*Sampson, 2001). This conference resulted in the establishment of many national environmental protection agencies as well as the United Nations Environmental Programme. The conference, however, focused solely on industrial pollution of air and water, while deeper ecological and social problems were not dealt with (Ferrero & Holland,2002).

In 1973 Schumacher (as cited in Blignaut) warned that: " *Modern man does not experience himself as part of nature but as an outside force destined to dominate and conquer it. He even talks of a battle with nature, forgetting that, if he won the battle, he would find himself on the losing side*". This can be seen as one of the first references of what is currently known as sustainable development.

1.1.2 Sustainable Development Defined

In 1980 the International Union for the Conservation of Nature (IUCN) (also known as World Conservation Union) in cooperation with the United Nations Environmental Program (UNEP) and the World Wildlife Fund (WWF) formulated the World Conservation Strategy. The concept of "sustainable development" was subsequently formally introduced, since the strategy recognized *"the planet's capacity to support people is being undermined by poor land management, profligate use of resources, and the sort of grinding poverty that forces people to destroy the very resources they need to survive"* (as cited in Ferrero & Holland, 2002). The United National General Assembly's 38th session meeting in 1983 led to the creation of the World Commission on Environment and Development (WCED) under the auspices of Ms. Gro Harlem Brundtland.

In 1987 the WCED finally published its now famous Brundtland Report as *"Our Common Future"*. In this report the term sustainable development was formally accepted and used for the first time. The commission defined sustainable development as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". According to Rees (1988) the commission defined needs as the "*essential needs of the world's poor to which overriding priority should be given"* and it also recognized the *"limitations imposed by the state of technology and social organization on the environment's ability to meet those needs*".

According to MacNeill (as cited in Rees) the book "Our Common Future" stimulated unprecedented levels of public discussions of the tensions between the environment and the economy in countries worldwide.

In 1990 the International Institute for Sustainable Development (IISD) was established followed by the World Business Council for Sustainable Development (WBCSD) in 1992.

In 1992 the United Nations Conference on the Environment and Development was held in Rio de Janeiro. The result of this conference was two important documents:

- Rio Declaration on Environment and Development: A statement of twenty-seven principles that sets out the basis upon which states and individuals are to co-operate to further develop international law in the field of sustainable development.
- Agenda 21: A blueprint or action plan for the implementation of sustainable development (Sampson, 2001).

The Rio Conference also accelerated the development of international environmental law reflecting principles seen as basic obligations of states (Sampson, 2001). A follow-up to the Rio Conference was the establishment of the Earth Council in 1992 as well as the first meeting of the Commission on Sustainable Development and the World Summit on Social Development, both held in 1995. Various international protocols with regard to environmental concerns were also agreed upon in this time period, e.g. Kyoto Protocol in 1997. In 1999 the first global sustainability index was launched and in 2000 the United Nations Millennium Summit took place that highlighted the importance of a fairer world economy in an era of globalisation.

In August 2002 the World Summit on Sustainable Development (WSSD) was held in Johannesburg to review global change in the ten years after the Rio summit. The slogan of the conference was "People, planet and prosperity" and it focused on five areas of concern: water and sanitation, agriculture, health, energy and biodiversity. It is believed by some that this summit shaped the future of a globally defined, sustainable development agenda; while others think the summit was a total failure with no meaningful outcomes (Zwecker, 2002).

1.2 The concept of "Sustainable Development"

1.2.1 Fundamentals of Sustainable Development

There are currently over 100 definitions of sustainability and sustainable development (WBCSD, 2002) and although the concept is understood intuitively it remains difficult to express it in concrete, operational terms (Briassoulis, 2001).

The World Bank distinguishes between three different aspects of sustainable development: economical, social and environmental, and believes that sustainable development can only take place if the objectives of all three aspects are equally taken into account during decision-making processes (World Bank Group, 1998). The different aspects and objectives are depicted in Figure 1.1. Most definitions agree on these three main objectives.

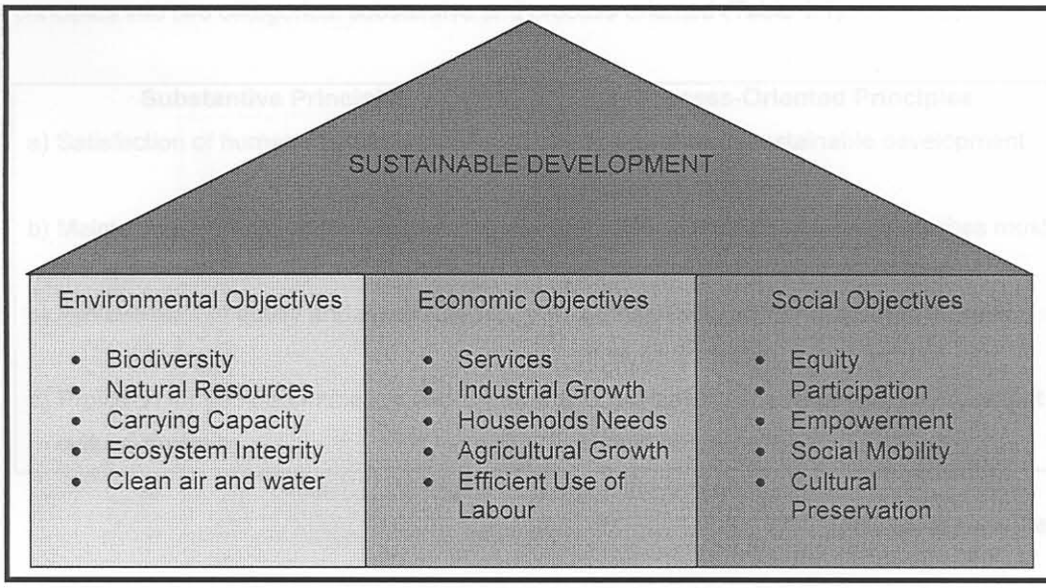


Figure 1.1: Objectives of Sustainable development

Source: World Bank Group, 1998.

According to Briassoulis (2001) "*Sustainable development can be conceptualized as a state of dynamic equilibrium between societal demand for a preferred development path and the supply of environmental and economic goods and services to meet this demand*" as shown in Figure 1.2.

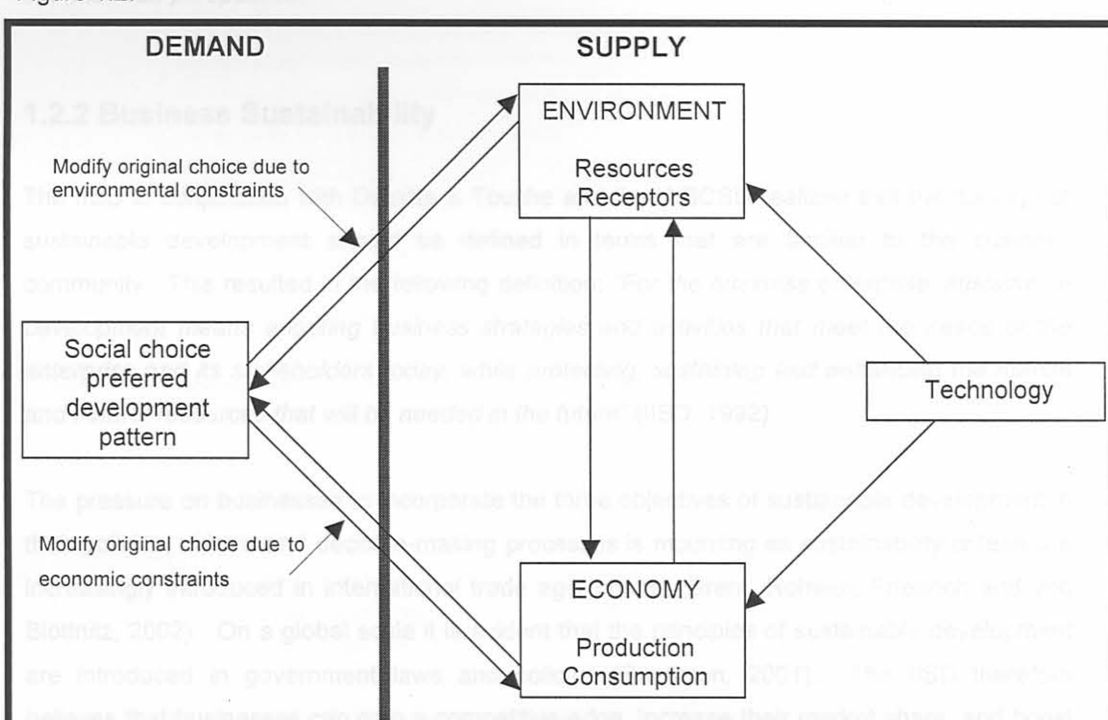


Figure 1.2: Schematic Presentation of Sustainable Development

Source: Briassoulis, 2001.

Gardner (1989) identified eight principles for Sustainable Development and divided the principles into two categories: substantive and process-oriented (Table 1.1).

Substantive Principles	**Process-Oriented Principles**
a) Satisfaction of human needs.	a) Approaches to sustainable development should be goal seeking.
b) Maintenance of Ecological Integrity.	b) Analytical aspects of the approaches must be relational and systems-oriented.
c) Achievement of equity and social justice.	c) Strategies for sustainable development must be adaptive.
d) Provision for self-determination and cultural diversity	d) Organization for sustainable development should be interactive.

Table 1.1: Principles of Sustainable Development

Source: Gardner, 1989.

It is evident that there is consensus on the objectives and basic principles of sustainable development but the details of how to achieve sustainable development or maintain sustainability are difficult to generalize as *"perceptions of and necessary actions for achieving sustainable development differ between social-cultural and political contexts and change over time"* (Lele, 1991; Henderson, 1994; O'Riordan & Voisey, 1998;Kane, 1999; Mormont et al., 1999; Schleicher-Tappeser,1999 as cited in Braissoulis, 2001). This is especially true from the business perspective.

1.2.2 Business Sustainability

The IISD in conjunction with Deloitte & Touche and the WBCSD realized that the concept of sustainable development should be defined in terms that are familiar to the business community. This resulted in the following definition: *"For the business enterprise, sustainable development means adopting business strategies and activities that meet the needs of the enterprise and its stakeholders today, while protecting, sustaining and enhancing the human and natural resources that will be needed in the future"* (IISD, 1992).

The pressure on businesses to incorporate the three objectives of sustainable development in their policies, culture and decision-making processes is mounting as sustainability criteria are increasingly introduced in international trade agreements (Brent, Rohwer, Friedrich and von Blottnitz, 2002). On a global scale it is evident that the principles of sustainable development are introduced in government laws and policies (Sampson, 2001). The IISD therefore believes that businesses can gain a competitive edge, increase their market share, and boost shareholder value by adopting and implementing sustainable practices.

IISD is also of the opinion that industry is on a three-stage journey towards sustainable development as graphically shown in Figure 1.3 and Table 1.2. (http://www.bsdglobal.com/sd_journey.asp).

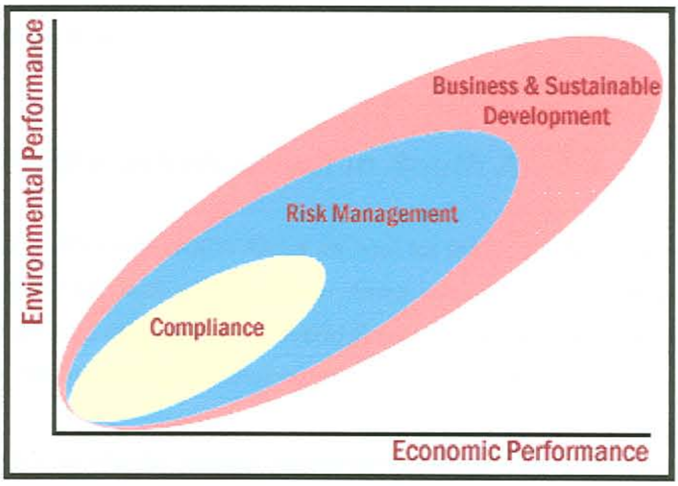
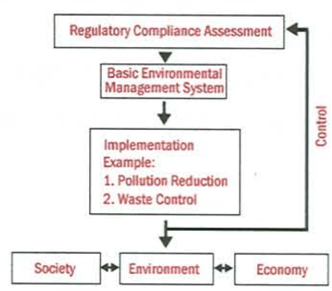


Figure 1.3: Three-stage journey towards sustainable development

Source: http://www.bsdglobal.com/sd_journey.asp

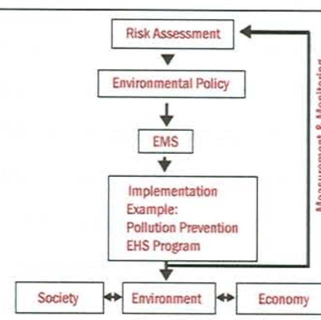
Stage 1: Compliance

The first stage is compliance with any regulatory measures or legislation. Most regulatory measures or legislations that are applicable to business focus on environmental aspects and most companies follow a reactive approach by making use of remediation and abatement measures. Environmental protection is often seen as an unnecessary costly burden during this stage.



Stage 2: Risk Management

Environmental risk management is stage two of the journey and companies enter this stage when they adopt more proactive strategies in dealing with environmental issues. Companies choose to go beyond compliance when the cost benefits of the risk management approach are realized.



Stage 3: Sustainable Development Strategies

The last stage is the stage in which companies start to incorporate sustainable development into their business strategies in pursuit of economic, environmental and community benefit. Environmental Quality, increase in wealth and enhancement in competitive advantages are the objectives that must be satisfied by win-win situations.

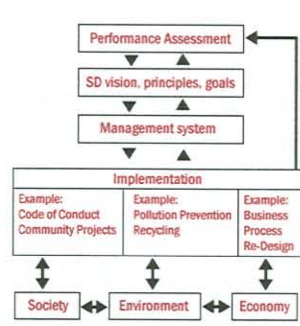


Table 1.2: The Three-Stage journey towards sustainable development

Source: http://www.bsdglobal.com/sd_journey.asp

Companies moving into stage three are increasingly concerned about initiatives such as corporate responsibility[1] and accountability[2], product stewardship and cleaner production mechanisms. Reporting of company sustainability is also an initiative undertaken by companies in stage three.

1.3 Sustainable Development in South Africa

The importance of choosing South Africa as host for the 2002 World Summit is emphasised through the citation of Cock (1991): *South Africa with its mix of First World environmental problems such as acid rain, and Third World Environmental problems such as soil erosion, is a microcosm of the environmental challenges facing the planet".*

South Africa has implemented various legislations over the past decade to ensure sustainable development and compliance with international expectations (Sampson, 2001). The global environmental drive in the marketplace has also been the catalyst for sustainability in South Africa and for this reason most of the legislation focused on environmental aspects. Legislation dealing with social aspects has been tabled but unlike environmental legislation it does not currently affect South African businesses in a direct way. The history and role of sustainable development can therefore be seen against the background of the way in which South Africa dealt with the environmental aspects.

1.3.1 Apartheid era

According to Khan (1990) (as cited in Sowman, Fuggle & Preston, 1995) evidence of concern for the environment can be traced to the earliest history of South Africa in terms of the practices and lifestyles of indigenous people as well as the initial conservation efforts of early foreign settlers and public officials, which focused on the protection of wilderness and wildlife resources. Khan believes that environmental degradation in South Africa as well as the negative, alienated stance of the majority of South Africans towards environmental issues in the late 1980's and early 1990's can be linked to the policies and practices of the colonial and apartheid eras. Environmental challenges or problems have consequently been largely ignored in South Africa's apartheid era.

South Africa was, however, still influenced by international events such as the Stockholm conference in 1972 and the first World Wilderness Congress[3] was held in Johannesburg in

[1] The concept refers to the "morals" of a company, which influence objectives or visions and consequently the selection of production methods, processes etc

[2] It refers to legal compliance; thus the way in which a company must ensure that its products, processes and operations conform to the prescribed norms and standards

[3] The aim of the World Wilderness Congress was/is to provide an international platform for the understanding and preservation of wild and natural areas.

1977. In 1982 the Environmental Conservation Act 100 was promulgated, which was mainly concerned with the coordination of environmental matters and contained limited provisions to regulate activities and/or decisions that might be harmful to the environment. This act led to the establishment of the Council for the Environment in 1983. The International Community exerted pressure on South Africa to introduce Environmental Impact Assessment (EIA) as a legal mechanism for regulating activities that might have an effect on the environment (Third World Wilderness Congress, Findhorn, Scotland, 1983).

In 1989 the new Environmental Conservation Act (Act 73 of 1989) replaced Act 100 of 1982. This act provided for the determination of environmental policy to guide decision-making and provisions existed to regulate activities that might have a detrimental impact on the environment. In the case of regulated activities EIAs had to be prepared. The Department of Environmental Affairs promoted Integrated Environmental Management[4] in 1992 by publishing a series of guideline documents and checklists (Sowman, Fuggle & Preston, 1995).

According to Horberry and Kennedy (as cited in Sowman, Fuggle & Preston, 1995) the key constraints for the development of environmental evaluation procedures in South Africa were:

- Absence of a general environmental policy
- Lack of political will and awareness of the need to consider environmental issues
- An authoritarian system of government
- Lack of accountability by decision-makers
- Inadequate public participation
- Inefficient administrative structures
- Lack of popular support for environmental issues
- Legislative inadequacies

1.3.2 Post-Apartheid Era

The political transformation from apartheid to democratic government has resulted in wide-ranging reviews of policy across sectors. The constitution that was accepted on 8 May 1996 and amended on 11 October 1996 is seen as the cornerstone of environmental law in the new South Africa (Sampson, 2001). The constitution recognises that all citizens have a right to an environment that is not harmful to their health or wellbeing and entrenches the notion of sustainable development and its supporting principles (Section 24). According to Sampson (2001) the constitution contains many other rights of relevance to the environment:

- The right to sufficient water (Section 27)
- Access to information (Section 32),

[4] *"IEM provides an integrated approached for environmental assessment, management, decision-making and to promote sustainable development and the equitable use of resources."* DEAT, 1998.

- Just administrative action (Section 33)
- Limitation of rights (Section 36)
- The application of rights (Section 8)
- The application of international and foreign law (Sections 39 and 233)

Figure 1.4 depicts the pyramid of sustainable development in terms of environmental law in South Africa.

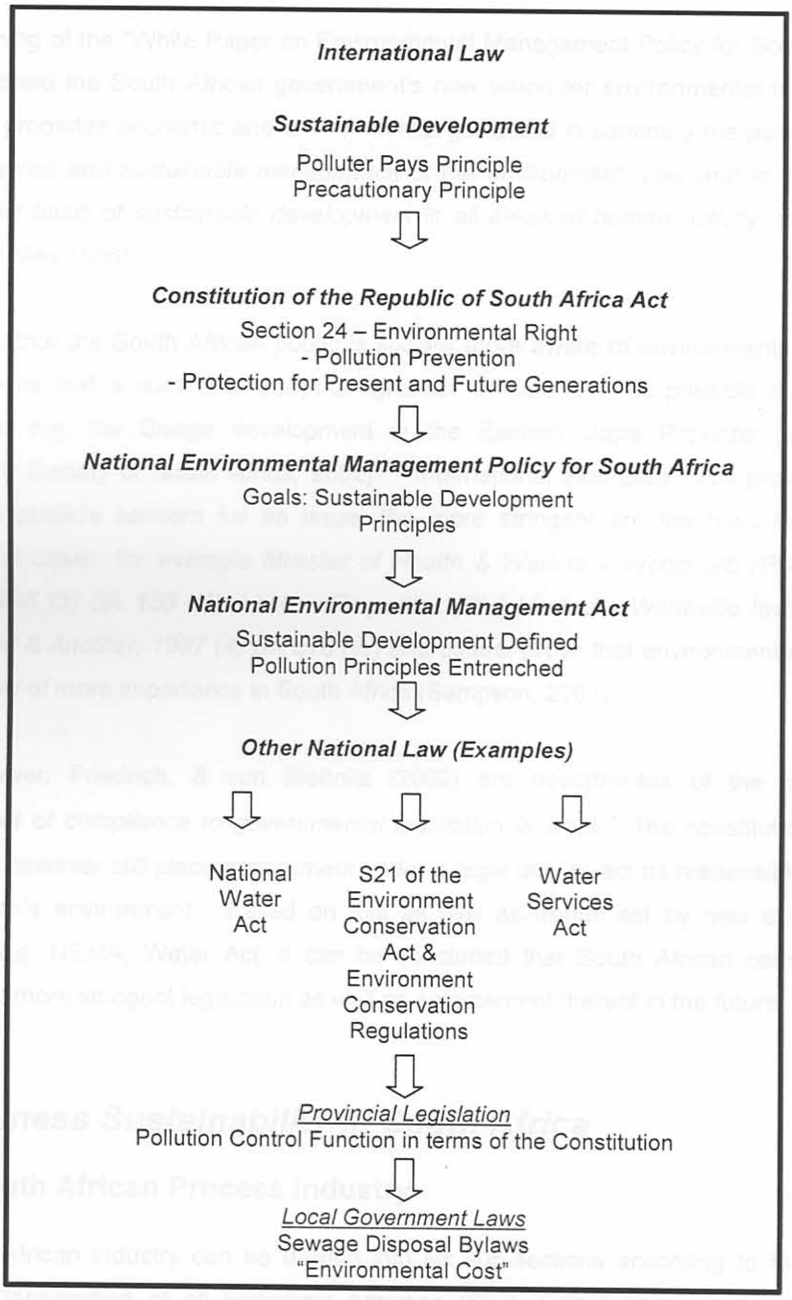


Figure 1.4: Sustainable development pyramid

Source: Sampson, 2001.

Environmental policies and legislation have developed and improved rapidly in South Africa during the past decade and are comparable to those of developed countries. The new water act as well as the new National Environmental Management act (NEMA) can be described as very progressive, particularly the provision for public participation (Government Gazette, 8 August 2002). Certain legislation, however, is out of date and is in the process of being revised, e.g. the Atmospheric Pollution Prevention Act of 1965 (Brent, Rohwer, Friedrich and von Blottnitz, 2002).

The publishing of the "White Paper on Environmental Management Policy for South Africa" in 1998 supported the South African government's new vision for environmental management. This policy promotes economic and environmental gains and in summary the policy emphasis that: "*integrated and sustainable management of the environment, now and in the future, is the essential basis of sustainable development in all areas of human activity*" (Government Gazette, 15 May 1998).

It is evident that the South African public is socially more aware of environmental impacts of human actions and is starting to adopt a 'greener' attitude towards possible developments and trends, e.g. the Coega development in the Eastern Cape Province (Wildlife and Environment Society of South Africa, 2002). International examples have proved that the greater the public's concern for an issue, the more stringent are the laws that develop. Recent court cases, for example *Minister of Health & Welfare v Woodcarb (Pty) Limited & Another, 1996 (3) SA 155 (N), Lascon Properties (Pty) Limited v Wadeville Investment Co. (Pty) Limited & Another, 1997 (4) SA 578 (W)* and others, prove that environmental issues are certainly now of more importance in South Africa (Sampson, 2001).

Brent, Rohwer, Friedrich, & von Blottnitz (2002) are nevertheless of the opinion that "*enforcement of compliance to governmental legislation is weak.*" The constitution of South Africa does however still place government under a legal duty to act as responsible custodian of the nation's environment. Based on this as well as trends set by new environmental legislation e.g. NEMA, Water Act, it can be concluded that South African companies can expect even more stringent legislation as well as enforcement thereof in the future.

1.4 Business Sustainability in South Africa

1.4.1 South African Process Industry

The South African industry can be divided into six sub-sections according to the Standard Industrial Classification of all Economic Activities (SIC), Fifth Edition used by the South African Statistical Services: Agriculture, forestry and fishing; Mining and quarrying; Manufacturing; Electricity and Water; Construction and Tertiary Sector. The SIC is based on the third revision of the International Standard Industrial Classification of all Economic Activities (ISIC), with suitable adaptations for local conditions.

The process industry, which is the focus of this document, forms part of the manufacturing sector and can be defined as the primary manufacturer or the first step in the supply chain where value is added to raw material (see Figure 1.5). The focus of the process industry is on the manufacturing of materials that can be used in the manufacturing of products and it hence forms the first part of the secondary industry sector.

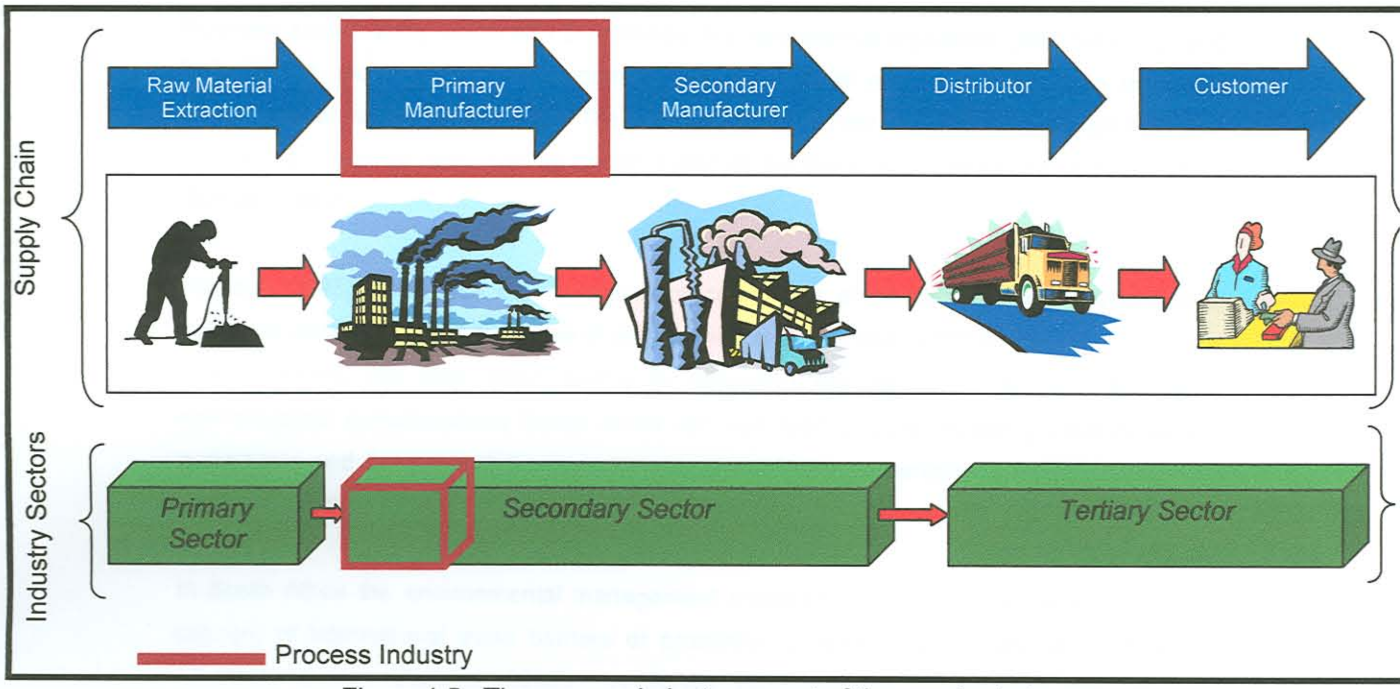


Figure 1.5: The process industry as part of the supply chain

The political transition from apartheid to a democratic government in South Africa also affected the process industry. During the apartheid regime most policies were strongly focused on national self-sufficiency and due to economic sanctions during the latter half of the 1980's many industries were protected through economic incentive schemes (Brent, Rohwer, Friedrich and von Blottnitz, 2002). In the energy sector for example, the apartheid government invested considerable sums of public resources into large-scale energy supply infrastructure such as SASOL, MOSGAS, the Koeberg Nuclear power station and others. These massive investments occurred over a period of more than thirty years; in the same period a complex regulatory system was put in place to protect these energy supply infrastructures and enormous subsidies and levies were granted to the industry (Van Horen 1996).

The manufacturing sector has been dominated by heavy industries relating to petroleum, chemical and metallurgical products prior to 1990, but in 2001 less than 4% of the total Gross Domestic Product (GDP) of South Africa was attributable to the chemicals manufacturing industry (Brent, Rohwer, Friedrich and von Blottnitz, 2002). With the political transition of the early 1990's new forces manifested themselves at policy level in the form of global market opportunities and companies had to come to terms with the reality of South Africa again being part of the international community. In order to survive, companies had to make the mind shift at policy level from national self-sufficiency to global competitiveness. "Green" issues are of greater concern internationally and a pre-requisite for global competitiveness is an environmental friendly image and therefore all concepts of business sustainability apply to the South African process industry.

1.4.2 State of Business Sustainability in South Africa

Business sustainability starts with compliance to environmental legislation (see Table 1.2) and typically the more dependent a company is on natural resources the more important environmental valuation becomes. The ethos of "develop now, minimize associated cost and, if forced to, clean up later" can no longer dominate the thinking of companies in South Africa (Barrow, 1997).

Blignaut (1995) postulates that countries or companies place self-imposed environmental sanctions on its exports if the issue of environmental awareness is not addressed. Sampson (2001) echoes this idea when saying by accepting and falling in line with first world environmental considerations South Africa can sell itself globally as being environmentally sustainable and thus exploit the investment opportunities and benefits of being regarded as environmentally conscious.

In South Africa the environmental management practices of most companies are driven by concern of international trade barriers or promotion by parent companies (Brent, Rohwer, Friedrich, & von Blottnitz, 2002). A survey conducted by KPMG and the Industrial Environmental Forum (IEF) also identified international trade as one of the four drivers that are setting the pace of environmental transformation in South African industry, the other three drivers are customer demands, public opinion and government policy and legislation (Visser, April 2002).

South African companies will therefore have to adapt to changing times by introducing the ethic of sustainable living into their corporate culture, policies, goals and philosophies. The Southern African Nature Foundation (SANF) and the IUCN published a strategy for sustainable living in South Africa in 1993 in which it states that companies can adapt their culture, policies, goals and philosophies as well as contribute to sustainable living by:

- *"adopting sound practices, from the planning stage through to realization, that avoid environmental damage; monitoring all impacts and consulting with local communities and the public at large;*
- *introducing processes that use minimum quantities of raw materials and energy, reduce waste and prevent pollution; and*

- *producing "environmentally-friendly" goods which have a minimum negative impact on human communities and the Earth"* (Yeld, 1993).

Sustainability principles can only manifest themselves within the company if the decision-making processes of companies incorporate sustainability objectives. A few international companies in South Africa are making the sustainable development mind shift and is starting to report on their sustainability. This new paradigm is nonetheless not part of general business culture yet.

1.5 Aim of the dissertation

This dissertation focus on the first suggestion of the SANF and IUCN namely *"adopting sound practices, from the planning stage through to realization, that avoid environmental damage; monitoring all impacts and consulting with local communities and the public at large"*
Sound practices can only be adopted if the methods used to implement these practices integrates and evaluates every aspects of environmental sustainable development objectives within its decision-making processes. Within this context, the aim of the dissertation is to develop a decision-making framework for projects in the process industry that incorporates environmental sustainability criteria.

1.6 Layout of document

The layout of the rest of the document is shown in Figure 1.6.

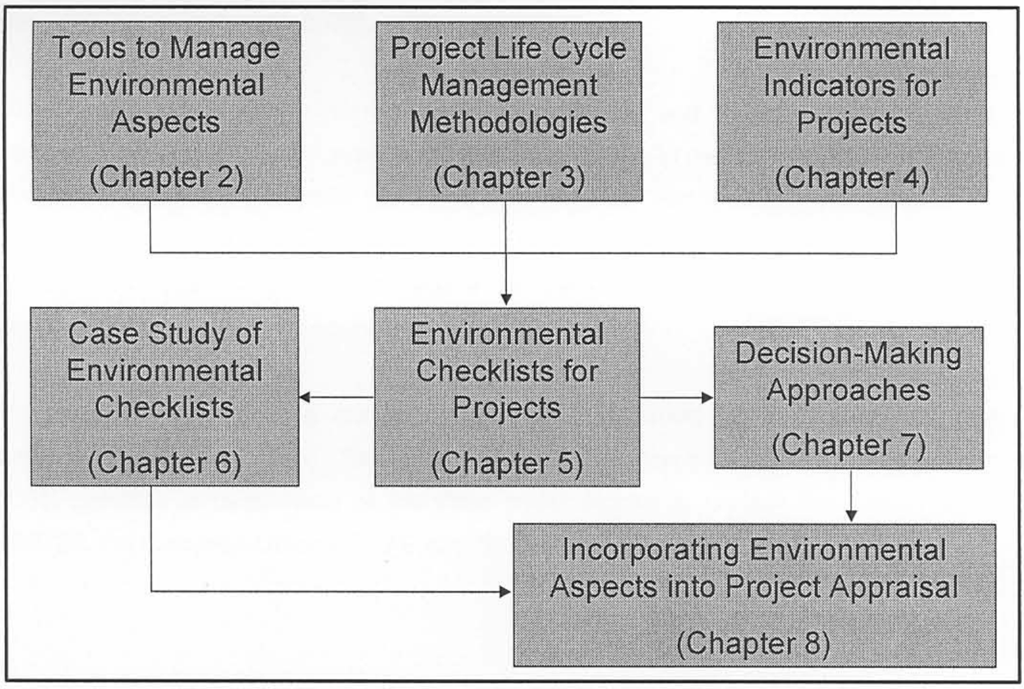


Figure 1.6: Layout of document

1.7 Conclusion

In the last few decades of the twentieth century man's attitude towards and view of the environment have changed dramatically. Economists and ecologists widely believe that the current environmental problems are the results of the social and economic paradigms that existed in society since the eighteenth century. Man has finally realised that the greatest threat is no longer from the armed forces of other nations, but in the massive and accelerating decline of the global environment (Caldwell, 1989). The international community has reacted to these environmental problems and a guaranteed environmental right has been written into the constitutions of at least 54 countries (Winstanley, 1995).

South African companies are facing the new challenges and emerging opportunities due to new international environmental laws, changing policies and globalisation. In order to do so the decision-making processes within companies must integrate and evaluate every aspect of environmental sustainable development.

The dissertation investigates the environmental pillar of sustainable development and proposes a decision-making framework for projects that incorporate environmental sustainability criteria.

Chapter 2: Environmental Management Tools

2.1 Introduction to Environmental Management

Society has identified various valid reasons *why* attempts must be undertaken to protect and conserve the environment, while the concept of "Sustainable Development" answers *what* needs to be done to achieve these goals. Environmental Management represents *"a set of practical tools that attempts to answer HOW this will be done"* (UNDP, 2002).

Environmental Management is defined as *"the process of allocating natural and artificial resources so as to make optimum use of the environment in satisfying basic human needs, if possible for an indefinite period, and with minimal adverse effects"* (Barrow, 1997).

It is a relatively new discipline for two reasons. Firstly, environmental issues were usually dealt with by engineers and technical people and not at management level. Secondly, until recently, companies believed that their environmental responsibilities ended at contributing to environmental endeavours, e.g. publishing books on environmental topics such as wildlife or endangered species and sponsoring ecological projects, and it was not integrated in the overall business practices. The development of extensive environmental regulations and the constant growth in environmental awareness, however, caused industry to rethink the role of environmental management in business practices. Engineers and technical people no longer possessed all the competencies needed to manage environmental issues; a more pro-active approach was needed. This resulted in the specialised field of environmental management (Tibor,1996, Labuschagne, 2002).

The increase in the cost of environmental protection as well as legal liabilities led to the development of a more system-oriented approach to environmental management. Governments across the globe promoted environmental management tools as well as the concept of integrated environmental management (IEM). An integrated Environmental Management System (EMS) can help a company manage, measure and improve the environmental aspects of its operations (Tibor, 1996).

Various standards were and are being developed in an effort to standardize procedures in environmental management. Table 2.1 (Grace, Grace, Perez & Maywah,1999 and Barrow, 1996) provides a comparison of the three major standards namely: the British Standard BS7750, the European Union's EMAS and ISO 14000.

	BS 7750	EMAS	ISO 14000
Focus Area	Whole organization, can be applied to any sector or activity	Specific sites an/or industrial activities	Whole organization, covers all activities, products and services
Frequency of Audits	Not specified	Maximum audit frequency at three years	Not specified can be negotiated
Focus on Environmental Performance	Audit is not concerned with environmental performance	Auditing is concerned only with environmental performance and compliance with relevant environmental legislation.	It is a process standard; this implies that the standards does not tell companies what environmental performance they must achieve but it offers building blocks for an environmental management system that will assist companies in achieving their own performance goals
Information that must be publicly available	Environmental policy programme and management system	Environmental Policy	Environmental Policy
Countries	UK and a few other	European Union	Internationally
Application	Open to non-industrial activities[1]	Non-Industrial Activities included on experimental basis	Applicable to non-industrial activities
Date of Acceptance of Standard	1992	1993	1996
Criticized Aspects of standard	1. Standard can be obtained by *promising* to improve. 2. Small companies find cost a problem.	1. Auditing Criteria are too vague. 2. It costs too much. 3. It badly disrupts activities of organizations. 4. It may generate hostility from the public and workforce.	1. Standard does not require sufficient public disclosure of company's environmental impacts. 2. Standard does not guarantee environmental performance or compliance with applicable national environmental legislation.

Table 2.1: Comparison between BS 7750, EMAS and ISO 14000

Sources: http://www.gdrc.org/uem/iso14001/info-3.html
Grace, Grace, Perez & Maywah, 1999.
Barrow, 1996.

[1] Non-Industrial activities are activities like transport, local government, etc.

2.2 ISO 14000

The growing need for one international EMS standard as well pressure on companies to demonstrate better environmental stewardship and accountability led to the development and publication of the ISO 14000 standards within two years. ISO 14000 thus aims to achieve "*standardization in the field of environmental management and tools*" (Tibor, 1996).

The Technical Committee 207 (TC 207) of the International Organization for Standardization (ISO) remains the driving force behind the ISO 14000 standards and has clearly distinguished two main focus areas of an EMS (See the internal organization for TC 207, Figure 2.1):

- Focus on organization evaluation
- Focus on product and process evaluation

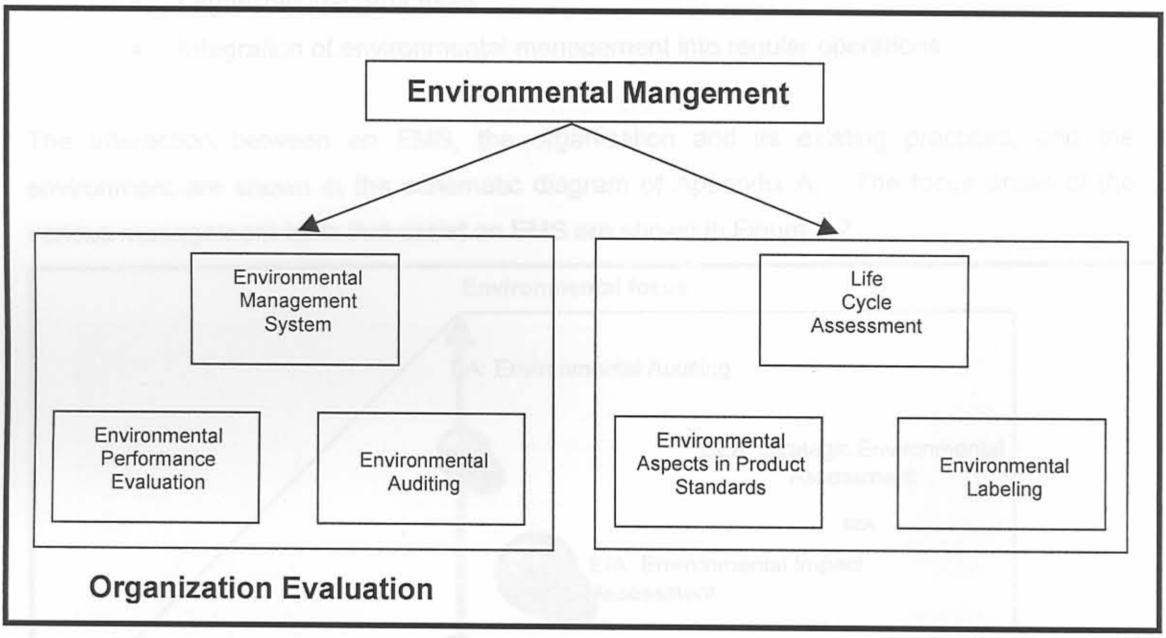


Figure 2.1: Focus areas of TC 207 committee

Source: Tibor, 1996

Tibor (1996) believes that the ISO 14000 standards are based on the simple equation that better environmental management will lead to better environmental performance, which will result in increased efficiency and a greater return on investment. The ISO 14000 family of standards clearly distinguish between environmental management systems and environmental management tools. The standards take the view that the implementation of an EMS is of central importance in determining an environmental policy, objectives and targets for a company. The recommended environmental tools can assist a company in realizing these targets and objectives (ISO, 1998).

2.3 *Incorporating ISO 14000 in existing business practices*

2.3.1 Environmental Management System (EMS)

ISO 14000 defines an Environmental Management System as *"that part of the overall management system which includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the organization's environmental policy"* (Tamura, 2002). Specific activities related to environmental protection and compliance can thus be effectively and efficiently carried out within the structure provided by an EMS. Tamura (2002) identified the following four core elements of any effective EMS:

- Environmental Policy
- Environmental Programme or Action Plan
- Organizational Structures
- Integration of environmental management into regular operations.

The interaction between an EMS, the organisation and its existing practices, and the environment are shown in the schematic diagram of Appendix A. The focus areas of the various management tools that assist an EMS are shown in Figure 2.2.

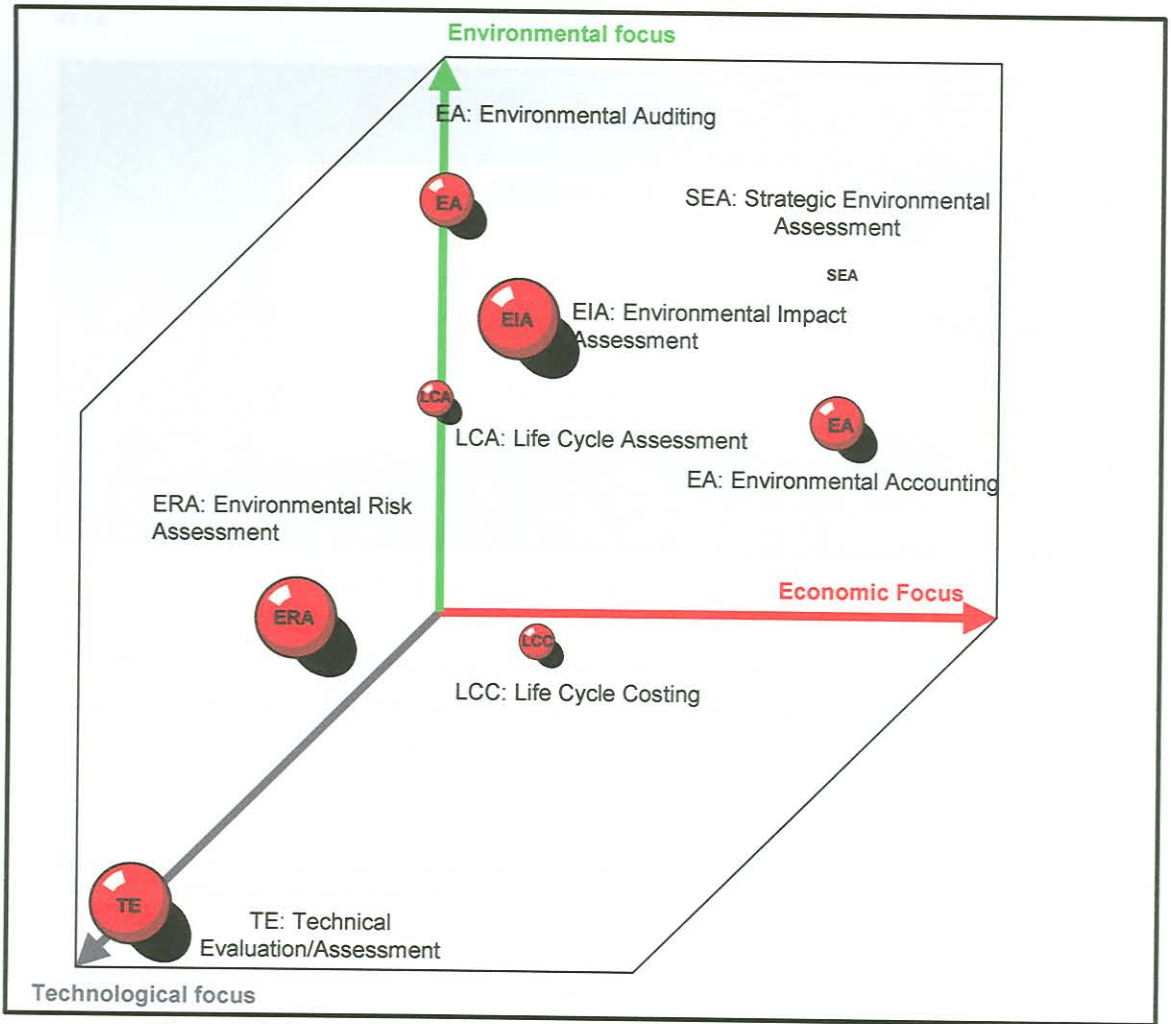


Figure 2.2: Focus Areas of different management tools for an EMS

Figure 2.2 shows that not one of the environmental management tools has a balanced economic, environmental and technological focus. Some of the tools do, nevertheless, incorporate certain economic and technical fundamentals. An understanding of concepts that integrate the economical, environmental and technical evaluation dimensions is therefore required.

2.3.2 Integrated concepts in environmental management tools

a) Environmental Costs

There is no universal definition for environmental costs (Ditz, Ranganathan & Banks, 1995). Although the United States' Environmental Protection Agency (EPA) states that each company can have a unique definition for environmental cost, it distinguishes between two dimensions of environmental costs:

- Private Costs: Costs that have a direct impact on a company's bottom line
- Societal Costs: Costs to individuals, societies and the environment (e.g. cleaning actions) for which a company is not accountable.

The relationship between these two dimensions is illustrated in Figure 2.3 (USEPA 742-R-95-001).

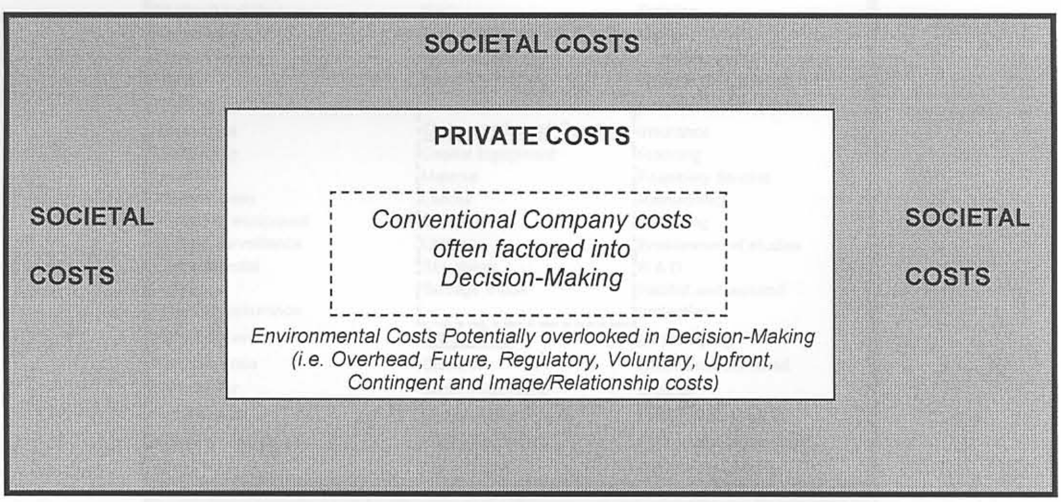


Figure 2.3: Private and Societal Environmental costs[2]

Source: USEPA 742-R-95-001

The US EPA further classified environmental costs incurred by companies into main categories (see Table 2.2 for definitions thereof and examples of each in Figure 2.4).

[2] Adapted by EPA from White, Becker, Savage, 1993, Environmentally Smart Accounting: Using Total Cost Assessment to Advance Pollution Prevention. *Pollution Prevention* Summer: 247-259

Type of Environmental Cost	Definition
Regulatory Costs	Also known as "compliance costs", it is all the costs incurred by a company in order to comply with national or local environmental laws.
Upfront costs	Pre-acquisition or pre-production costs incurred for new processes, products, facilities or systems.
Voluntary costs	Costs incurred by the company to go beyond compliance with environmental laws.
Conventional Costs	Costs typically recognized in capital budgeting exercises.
Back End costs	Environmental costs that arise following the useful life of processes, products, systems or facilities. It can thus be all the costs that must be incurred for proper closure, decommissioning and clean-up at the end of the useful life of a process, system or facility.
Contingent Costs	These are environmental costs that might occur in the future but depend on uncertain future events. Also referred to as "environmental liabilities", "liability costs" or "contingent liabilities".
Image and Relationship Costs	Also termed "Less tangible costs". It refers to costs incurred for corporate image purposes or for maintaining or enhancing customer relationships or relationships with the general public, regulators and suppliers.

Table 2.2: Environmental Cost Definitions

Source: USEPA 742-R-95-001

Potentially Hidden Costs		
Regulatory	**Upfront**	**Voluntary (Beyond Compliance)**
Notification Reporting Monitoring/Testing Studies/Modelling Remediation Recordkeeping Plans Training Inspections Manifesting Labelling Preparedness Protective equipment Medical surveillance Environmental insurance Financial assurance Pollution Control Spill response Stormwater mangement Waste Management Taxes/fees	Site studies Site Preparation Permitting R&D Engineering and procurement installation **Conventional Costs** Capital Equipment Material Labour Supplies Utilities Structures Salvage Value **Back End** Closure/ decommissioning Disposal of inventory Post closure care Site Survey	Community Relations/ outreach Monitoring/testing Training Audits Qualifying suppliers Reports (e.g. annual environmental reports) Insurance Planning Feasibility Studies Remediation Recycling Environmental studies R & D Habitat and wetland protection Landscaping Other Environmental projects Financial Support to environmental groupd and/or researchers
Contingent Costs		
Future Compliance costs Penalties/fines Responses to future releases	Remediation Property Damage Personal Injury damage	Legal expenses Natural resource damage Economic loss damages
Image and Relationship Costs		
Corporate Image Relationships with customers Relationships with investors Relationships with insurers	Relationship with professional staff Relationship with workers Relationship with suppliers	Relationship with lenders Relationship with host communities Relationship with regulators

Figure 2.4: Environmental Costs incurred by companies

Source: USEPA 742-R-95-001

Evidence presented in case studies of the World Resource Institute (WRI) show that environmental costs can account for up to 20% of total cost of a project, process or product. Traditional accounting practices tend to hide these environmental costs, due to the following practices:

- Costs are "buried" in non-environmental accounts.
- Costs are not linked to the activities that generate them (Ditz, Ranganathan, & Bank,1995).

b) Environmental Impact

Julien, Fenves & Small (1992) define an environmental impact as *"a cause-effect relationship between a source, the cause of the impact, and a receptor, the environmental element affected by the impact"*. The impact can either be direct or indirect, both of these can also be cumulative impacts. An indirect impact is an impact between interacting environmental elements. The Council on Environmental Quality (CEQ) regulation section 1508.7 (1978) defines a cumulative environmental impact as *"the impact on the environment that results from incremental impact of the action when added to other past, present, and reasonable foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions"* (as cited in Canter & Kamath, 1995).

Environmental impacts are often described in terms of cause-effect chains that link emissions and activities to the consequences (Figure 2.5) (Finnveden, G.; Andersson-Sköld; Samuelsson, M.O.; Zetterberg, L.; Linfors, L.G. (1992) as cited in Brent, 2002). These chains show that impacts can be described at different levels of effects, e.g. a direct impact is a primary effect. The example of greenhouse gas release is used in Table 2.3 to illustrate the different levels of effects (Baumann, H.; Tillman, A.M. (1999) as cited in Brent ,2002).

Graedel & Allenby (1995) stress the important fact that *"most sources of emission to the environment have multiple effects, and most effects have multiple causes"*

ISO 14000 Terminology	Level	Cause – Effect
Aspect	Activity	Combustion processes, e.g. electricity generation from coal
	Pollutants emitted	Carbon dioxide (CO_2), methane (CH_4), etc.
Impacts	Primary effect	Radiative forcing, i.e. absorption of thermal infra-red radiation in the atmosphere
	Secondary effect	Increase in global temperature
	Tertiary effect	Ice-melting, rising sea levels, change in weather patterns
	Further effects	Specific changes in ecosystems

Table 2.3: Different levels of effects caused by greenhouse gas release

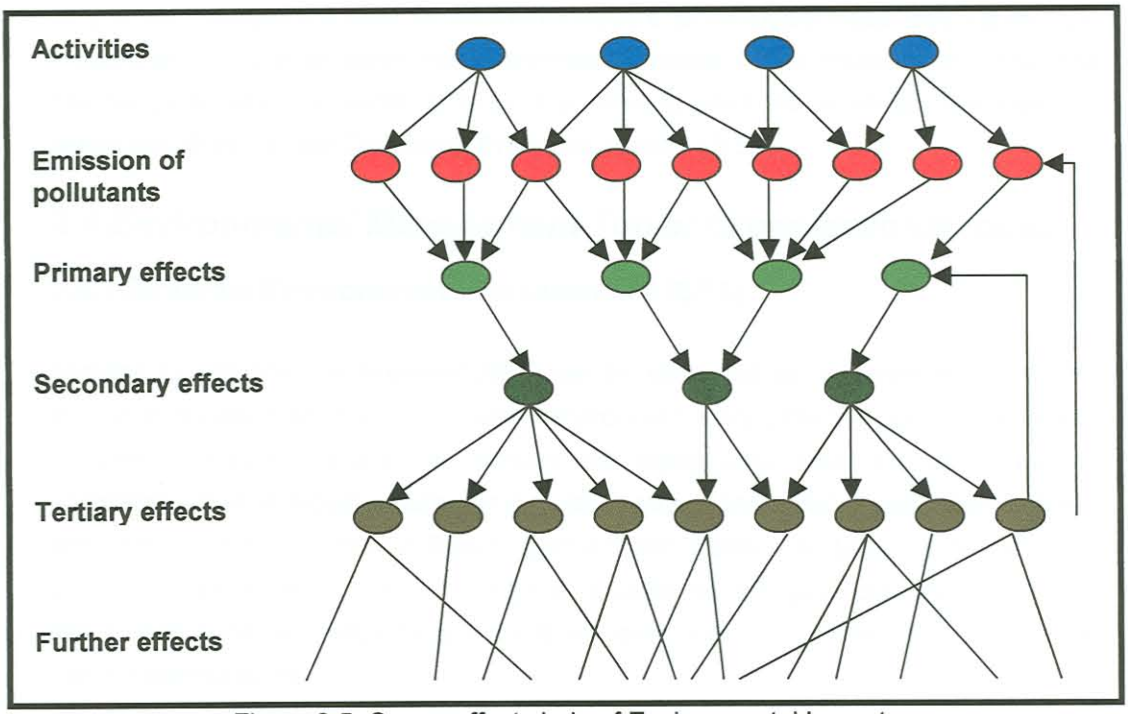


Figure 2.5: Cause-effect chain of Environmental Impacts

Source: As cited in Brent, 2002.

c) Technology Aspects

Van Wyk (1988) defines technology as *"created capability: it is manifested in artefacts, the purpose of which is to augment human skill."* Pretorius (2002) distinguishes between four types of technology (see Table 2.4) and states that technology progresses through different stages (see Table 2.5).

Technology type	Definition of Technology Type
Product Technology	Technology directly related to performance of product
Process Technology	Technology directly related to manufacturing process
Support Technology	Technology indirectly related to manufacturing, e.g. distribution
Information Technology	Technology associated with gathering, storage and access to information related to product, manufacture and support

Table 2.4: Types of Technology

Source: Pretorius (2002)

Technology Stage	Definition of Technology Stage
Emerging Technology	New technology, not widely known
Pacing Technology	A few companies make use of the technology
Key Technology	Technology is known and essential to the business
Base Technology	Technology is widely applied across the industry

Table 2.5: Technology Stages

Source: Pretorius (2002)

Only a few management tools for an EMS include a technological focus (see Figure 2.2). Those that do focus on either the environmental impacts of the chosen technology (see Technology Assessment, section 2.5.4) or the extent to which the technology can meet the design specifications (see Technology Evaluation, section 2.5.5.c))

2.4 Environmental Management Tools: Organizational focus

2.4.1 Strategic Environmental Assessment (SEA)

Strategic Environmental Assessment (SEA) can be interpreted as *"a systematic process for evaluating the environmental consequences of proposed policy, plan or programme initiatives in order to ensure they are fully included and appropriately addressed at the earliest appropriate stage of decision-making on par with economic and social considerations"* (Sadler and Verheem (1996), as cited in Dalal-Clayton & Sadler, 1998). An SEA can include socio-economic impacts, macro-economic impacts, impacts on biological diversity and human health, institutional and instrumental impacts and even cumulative impacts on e.g. resource use or water resources.

The aim of an SEA is to contribute to the achievement of sustainable development by promoting integrated environment and development decision-making. Consideration towards best practice environmental options and alternatives for the design of sustainable policies and plans is promoted through the tool. Furthermore, it is not necessary for an SEA to fulfil the same procedural obligations of a typical environmental impact assessment (Partidário, 2000). The purpose of an SEA is to provide a framework within which EIAs can be performed as well as to add value to the decision making process.

A study initiated by the European Union and conducted by ICON (2001) identified four broad models of SEAs:

- EIA-inspired SEA: Originated from ecological and/or resource management disciplines. This type of SEA is used at programme level and includes a systematic assessment procedure with more emphasis on technical methodologies.
- Policy analysis/appraisal-inspired SEA: This type of SEA does not include a baseline survey, has little or no public involvement and appraises options against objectives. It originated from political science.
- Integrationary SEA: This is a combination of an EIA inspired SEA and an appraised-inspired SEA. It has public participation as a vital component and impacts are appraised against a combination of the environmental baseline survey and the objectives.
- Ad hoc SEA: There is no systematic process and practices like environmental auditing and state of the environment reports are used to provide information.

The relationship between the four models is graphically shown in Figure 2.6.

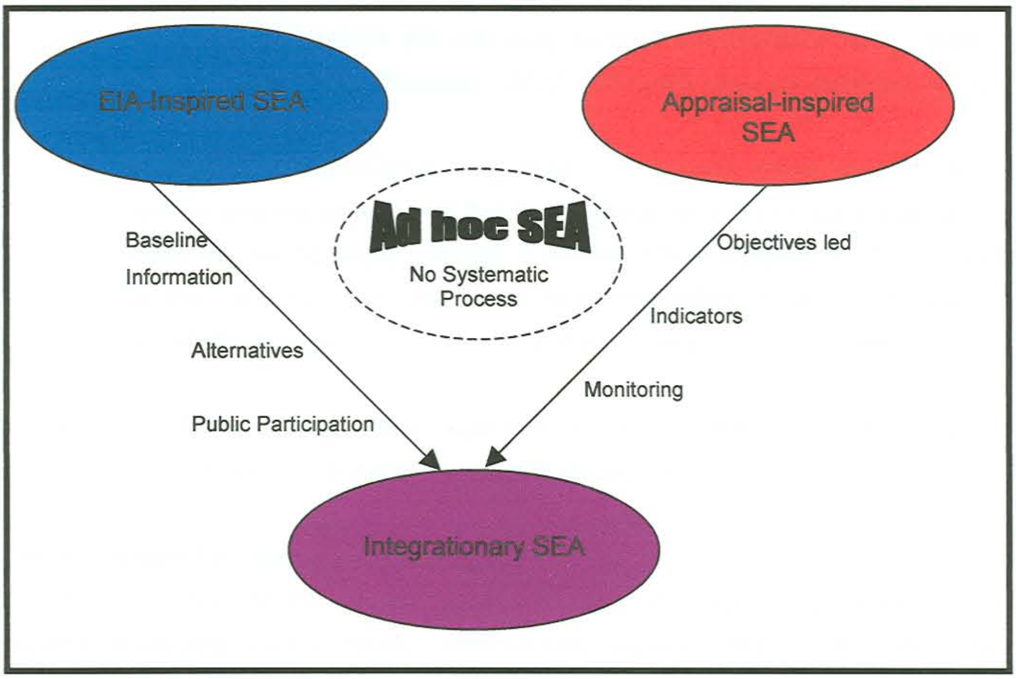


Figure 2.6: Relationship between different SEA Models

Source: European Commission Contract B4-3040/99/136634/MAR/B4; 2001

An SEA considers environmental and economic aspects in broader terms through a holistic approach and lacks a technology specific analysis. An SEA is not designed for purposes of assisting in detailed process or product designs.

2.4.2 Environmental Accounting

a) Definition & Goal of Environmental Accounting

The inability of economic theory and traditional accounting practices to address environmental costs was already identified by Tinbergen in 1976 (Blignaut, 1995). This led to the emergence of a whole new field in accounting, i.e. environmental accounting. Numerous definitions for the term environmental accounting exist. Blignaut (1995) defines it as "*the act of ascribing a value, a monetary unit, to what was previously conceived as free (or as unimportant) – the environment and natural resources.*" The United States' Environmental Protection Agency (EPA) distinguishes between three different types of environmental accounting namely:

- Natural Resource Accounting: This is a macro-economic measure where the focus is on the nation. This field can be used to express the consumption of the nation's natural resources (both renewable and non-renewable) in physical or monetary units. Indicators include Gross Domestic Product taking environmental costs into consideration.

- Environmental accounting in the context of financial accounting: In this context the focus is a company and it refers to the estimation and public reporting of environmental liabilities and financially material environmental costs. Generally Accepted Accounting Principles (GAAP) forms the basis for reporting within this context.
- Managerial Environmental Accounting: The main difference between this context and the other two is that the audience for this context is internal. The focus may be the whole company, a division, a facility, a specific product, system or line. Managerial Environmental Accounting refers to the use of data about environmental costs and performance in business decisions and operations.

The goal of Environmental Accounting, regardless of which context, remains to increase the amount of relevant financial information available to decision makers.

b) Problems with Environmental Accounting

After the publication of the United Nation's "System of Integrated Environmental and Economic Accounting" (SEEA), Holub, Tappeiner and Tappeiner(1999) identified the following two main problems with environmental accounting:

- The fundamental incompatibility of economic and ecological scales.
- The questionable emphasis placed on data artificially generated with hypotheses instead of making use of empirical observational data.

Environmental Accounting does not bring economic and environmental considerations successfully together for all aspects and consequently does not fully incorporate environmental issues into decision-making. However, the results from the application of the tools can be useful at certain points in the decision-making process.

2.4.3 Environmental Auditing

United States' Environmental Protection Agency defines Environmental Auditing as *"a systematic, documented, periodic and objective review by a regulated entity of facility operations and practices related to meeting environmental requirements."* Barrow (1996) specifically refers to the multidisciplinary approach of environmental auditing and states that it is used to assess environmental performance of an organization, authority or even a region.

Auditing is a total voluntary process and it assesses *actual* impacts and effects of existing activities. This information can be used as "Hindsight Knowledge" in future developments and environmental assessments and provides feedback to an EMS.

Establishing standard procedures for the environmental auditing process is one of the tasks of TC 207, i.e. ISO 14010; ISO 14011 and ISO 14012. Fava, 1994 (as cited in Barrow) defined the following types of Environmental Audits:

- Site or Facility audit
- Compliance audit
- Issues audit
- Property Transfer audit
- Waste Audit
- Life Cycle Audit – process or product focus

Environmental Auditing marked the growing shift from companies merely complying with regulations to companies developing forward-looking sustainable environmental management strategies. Environmental Auditing can be economically justified, as practice has shown that it leads to more favourable insurance rates, improved public image and avoided legal action for environmental damage (Barrow, 1996).

The tool is divided into two broad categories:

- Industrial or private sector corporate environmental audits.
- Local authority or higher-level government environmental audits.

Barton and Bruder (as cited in Barrow) distinguish between two phases in environmental auditing:

- External – this refers to the collection of available data and the output of this phase should be a state-of-the-environment-report.
- Internal – this refers to the assessment of current policies and practices against the state-of-the-environment report.

Environmental Audits can be performed by consultants, government agencies or even "in-house". These audits start to play a key role in environmental management (ISO, 2002).

2.5 *Environmental Management Tools: Product/Process Focus*

2.5.1 Environmental Labelling

Barrow, 1996 defines an environmental label as *"a marker on goods indicating that those goods are 'environmental friendly'"*. Environmental Labelling is hence the assessment of a product by an independent judge. This tool does not require an environmental audit, but it does access the environmental impacts of a product and communicates this information to customers or consumers. The focus is therefore primarily on the product, while the process and organizational issues are taken into consideration some of the times.

Examples of environmental labelling the European Union that introduced an environmental labelling scheme in the 1990s. This scheme awards a label for a product if the impacts associated with the product is less than that for similar products.

This tool is criticized for the fact that it is not backed by adequate legally enforced standards and that it can consequently easily become a mere marketing gimmick (West, 1995 as cited in Barrow, 1996). The ISO 14020 standard is an attempt to standardise the general principles of environmental labels and declarations (ISO, 2002).

Within the South African context, the tool is only applicable where product export is considered, as no labelling scheme exists in South Africa. The tool also does not add value for internal decision-making purposes, as it does not focus on the processor's organizational issues. For these reasons, it is not currently formally applied or included in South African environmental management systems. However, the procedure of Environmental Labelling, does interact strongly with other tools, e.g. Life Cycle Assessment (LCA).

2.5.2. Environmental Risk Assessment (ERA)

Risk is defined as the likelihood that a harmful consequence will occur as the result of an action or condition. Risk Assessment is therefore defined as *"the process of assigning magnitudes and probabilities to adverse effects of human activities (including technical innovation) or natural catastrophes… This process involves identifying hazards and using measurement, testing and mathematical or statistical methods to quantify the relationship between the initiating event and the effects "* (Combined definition by Horlick-Jones and Suter as cited in Barrow, 1996). Risk assessment goes one step beyond hazard evaluation as it includes the quantitative estimate of the probability of occurrence of the hazard (Finizio & Villa, 2002).

Environmental Risk Assessment (ERA) is viewed as a sub-field of risk assessment and assesses the risks to the environment resulting form industrial activity, product usage, new developments or any other human intervention. It typically evaluates the probabilities and magnitudes of harm that can result from environmental contaminants.

The United Nations distinguish between two components of Environmental Risk Assessment:

- Human Health Risk Assessment
- Ecological Risk Assessment

The tool aims to minimize environmental impacts as well as impacts to humans while maximizing sustainability for any development or concept being assessed (Cardenas, 2002). In order to achieve these aims Environmental Risk Assessment should be incorporated into the decision-making process. The US Environment Protection Agency's definition of ERA also emphasises that risk assessment should be a decision-making process that promotes sound environmental decisions and not only a computational technique (Barnthouse, 1995 (as cited in Finizio & Villa, 2002).

The growing importance of environmental risk assessment causes management focus to fall on environmental risk management, i.e. these potential consequences that were assessed should be managed. Environmental Risk Management is defined as *"the process whereby decisions are made about whether an assessed risk needs to be managed and the means for accomplishing it"* (Linghurst et al, 1995 as cited in Finizio & Villa, 2002). Figure 2.7 illustrates the relationship between Risk Assessment and Risk Management.

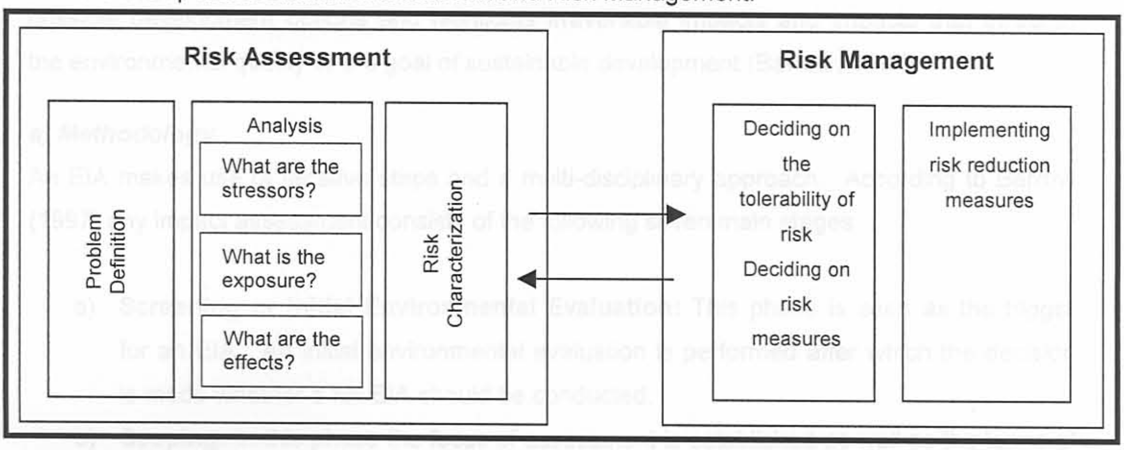


Figure 2.7: Relationship between Risk Assessment and Risk Management

Source: Health Council of the Netherlands
As cited in Eduljee, 2000.

Effective environmental risk assessment and risk management have economic benefits for a company as *"poor environmental risk management can undermine a firm's financial position and reduce stakeholders' confidence in the firm"* (Sharratt and Choong, 2002).

2.5.3. Environmental Impact Assessment (EIA)

Recorded history indicates that commissions were often charged with the task of examining the effects man's actions had or would have on the environment, society and human health. Similarities between these commissions and the modern environmental impact assessments (EIA) do exist. As an example, the Royal Commission's investigation into Weald Iron Mills and furnaces in Southern England in AD 1548 can be seen as an early version of an EIA (Fortlage (1990) as cited in Barrow, 1997). *"The EIA concept is rooted in the common sense wisdom that it is better to prevent a problem than to cure it"* (Kozlowski as cited in Barrow, 1997).

The concept of EIA was developed in reaction to the identification of the need to internalize environmental considerations in planning, programming and decision making processes in order to improve the quality of decisions with respect to environmental matters (Armour, 1991). The 1969 National Environmental Protection Act (NEPA) of the USA is recognized worldwide as the formal inception of the environmental impact assessment (EIA) procedure (Sowman, Fuggle & Preston, 1995) and EIAs are now required in one form or another in more than half the nations of the world (Ortolano & Shepherd, 1995). The procedural, methodological and institutional arrangements as well as the scoping and quality of EIAs do, however, differ from country to country and an EIA is even viewed as a philosophy with little practical value by some (Ofori, 1991, Ortolano & Shepherd, 1995).

Environmental Impact Assessment (EIA) is defined as an accurate, critical and objective assessment of the likely environmental impacts of a development by making use of a multidisciplinary approach. The EIA usually compares the environmental impacts of various possible development options and highlights irreversible impacts and impacts that threaten the environmental quality or the goal of sustainable development (Barrow, 1997).

a) Methodology

An EIA makes use of iterative steps and a multi-disciplinary approach. According to Barrow (1997) any impact assessment consists of the following seven main stages:

a) **Screening or Initial Environmental Evaluation:** This phase is seen as the trigger for an EIA. An initial environmental evaluation is performed after which the decision is made whether a full EIA should be conducted.

b) **Scoping:** In this phase the focus of assessment is established as well as the terms of relevance for the Impact Assessment. Some countries, for example Canada, even have scoping legislation. Scoping can be done from different perspectives for example: bio-geophysical, socio-economic, physical, ecological etc.

c) **Consideration of alternatives:** The different alternatives considered by the project and on which the EIA should focus are decided on.

d) **Identification and Quantification of Impact:** An impact is a result caused by human activity and is not a natural effect. In this phase possible direct, indirect and cumulative impacts are identified; the significance of each impact is assessed, the likelihood of occurrence is evaluated and a forecast is made of how or when these specific impacts might manifest themselves. This stage is viewed as the core stage of an Impact Assessment.

e) **Mitigation and Avoidance Recommendations:** Suggestions of mitigation or avoidance measures are made during this phase.

f) **Communication of EIAs to Interested and Affected Parties (IAPs)**

g) **Review of the Impact Assessment**

In South African the Government Gazette of 5 September 1997 (DEAT, April 1998) published a list of activities for which an EIA is required in terms of sections 21, 22 and 26 of the Environment Conservation Act, 1989. The application and EIA process procedure that is suggested by the South African Department of Environmental Affairs and Tourism (DEAT) is shown in Appendix B.

b) Economical Aspects in Environmental Impact Assessment

The fundamental goal of incorporating economics in environmental impact assessments is to ensure that the cost of environmental effects is internalized and that minimal externalities[3] arise. The only difference between a traditional EIA and an EIA that incorporates an economic approach is the method in which significance is assigned to individual impacts. In traditional EIA's significance is assigned in an ad hoc manner while an economic approach measure the social and other costs and benefits of the impact rigorously and then expresses the significance in terms of one unit: monetary value (James, 1994).

The importance of economic analysis as a planning and evaluation method in environmental impact assessments is increasing due to the fact that this inclusion provides the process with a framework for the collection, analysis and interpretation of information. Advances in valuation methods make it easier to place an economic value on an environmental impact (see section 7.2). This type of information can then be incorporated into benefit-cost appraisals. The most practicable approach when economic approaches are incorporated into an EIA is thus to conduct the whole EIA as a cost-benefit analysis (James, 1994).

The appropriateness of these economic valuation methods for environmental impacts are, nevertheless, widely criticized and disputed (See 2.4.2).

[3] Cost of a company's impacts on the environment and society for which the business is not financially responsible.

c) Social Impacts in EIA or Social Impact Assessment

Social Impact Assessment (SIA) can be viewed as a subdivision of EIA or alternatively as the opposite end of the same spectrum of activities. SIA is defined as an assessment that it concerned with the impact of development on people, individually and/or groups, ranging from households up to global society (Barrow, 1996). SIA are also concerned with the impact of people on the development and the environment. Changes in the social paradigm can have direct consequences for development and an SIA must therefore take it into consideration.

Technology Assessments (TA) and Risk Assessments are other techniques that can either support an EIA or be integrated with EIA. Figure 2.8 shows the interrelationship of EIA, TA, SIA and Risk Assessment.

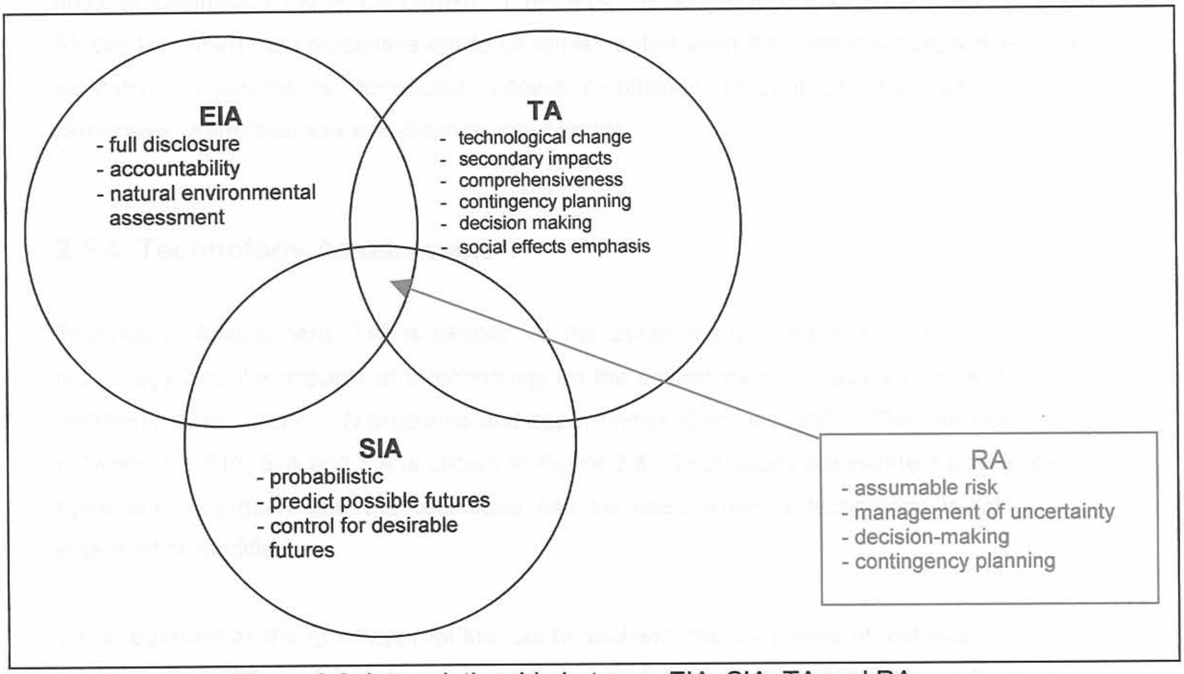


Figure 2.8: Interrelationship between EIA, SIA, TA and RA

Source: Barrow, 1997. Based on Covello et al (1985)

Social Impact assessment and risk assessment are, however, frequently omitted from EIAs as social impacts and other non-biophysical effects are not fully included in EIA legislation. EIA is accordingly in practice often narrowly focused on biophysical impacts (Ortolano & Shepherd, 1995).

d) Problems with the EIA process

One of the main problems with EIAs is that it is still not effectively utilized in the decision-making process neither integrated into the planning process, although various legislation are bringing EIA procedures into force. The reason for this can be the over-preoccupation with the process as too much focus on procedural requirements causes the contribution of impact assessment to be lost (Armour, 1991). Another major weakness of environmental impact assessments is the fact that it is still conducted on a reactive, project-by-project, short-term basis (Rees, 1988). Strategic Environmental Assessments attempt to address this weakness.

Barrow (1997) identifies the following problems with the EIA process:

- Cumulative Impacts are not assessed adequately and a Cumulative Impact Assessment (CIA) is necessarily for this purpose.
- Public Participation is often inadequate.
- EIA Monitoring is seldom conducted.
- Assessment of risk as well as social impacts is often omitted.
- EIA fails to ensure that developments are environmentally sound.

The contribution of EIAs to decision-making, albeit limited, cannot be overlooked where process commissioning is concerned. It remains the single tool that is required by South African law when new processes are to be implemented apart from standard procedures such as zoning requirements, scheduled process certificates, effluent permits, hazardous site certificates, water licenses and disposal site permits.

2.5.4. Technology Assessment

Technology Assessment (TA) is defined as the assessment of the risks associated with a technology and the impacts of a technology on the environment or society in order to inform decision-makers and clarify problems and opportunities (Barrow, 1996). The interrelationship between TA, EIA, SIA and RA is shown in Figure 2.8. Technology assessment also follows a systematic approach and the technique can be used when a technology is introduced, extended or modified.

TA is regarded as the most appropriate tool to deal with the unknowns of technical innovation as a hazard or risk assessment only examines established practices (1985 World Bank report as cited in Barrow, 1996). The history of TA dates back to approximately 1967 and as early as 1973 the United States Congress created the Office of Technology Assessment (OTA) with the objective of promoting the use of the tool.

A technology impact is a function of a variety of factors which include technology failure, operator failure, poor maintenance, poor design, faulty installation, natural or human accidents as well as adaptations prompted by innovation (Barrow, 1996). The focus of technology assessment is progressively shifting towards threats relating to morbidity or mortality and incorporates civil liberties and social impacts.

Coates and Porter (as cited in Barrow, 1996) promote the view that technology assessment supports sustainable development as the assessment can help to identify appropriate technology and practices for promising development paths while it also identifies potential and actual threats. On the other hand Porter and Rossini (1980) are of the opinion that EIA, SIA, TA an RA as well as other related approaches that support sustainable development should all be integrated into one tool (Barrow, 1996).

2.5.5 Life Cycle Engineering

The aim of life cycle engineering is to ensure holistic decision assistance by characterizing a product, process or technology by three dimensions: **ecology**, **economy** and **technology**. The whole life cycle of a product, process or system is considered in order to identify the phase that contains the relevant parts of a potentially negative effect in terms of environmental or economical impacts. Life Cycle Engineering consists of three supporting techniques, which are used to obtain interpretable results from available data:

- Life Cycle Assessment (LCA) that focus on ecologically relevant effects. The focus is thus on environmental objectives.
- Life Cycle Costing that focus on cost structures and economical implications of a product, process or system.
- Technology Evaluation that analyses processing and operating information.

The Life Cycle engineering methodology is shown in Figure 2.9.

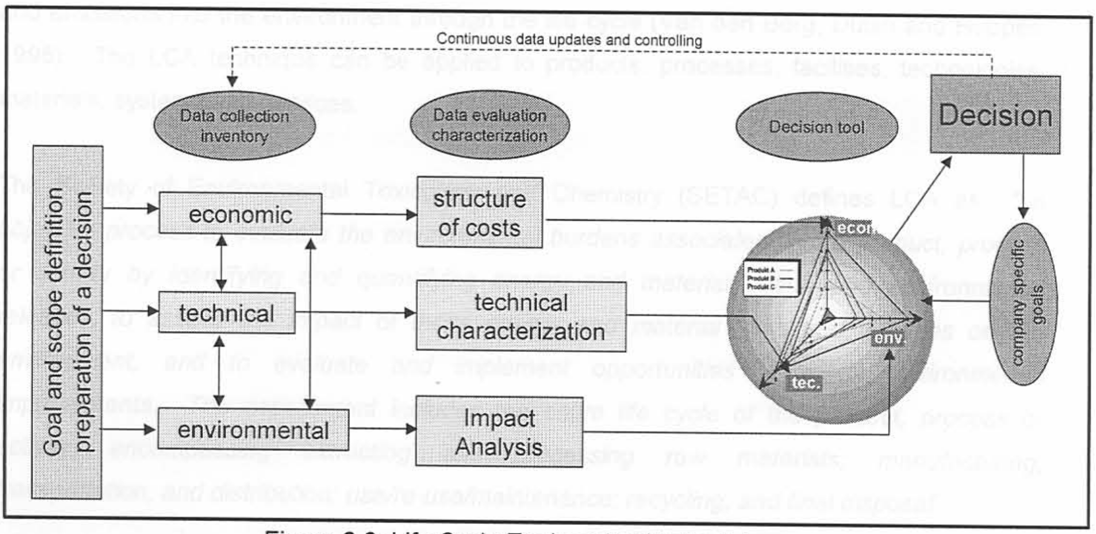


Figure 2.9: Life Cycle Engineering Methodology

Source: GaBi Software, 2002

The differences between LCC and LCA are summarized in Table 2.6.

Tool/Method	LCA	LCC
Purpose:	Compare relative environmental performance of alternative product systems for meeting the same end-use function, from a broad, societal perspective.	Determine cost-effectiveness of alternative investments and business decisions, from the perspective of an economic decision maker such as a manufacturing firm or a consumer.
Activities which are considered as part of the "Life Cycle"	All processes causally connected to the physical life cycle of the product, from pre-usage supply chain to processes supplying end-of-life steps.	Activities causing direct costs or benefits to the decision maker during the economic life of the investment, as a result of the investment.
Flows considered	Pollutants, resources and inter-process flows of materials and energy.	Cost and benefit monetary flows directly impacting decision maker.
Units for tracking flows	Primarily mass and energy; occasionally volume or other physical units.	Monetary units (e.g. $, R, euro)
Time treatment and scope	Timing of processes and their releases or consumption is traditionally ignored although the impact assessment can address a fixed time window. Future impacts are however generally not discounted.	Timing is critical. Present valuing of costs and benefits. A specific time horizon scope is adopted and any cost or benefits that occurs outside that scope is ignored.

Table 2.6: Differences between LCA and LCC

Source: Norris, 2001

a) Life Cycle Assessment (LCA)

Life Cycle Assessment deals with the environmental impacts of an activity over its entire life cycle (cradle-to-grave); these impacts are formed by all the extractions from the environment and emissions into the environment through the life cycle (Van den Berg, Dutilh and Huppes, 1995). The LCA technique can be applied to products, processes, facilities, technologies, materials, systems and services.

The Society of Environmental Toxicology and Chemistry (SETAC) defines LCA as *"an objective process to evaluate the environmental burdens associated with a product, process or activity by identifying and quantifying energy and material usage and environmental releases, to assess the impact of those energy and material uses and releases on the environment, and to evaluate and implement opportunities to effect environmental improvements. The assessment includes the entire life cycle of the product, process or activity, encompassing extracting and processing raw materials; manufacturing, transportation, and distribution; use/re-use/maintenance; recycling; and final disposal"*

The interaction between the main phases of LCA (as identified by SETAC) is shown in Figure 2.10.

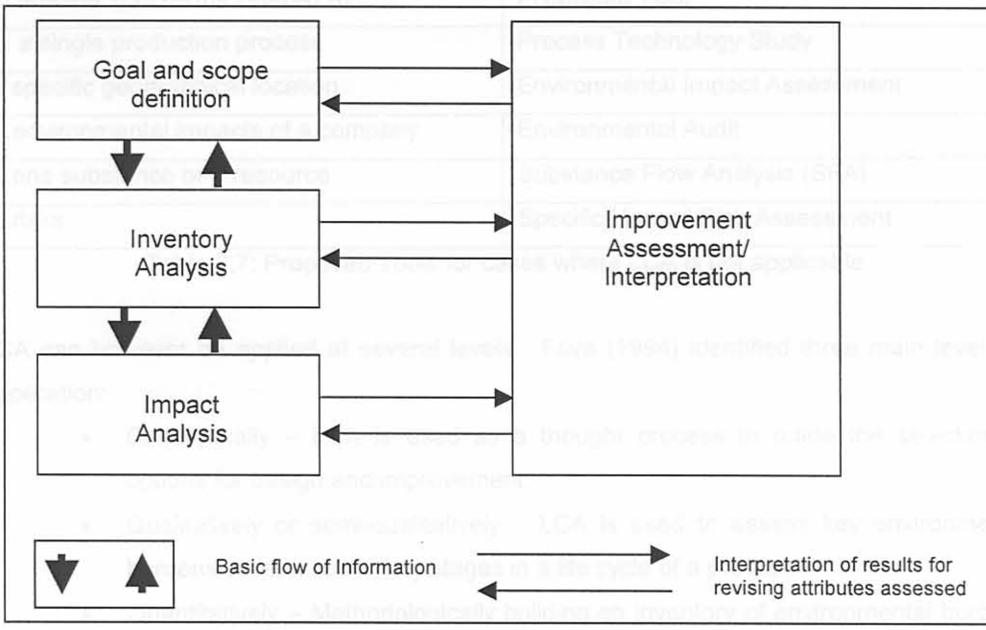


Figure 2.10: LCA Framework

Source: SETAC as cited in Graedel (1998)

The possible reasons for executing an LCA according to Van den Berg, Dutilh and Huppes (1995) are:

- To depict in as detailed way as possible the interaction of a product or activity with the environment.
- To ensure a thorough insight into the interdependent nature of the environmental impacts of a human activity.
- To supply decision-makers with information on the environmental impacts of activities and the possibilities for improvement.
- To compare the environmental impacts of different products with the same function or of one product with a reference or standard.
- To indicate strategically the direction of development and to assist in the design of new products and services.
- To identify the environmentally most dominant stage in a product or process life cycle and to then indicate the main routes to environmental improvements of existing products.

Table 2.7 summarizes situations in which LCA is not applicable and suggests better environmental management tools to use: (Van den Berg, Dutilh and Huppes, 1995).

To answer questions related to	*Proposed Tool*
.... a single production process	Process Technology Study
... specific geographical location	Environmental Impact Assessment
....environmental impacts of a company	Environmental Audit
....one substance or a resource	Substance Flow Analysis (SFA)
....risks	Specific Hazard Risk Assessment

Table 2.7: Proposed Tools for cases where LCA is not applicable

LCA can however be applied at several levels. Fava (1994) identified three main levels of application:

- Conceptually – LCA is used as a thought process to guide the selection of options for design and improvement.
- Qualitatively or semi-qualitatively – LCA is used to assess key environmental burdens or releases or key stages in a life cycle of a product.
- Quantitatively – Methodologically building an inventory of environmental burdens or releases, evaluating the impacts of those burdens or releases and considering alternatives to improve environmental performance.

According to Frankl, Rubik & Bartolomeo (2000) there is a wide range of other Life Cycle instruments that can also be used for the purpose of environmental management:

- Life Cycle Inventory (LCI) - this is a single phase in LCA and should be combined with improvement analysis in order to provide useful information to managers. In the past many "LCAs" carried out by companies were actually limited to LCI.
- Streamlined Life Cycle Assessment (SLCA) and Bottleneck LCA – both of these are simplified LCA's. Graedel (1998) discusses various approaches for SLCA's for example: Migros Concept, Dow Chemical Company Matrix, Monsanto Matrix and Jacob's Engineering Approach to name a few.
- Material Intensity Per Service unit (MIPS) and eco-point evaluations – these are methods that present a single aggregated number to describe the use and impacts of a product.

The major disadvantage of LCA is the fact that the methodology is time-consuming and may result in an expensive exercise. A wrongly defined system-boundary can cause the methodology to underestimate environmental effects (Hendrickson, Horvath, Joshi & Lave; 1998). Graedel (1998) regards the choice of a functional unit as another obstacle in the LCA process. An LCA without an LCC also limits the influence and relevance of the LCA for decision-making and results in an inability to capture the relationship between the environmental and cost consequences (Norris, 2001).

b) Life Cycle Costing

In 1976 White and Ostwald defined Life Cycle Costing as *"the sum of all funds expended in support of the item from its conception and fabrication through its operation to the end of its useful life"* (as cited in Woodward, 1997).

The Royal Institute of Chartered Surveyors identified the following four objectives for LCC in 1983:

- Enable more effective evaluation of investment options.
- Consideration of the impact of all costs and not only initial capital costs.
- Assist in the effective management of completed projects.
- Facilitate choice between competing alternatives.

In order to achieve the above mentioned objectives the following seven elements must be considered in LCC: initial capital costs, life of the asset, the discount rate, operating and maintenance cost, disposal cost, information and feedback and uncertainty and sensitivity analysis.

Life Cycle Costing methods is applied during product, process or system design and development by means of Life Cycle Cost Analysis (LCCA). A LCCA is defined as *"a systematic analytical process for evaluation various designs or alternative courses of actions with the objective of choosing the best way to employ scarce resources"* (Durairaj, Ong, Nee & Tan, 2002). Various LCCA methodologies exist and Table 2.8 compares nine different LCCA methodologies (Durairaj, Ong, Nee & Tan, 2002):

A. LCCA Model of Fabrycky and Blanchard
B. LCCA Model of Woodward
C. LCCA Model of Dahlen and Bolmsjo
D. Activity Based Costing (ABC) Model
E. Economic Input-Output (EIO) LCA Model
F. Design to Cost (DOC) Model
G. Product Life Cycle Cost Analysis (PLCCA) Model
H. Total Cost Assessment (TCA) Model
I. Life Cycle Environment Cost Analysis (LCECA) Model

The methodologies are discussed in more detail in Appendix C.

No	Features	Life Cycle Cost Analysis (LCCA) Methodologies								
		A	B	C	D	E	F	G	H	I
1	Objective	Cost Alternates	LCC of Assets	LCC of Labour	Cost Reduction	EIO Analysis	Cost Evaluation	LCC Estimates	TC Calculation	Eco-design
2	Identification of Alternatives	A	A	A	A	NA	A	NA	NA	A
3	Development of CBS & CBRs	E	E	E	E	G	G	G	A	E
4	Identification of Suitable Cost Model	E	G	G	E	A	A	A	A	E
5	Generation of Cost Estimates	E	E	E	E	NA	A	NA	A	G
6	Availability of Cost Profiles	G	A	A	A	NA	A	NA	NA	G
7	Break Even Analysis	A	A	A	A	NA	NA	NA	NA	A
8	Determination of High Cost Contributors	A	NA	NA	A	A	NA	NA	NA	A
9	Total Cost Determination	A	A	A	A	A	A	A	G	A
10	Incorporation of Eco-costs	NA	NA	NA	NA	NA	NA	NA	NA	G
11	Correlation with Design Changes	NA	NA	NA	A	NA	A	A	NA	A
12	Implementation of a Design solution	NA	NA	NA	A	NA	A	A	NA	A
13	Quality Aspects	NA	NA	NA	NA	NA	A	E	NA	NA
14	Inclusion of Supplier Relationships	NA	NA	NA	NA	E	NA	NA	A	A
15	Trade-offs	NA	E	NA	A	A	A	A	A	A
16	Employment Cycles	NA	NA	E	NA	A	NA	NA	A	NA
17	Sensitivity Analysis	A	A	A	A	NA	NA	NA	NA	A
18	Risk Analysis	A	A	A	A	NA	A	A	NA	A
19	De-manufacture Concept	NA	NA	NA	A	NA	A	A	NA	A
20	Any Special Feature	Holistic Model	Asset Model	Human Factor	Uncertainty	LCA Upgrading	Product system design	Redesign	For projects	Eco-design

A : Available; NA: Not Available; G: Good; E: Excellent

Table 2.8: Comparison of Existing LCCA Methodologies

Source: Durairaj, Ong, Nee & Tan (2002)

c) Technology Evaluation

Technology Evaluation as a technique focuses on the extent to which the technology can meet the design specifications. In order to determine whether technology can meet specifications technical data like process engineering and physical product properties must be determined and analysed (GaBi Software, 2002). The technique therefore relies on essential eco-design principles that must be applied within the constraints of the design. Technology evaluation can be seen as applying basic engineering principles; but the value there-off should not be underestimated as technology have a direct influence on cost, quality as well as competitiveness (Eversheim, Hachmöller & Rosier 2002).

d) Conclusion

The concepts behind LCE provide industry with new paradigms to build upon and the tool has a definite role to play in environmental management. The use of the three dimensions (economy, environment and technology) as points of consideration "*makes it possible to compare reasonably different technologies and to evaluate a project under the aspect of an overall optimum or an optimal compromise respectively*" (GaBi Software, 2002). Life Cycle Engineering enhances decision making by weaving cost, environmental and technological information into the decision-making process. Procedures to weigh the results of different aspects, i.e. environmental, economic and technical, and its implications on decision-making processes is part of on-going research (Petrie, Basson, Stewart, Notten & Alexander, 2001). One of the shortcomings of LCE, although much debated, is the lack of social considerations, especially in the LCA component (Sonnemann, Solgaard, Saur, Udo de Haes, Christiansen & Jensen, 2001).

2.6 Conclusion

The chapter aimed to clarify the unique focus of each one of the environmental management tools on environmental, economical and technological aspects (Figure 2.2). These tools are nonetheless not applicable in all phases of a system's life cycle and Figure 2.11 illustrates the application of the different tools through the life cycle of a system.

It is evident from Figure 2.11 and the discussion that the necessary environmental management tools to address environmental sustainability criteria do exist. Companies will have to decide which tools or part of the different tools the business needs to implement in order to achieve business sustainability. Concepts such as Life Cycle thinking and the sustainability paradigm must become part of business culture and cannot only be part of separate activities or processes. The same applies to tools such as environmental accounting that have to be implemented in the entire business. Business must apply the available environmental management tools and concepts to all core business practices and processes. A proactive approach is necessary to ensure future sustainability.

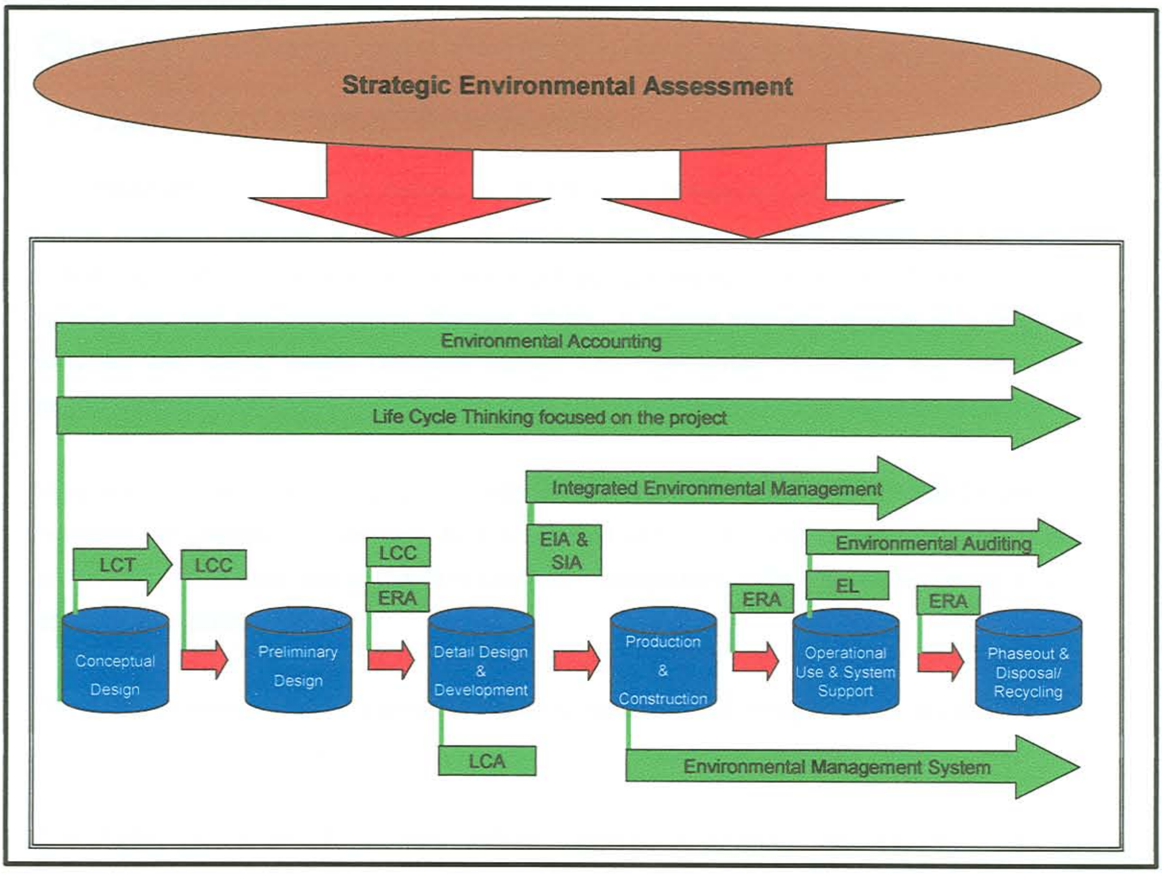


Figure 2.11: Environmental Management Tools applied over a generic System Life Cycle

In order to stay competitive companies need to be innovative and must be able to adapt speedily to any new challenges. Projects enable companies to accommodate new ideas for improvement and are often implemented as a means of achieving the company's strategic plan. In the South African process industry most new business practices or processes are driven by means of projects. A proactive approach can thus be achieved if corporate project management, as a core competency, incorporates business sustainability criteria.

Chapter 3: Corporate Project Life Cycle Management

3.1 History of Project Management

The PMBOK® Guide (2000) defines a project as *"a temporary endeavour undertaken to create a unique product or service"*. In the business environment a project can be better defined as a finite piece of work directed at achieving a stated business benefit within certain defined cost and time constraints (Buttrick, 2000). A project normally consists of a series of activities and tasks, which consume human and non-human resources and which are multifunctional.

In recent years projects have become strategic management tools and are frequently used as "vehicles" of change. In response to this the field of project management is no longer the preserve of specialists and a company's project management skills are fast becoming a core competence (Buttrick, 2000).

"Project Management, once considered nice to have, is now recognized as a necessity for survival" (Kerzner, 2001: xix).

The PMBOK® Guide (2000) also defines project management as *"the application of knowledge, skills, tools and techniques to project activities to meet project requirements"* while Meredith & Mantel (1995) defines it as *"the means, techniques and concepts used to run a project and achieve its objectives"*.

The growth of project management in the late 1980's and early 1990's was not only due to the recession of that time, but also to the development of new processes that supported project management (Kerzner, 2001). It has primarily been supported by the following concepts or philosophies that has been introduced or re-discovered since 1985:

- 1985: Total Quality Management
- 1990: Concurrent Engineering
- 1991-1992: Empowerment and Self Directed Teams
- 1993: Reengineering
- 1994: Life Cycle Costing
- 1995: Scope Change Control
- 1996: Risk Management
- 1997-1998: Project Offices and CEO's
- 1999: Co-Located Teams
- 2000: Multi-National Teams

Kerzner (2001) defines five life cycle phases that an organization goes through in order to implement project management as a core competency. The phases as well as some characteristics are shown in Table 3.1.

Embryonic Stage	Executive Management Acceptance Stage	Line Management Acceptance Stage	Growth Stage	Maturity Stage
• Recognize need • Recognize benefits • Recognize applications • Recognize what must be done	• Visible Executive Support • Executive understanding of project management • Project Sponsorship • Willingness to change way of doing business	• Line Management Support • Line Management commitment • Line Management education • Willingness to release employees for project management training	• Use of life-cycle phases • Development of a project management methodology • Commitment to planning • Minimizing of "creeping scope" • Selection of a project tracking system.	• Development of a management cost/schedule control system • Integrating cost and schedule control • Developing an educational program to enhance project management skills.

Table 3.1: Life-Cycle Phases for Project Management Maturity

Source: Kerzner, 2001

Companies are increasingly compiling procedural manuals to guide and train personnel in project management as they strive to enter the maturity stage. A well-defined project management methodology is, however, a prerequisite for the maturity stage. A benchmarking study conducted by Robert Buttrick concluded that companies, which are successful in project management, all use a company-specific, simple and well-defined project management framework. It defines a staged approach for all projects under all circumstances (Buttrick, 2001:17).

The influence of concurrent engineering on project management has further resulted in a "*checklist with periodic review points*" methodology. This type of methodology relies on checklists, addressing the same evaluation criteria but progressing in detail, for evaluating the project at different review points over the life cycle. The result is a more informal project management atmosphere in which the phases of a project can and often do overlap (Kerzner, 2001).

Projects, as well as project management, have an impact in a sphere broader than that of the project itself. Viewed against the background of sustainable development as discussed in Chapter 1, companies are increasingly accountable for the impacts resulting from a project as well as the effects of the project on the people, environment as well as economy, even long after the project has been completed (PMBOK® Guide, 2000:27).

In order for projects to support sustainable development, the concepts thereof must be integrated into the planning and management of a project over the whole life cycle. An analysis of the project life cycle management framework is therefore required in order to establish how these impacts and effects are currently dealt with in project management.

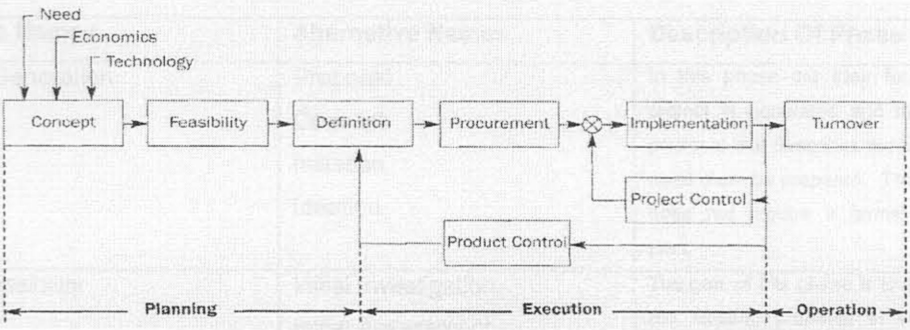
3.2 Project Life Cycle Management

3.2.1 Project Life Cycle

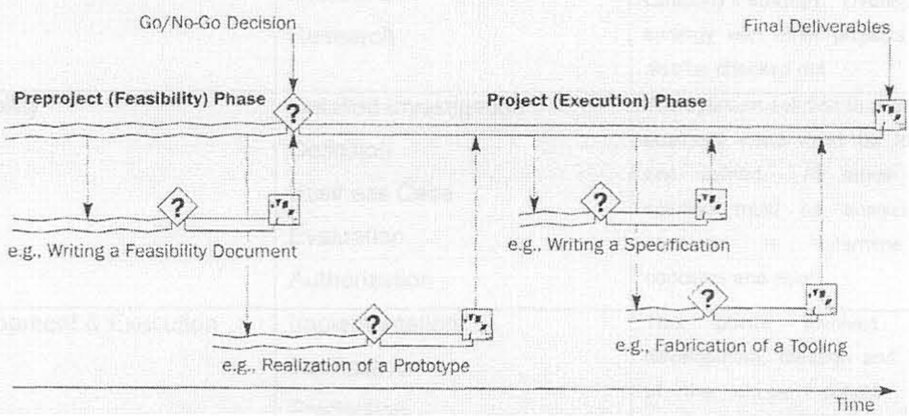
Projects consist of various stages also referred to as phases of development. Buttrick (2000), defines a project phase as a period during which certain work on the project takes place by collecting the correct information and creating specified outputs. The outputs or deliverables of a phase is normally used as a functional input to the next. Collectively the project phases are referred to as the project life cycle.

Various project life cycle approaches exist in literature, e.g. control-oriented model, quality-oriented model, risk-oriented model, a fractal approach to the project life cycle, as well as some company specific project life cycles (Bonnal, Gourc & Lacoste, 2002). These life cycle approaches are shown in Figure 3.1.The number of phases within each of these approaches differs as well as the names used to describe the phases. According to Kerzner (2001:76) "*there is no agreement among industries or even companies within the same industry, about the life-cycle phases of a project*" due to the complex nature and diversity of projects.

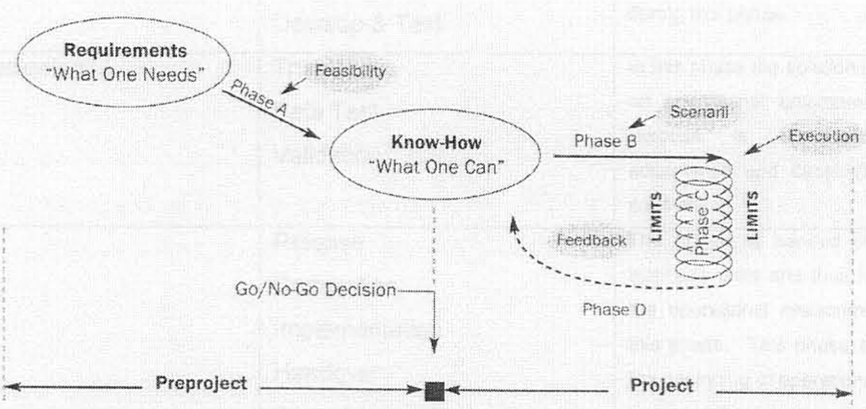
Various authors hence define various life cycle phases for a project. According to Buttrick (2000) it is possible to distinguish between seven life cycle phases. The generic phases together with a basic description as well as alternative phase names are summarized in Table 3.2.



Control Oriented Project Life Cycle Model (Kelley, 1982 as cited in Bonnal, Gourc and Lacoste,2002)



Fractal Approach to Project Life Cycles



Risk Oriented Project Life Cycle Model (Lacoste, 1999 as cited in Bonnal, Gourc and Lacoste,2002

Figure 3.1: Project Life Cycle Models

Source: Bonnal, Gourc & Lacoste, 2002

Phase Names	Alternative Names	Description Of Phase
Idea Generation	Proposal Concept Initiation Ideation	In this phase the idea for a new project is generated and the initial proposal that describes the business need must be prepared. This phase does not require a formal project plan.
Pre-feasibility	Initial Investigation Initial Assessment Preliminary Investigation Evaluation Research	The goal of this phase is to evaluate the existing proposal in terms of financial, operational and technical viability as well as against the company's strategy. Overlapping or synergy with other projects should also be checked out.
Feasibility	Detailed Investigation Definition Business Case Evaluation Authorization	The optimum solution to address the business need must be identified and defined. All areas of this solution must be analyzed and assessed to determine killer concerns and risks.
Development & Execution	Implementation Realization Production Construction Build Develop & Test	This phase involves design, development, creation and building of the chosen solution. The supporting system, manuals, business processes and training for the solution must also be developed during this phase.
Commissioning	Trial Beta Test Validation	In this phase the solution is tested in an operational environment. The purpose is to validate the acceptance and capabilities of the solution.
Launch	Release Completion Implementation Handover Acceptance	The project is handed over to the business units and thus released to the operational environment during this phase. This phase also marks the beginning of operational support.
Post Implementation Review (PIR)	Business Review Project audit Post Project Review	After sufficient time (9 –15 months) the project should be assessed to determine if the benefits were delivered and what the impact of the project was on the business. Lessons learned should be captured for future reference.

Table 3.2: Phases in the Project Life Cycle

Source: Adapted from Buttrick, 2000

Although specific projects may require a separately defined project life cycle methodology, the frameworks can be typically matched with the Buttrick generic project life cycle as illustrated in Table 3.3.

Projects Types	**Buttrick's generic project life cycle**				
	Pre-feasibility	**Feasibility**	**Development & Execution**	**Commissioning**	**Launch**
Product Development	Concept	Alternatives & feasibility	Develop and test	Market validation	Launch
Product withdrawal	Initial Investigation	Detailed Investigation	Develop and test	Pilot withdrawal	Close operations
Information systems	Analysis	Logical and outline physical design	Detailed design, build and test	Pilot	Cutover
Bid or tender	Receive request and evaluate	Prepare detailed tender	Develop, build internal test	Commissioning trails	Handover
Construction	Inception study	Feasibility study, tender design	Detailed design and construction	Commissioning trails	Handover
IT	Requirements review	Analysis and design	Build	Beta test	Cutover

Table 3.3: Alignment of individual project life cycles with generic project life cycle

Source: Buttrick, 2000.

The generic project life cycle can be tailored to suit the requirements of individual projects and it does happen that phases are combined, e.g. the development and execution phase is often combined with the commissioning phase. Some literature does not regard the idea generation and post-implementation review as phases of the project life cycle while other sources, such as Kerzner (2001), states that the theoretical system life cycle phases should be applied to a project. These phases are: Conceptual, Planning, Testing, Implementation and Closure.

In the South African context there is no agreement on a generic project life cycle model. The life-cycle has, nevertheless, been adapted for the South African process industry to address identified specific needs of the industry sector (Labuschagne, 2002). The generic life cycle proposed by Buttrick (2000) is taken as a basis due to its adaptability and comprehensiveness. The preferred project life cycle for the remainder of this document is shown in Figure 3.2.

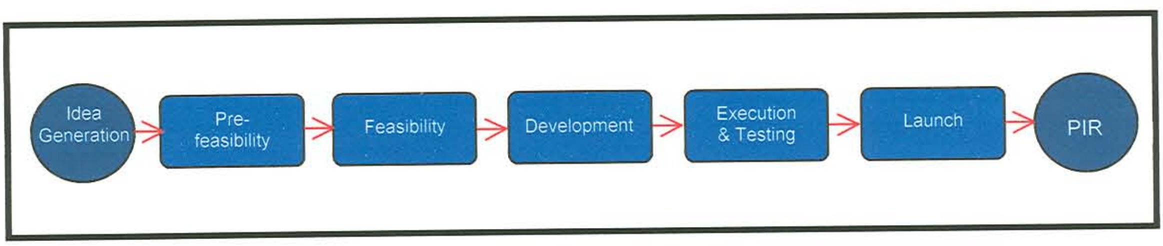
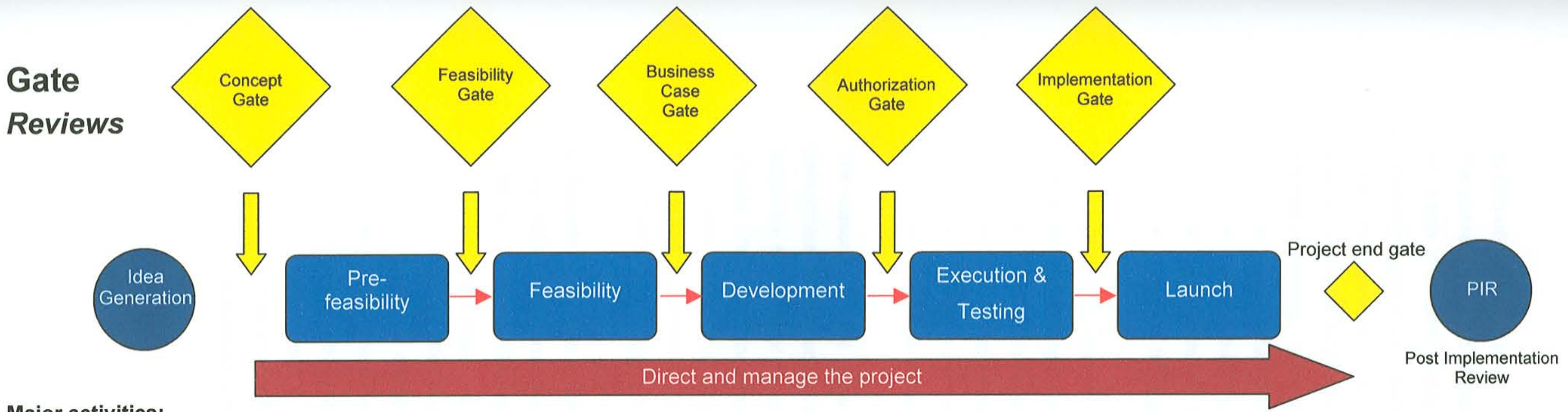


Figure 3.2: Project Life Cycle

3.2.2 Project Life Cycle Management Framework

A staged project management framework that relies on the "*checklist for end-of-phase review*" methodology is chosen as basis for sustainable project life cycle management (Figure 3.3). The decision is motivated by the fact that in recent years it was proven that the use of project life cycle phases improve management control and provide links for the ongoing operations, as most of the processes within project management are iterative in nature. Another advantage of the framework is the fact that the "*checklist for end-of-phase review*" methodology results in less documentation (Kerzner, 2001). The benchmarking study performed by Buttrick (2000) as discussed in Section 3.1, supports the choice of the framework. The framework can be adapted with ease for various project life cycle models.



	Idea Generation	Pre-feasibility	Feasibility	Development	Execution & Testing	Launch	PIR
Major activities:	• Identify opportunity • Assess fit with strategy and other product portfolios • Identify stakeholders	• Evaluate, in outline, operational, technical and commercial viability • Assess impact on organization • Check any legal, regulatory or patent issues • Identify options • Undertake initial investment appraisal • Preliminary assessment of risks and uncertainties • Plan the next stage of the project	• Define technical and operational requirements • Assess possible solutions • Design solutions in outline • Obtain quotes from suppliers • Undertake feasibility review • Define the chosen solution • Technology selection • Do investment appraisal • Re-check legal, regulatory and patent issues • Reduce uncertainties • Plan remainder of project	• Develop the solutions • Develop training • Finalize supplier arrangements • Obtain legal, patent and regulatory permissions • Optimal integration of all issues into the final business plan • Check and refine plans for remainder of project	• Train users • Manage the quality of deliverables • Provide assets and deliverables according to final business plan • Test solutions • Conduct trials in operational environment and refine solution	• Launch/release capability or service • Carry out remaining training • Handover solutions for on-going management • End-of-job documentation • Carry out closure review	• Assess the effectiveness of project in meeting the business objectives • Check that operational aspects are working effectively • Start business support • Capture Best Practices/Learnings
Deliverables:	• Proposal	• Initial Business Case • Preliminary Plan of execution • Preliminary engineering proposal	• Output definition • Conceptual engineering proposal • Feasibility report • Plan of execution • Detailed Business Plan	• Plan of Execution • Final Business Plan • Complete Engineering Proposal	• Trial results • Ready to service review report	• Project Closure report	• Post Implementation Review (PIR) Report • Certified Performance Report

Figure 3.3: Staged Project Life Cycle Management Framework

a) End-of-Phase Review

The phase-end or end-of-phase reviews are often called phase exits, stage decision gates or kill points (PMBOK® Guide, 2000). It serves the purpose of reviewing both the key deliverables and project performance at the end of each phase in order to ensure proper project management. The question whether these decision gates serves as end points to ensure that the full scope of a phase has been covered or as entry points to the next phase, is debated in literature. According to Buttrick (2000) the decision gates serve as points to:

- Ensure that the project is still required and that the risks are acceptable.
- Confirm the priority of the project relative to other projects.
- Decide whether the project should be continued.
- Agree on the project plan for the remainder of the project.

Kerzner (2001:559), emphasises that some companies have identified four possible decisions that can be taken during these end-of-phase review meetings:

- Proceed to the next phase based on an approved funding level.
- Proceed to the next phase **but** with a new or modified set of objectives.
- Postpone decision to proceed based on a need for additional information.
- Terminate the project.

The reasoning is that unless specific criteria have been met, as evidenced by approved deliverables, the subsequent phase should not be started. These criteria can however be met before the full scope of a phase is finished. Therefore, although the gates are entry points to phases, phases can consequently overlap, thereby reducing the timescale without increasing associated risks. This is a very powerful characteristic of the staged framework and emphasizes the principle that gates are compulsory but phases not. This is supported by concurrent engineering principles as stated in section 3.1.

b) Aspects addressed at Decision Gates:

Three distinct questions need to be answered at each decision gate to ensure that gates serve their purpose as discussed. The three questions are:

- *Is the project viable?*

  The question address the acceptability of risks, the business sense behind the project as well as how the project fit into overall company strategy.
- *What is the priority of the project relative to other projects?*

  The question concerns the project in its context and compares its priority with all other projects.
- *Is there funding available to undertake the project?*

  The question addresses the availability of working capital to finance the project.

In order to answer these questions a project must be evaluated against certain criteria at the different gates. It is important to address all aspects of the project in parallel and to take into consideration that gate criteria are often repeated in consecutive gates. This ensures that certain issues are addressed throughout the project life cycle (Buttrick, 2000).

In conclusion, the criteria that are most often used for the evaluation of projects can be divided into three main categories:

- Criteria concerned with the overall business strategy and business management of the project. The aim of these criteria is to integrate the project decisions with the overall business strategies and operational activities.
- Criteria concerned with Technical Management.
- Criteria concerned with Project Management.

Typical criteria for each one of the main categories that can be used at the different gates are listed in Figure 3.4. The criteria are listed in the form of questions, but the most common practice is to translate the criteria into financial requirements and to take decisions based on the financial values.

Gate Reviews: Typical Questions

	Business Strategy	Technical Management	Project Management
Idea Generation			
Concept Gate	• Is it clear which business units or function the proposal support? • Does the proposal fit the strategy? • Is the opportunity attractive relative to alternative proposals? • Is the proposal likely to be acceptable to the customers and shareholders? • Do any competitors have capabilities similar to this? • Will the proposal provide the business with an competitive advantage? • Has a project sponsor been identified for at least the next phase/stage of the project?	• Can resources be committed to do the pre-feasibility study? • Is the business likely to be able to develop or acquire the required capabilities to support the proposal? • Is the proposal technically feasible with current technology? • Has the organization operational capability to support the proposal?	• Has a project manager been identified for the pre-feasibility phase/stage?
Pre-feasibility			
Feasibility Gate	• Is it clear which business units or function the project support? • Does the project fit the strategy? • Is the business opportunity attractive? • Are the risks acceptable? • Is the initial business case and investment appraisal acceptable? • Have all the relevant business units and functions been involved in creating and reviewing the deliverables? • Has a project sponsor been identified for the project?	• Can resources be committed to perform the feasibility study? • On current knowledge is it technically feasible with current technology, or it there a possible technical development path to provide the capability or service? • Does the business currently possess the operational capability to support the project? If not is it likely that this can be put in place within the current/proposed process architecture?	• Has a project manager been identified for the project? • Is there a detailed schedule, resource and cost plan for the Feasibility Phase/Stage? • Is there an outline schedule, resource and cost plan for the full project?
Feasibility			
Business Case Gate	• Is it clear which business units or function the project support? • Does the project still fit the strategy? • Have the development concepts e.g. marketing been researched and tested on target segments and the need reaffirmed? • Is the detailed business plan acceptable and compelling? • Have the key sensitivities and scenarios for the recommended option been checked and confirmed as acceptable? • Is the output definition clear? • Is the business case ready to be build into the overall business plan?	• Is it technically feasible with current technology? • Does the organization have the operational capability to support the project? • Are there resources to undertake the Development and Execution phase/stage? • Have formal commitments been made by the relevant line managers? • **Have all relevant environmental permits been obtained?**	• Are the project plans full and complete? • Is there a detailed schedule, resource and cost plan for the Development and Execution Phase/Stage? • Is there an outline schedule, resource and cost plan for the full project? • Are there sufficient review points in the plan? • Has the project been designed to eliminate known high risks?

Development

	Business Strategy	Technical Management	Project Management
Authorization Gate	• Is the project still a good business proposition? • Is the project still correctly reflected in the overall business plan of the business? • Have all the high risks been eliminated?	• Is this the most suitable technical solution? • **Has the EIA study been completed and environmental approval been obtained?** • Have all the alternatives been evaluated?	• Is the project plan up to date, full and complete? • Is there a detailed schedule, resource and cost plan for the Execution and Testing Phase/Stage? • Is there an outline plan for the remainder of the project? • Are sufficient resources allocated to conduct the execution and testing?

Execution & Testing

	Business Strategy	Technical Management	Project Management
Implementation Gate	• Is the project still a good business proposition? • Have all the high and medium risks been eliminated from the project? • Have the costs and benefits been reforecast against the business plan?	• Have the tests been finalized and the results accepted? • Have process design across the business been accepted and is all training completed? • Are benefits/results monitoring systems in place?	• Is the project plan updated, full and complete? • Is there a detailed schedule, resource and cost plan for the Launch Phase/Stage? • Are sufficient resources allocated to undertake the launch?

Launch

	Business Strategy	Technical Management	Project Management
Project end gate	• Has the business forecast been updated to take into account the benefits arising from the project? • Has someone agreed to be accountable for monitoring the benefits? • Have review points and metrics for measuring the benefits been defined? • Has the project account been closed so that no more costs can be incurred? • Have all relevant stakeholders been informed of the project closure? • Have all issues been resolved?	• Have all issues been resolved? • Has ownership of each outstanding risk and issue been accepted by a NAMED person in the line or in another project?	• Have the timing, accountability and terms of reference for the Post Implementation Review been agreed on? • Have team appraisals relating to the project team been completed? • Have all lessons learned been recorded and communicated to the relevant process and documentation owners?

PIR

Post Implementation Review

3.2.3 Evaluation of the project life cycle management framework

Surveys conducted by Hellings & Pike in Britain confirmed that project appraisal through the life cycle concentrates only on the assessment of the financial and technical feasibility of a project (Lopes & Flavell, 1998). The appraisal in the generic project management framework proposed by Buttrick, focuses strongly on technical and financial feasibility as well as resource availability for project execution.

In the South African context the content of certain deliverables, e.g. business case and plan and engineering proposals (see Figure 3.3), were studied more closely in order to identify any environmental activities or aspects that are addressed. Figure 3.5 summarizes the main activities and appraisal issues concerned with environmental aspects over a project's life cycle in South Africa.

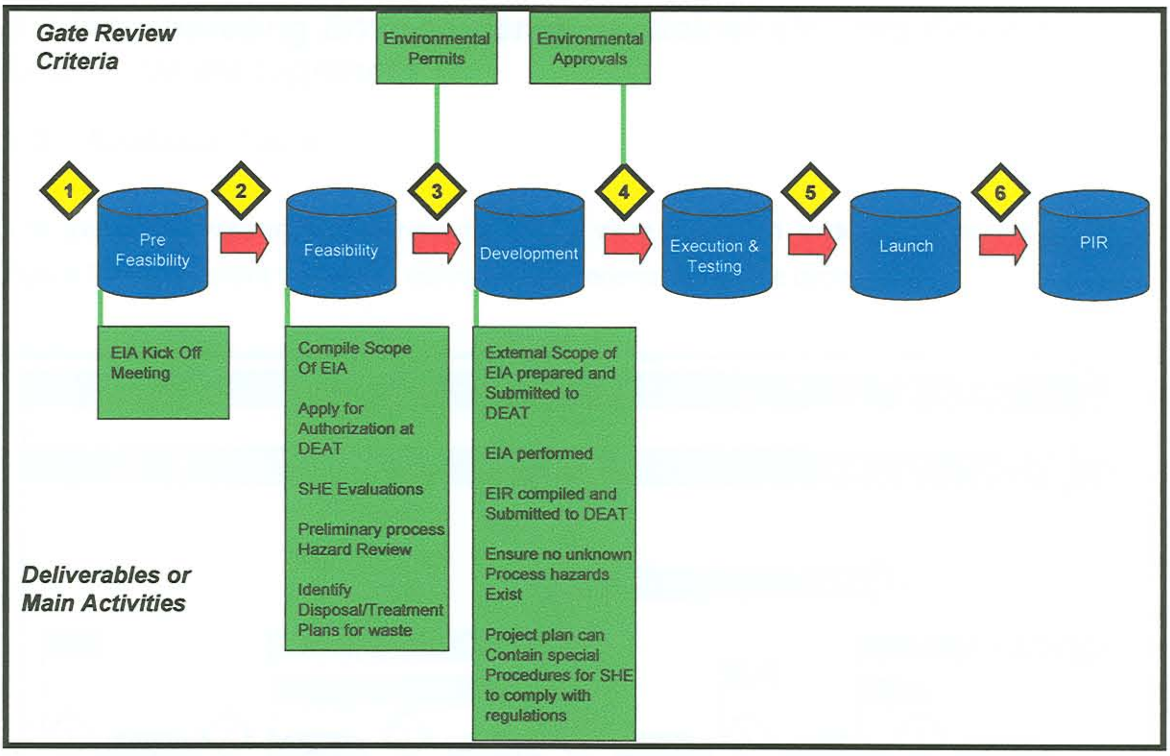


Figure 3.5: Extent of current environmental considerations during project management in South Africa

The figure indicates that social factors are currently not included in the normal project appraisal process, while environmental factors are only addressed by means of one question at the business case and authorization gates. It is consequently concluded that in South African context the emphasis is on financial feasibility during project appraisal. Economic objectives of business sustainability are thus efficiently addressed. The deliverables at gates do not include specific mentioning of social aspects, although it can form part of the environmental impact assessment (EIA) (see chapter 2.5.3 c). Environmental impacts are mostly addressed on a deliverable level by following the formal guidelines of the national Department of Environmental Affairs and Tourism (DEAT) for conducting Environmental Impact Assessments (EIAs) (see Figure 3.5 and Appendix B).

Environmental factors are consequently addressed in a reactive way and environmental liabilities and risks are not considered at a strategic management level. It can hence be concluded that sustainable development factors are not efficiently addressed in the project management framework since the three objectives are not addressed similarly. A mechanism is therefore required to ensure that social and environmental considerations receive the same attention as economic factors at the project decision gates. The aim of this dissertation is to incorporate environmental sustainability in the project life cycle management framework.

3.3 Incorporating Environmental Sustainability into Project Life Cycle Management

3.3.1 Available Tools

The available environmental management tools were discussed in detail in Chapter 2. In Figure 3.6 the relevant tools were applied to the generic project life cycle.

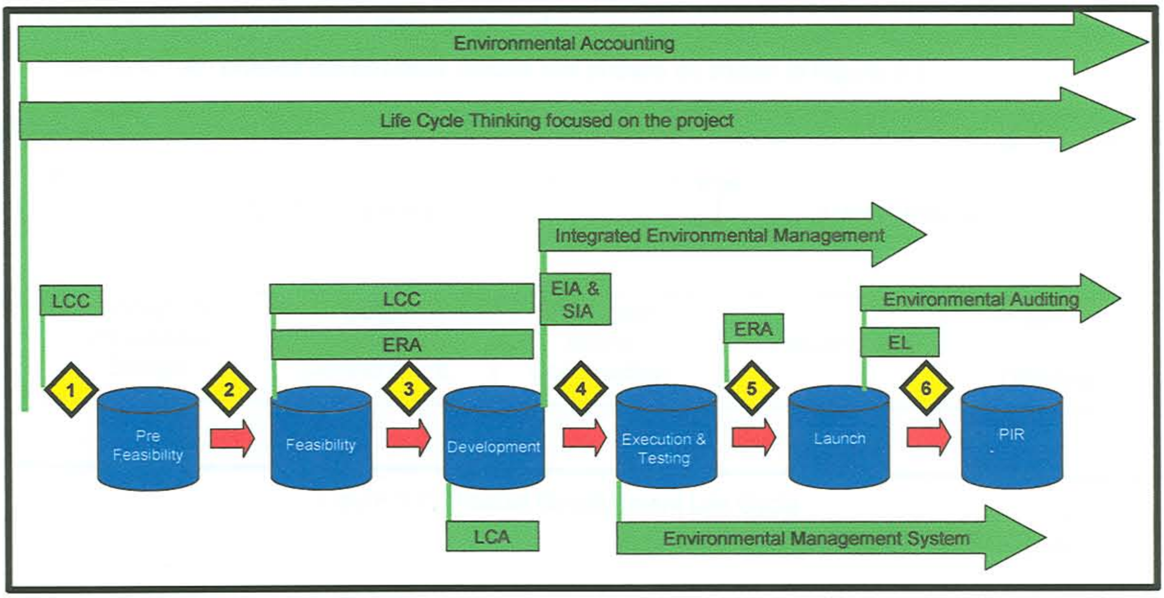


Figure 3.6: Environmental Management Tools applied over a generic project life cycle

A comparison of Figure 3.5 and 3.6 shows that all the available environmental management tools are not effectively utilized for project management purposes as only EIA and ERA are officially documented as part of the management process. There is thus room for improvement in incorporating environmental concerns into the project life cycle management framework. It can be concluded form Figure 3.6 that concepts such as Life Cycle Thinking must be integrated into the business culture as it can be applied at all levels and should guide the paradigm of decision-makers. The importance of considering the "product/service" of the project is emphasized by the applicability of tools such as Environmental Labelling. In the process industry the "product" of a project is usually either a new or improved process that produces consumable products. The interactions between the three life cycles (product, process and project) must thus be analysed.

3.3.2 Life Cycle Interaction

The American Heritage® Dictionary of the English Language defines a life cycle as *"a progression through series of different stages of development"*. The life cycle of a product or process can accordingly be defined as the various development phases through which the project, process and/or system passes from its initialization until the final phase-out. The project life cycle is discussed in detail in Section 3.2.1.

a) Product Life Cycle

Various Product Life Cycles exist in literature. As with the project life cycle there is no general consensus among industries. It is possible to distinguish between a product development and a product manufacturing life cycle. Blanchard and Fabrycky's definition of life cycles supports a systems engineering approach and is a good example of a product development life cycle. Blanchard and Fabrycky (1998) believes that the product life cycle starts with the identification of a need and then consist of two main phases: Acquisition and Utilization. These two main phases are however divided into phases as shown in Figure 3.7.

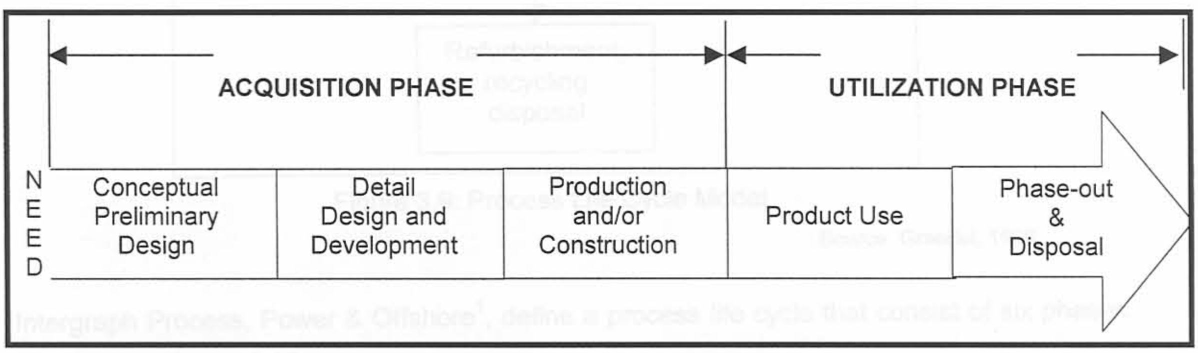


Figure 3.7: Product Development Life Cycle

Source: Blanchard & Fabrycky (1998)

An example of a product manufacturing life cycle that supports supply chain principles is shown in Figure 3.8.

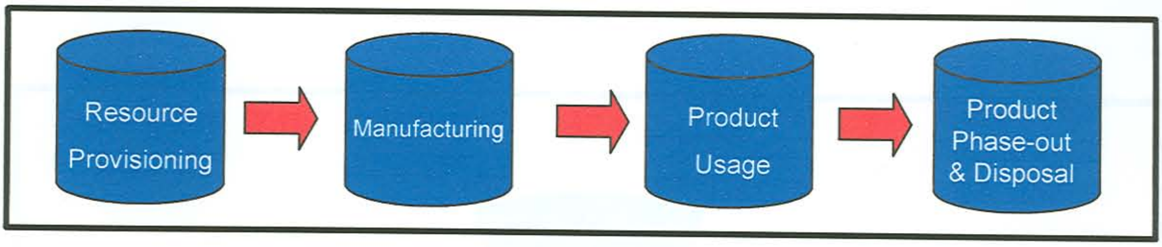


Figure 3.8: Product Manufacturing Life Cycle

b) Process Life Cycle

Various process life cycles are described in literature and it is evident that the type of process defines the characteristic life cycle stages. Graedel (1998) believes that the life cycle of industrial processes consist of five phases, but only three epochs as graphically shown in Figure 3.9.

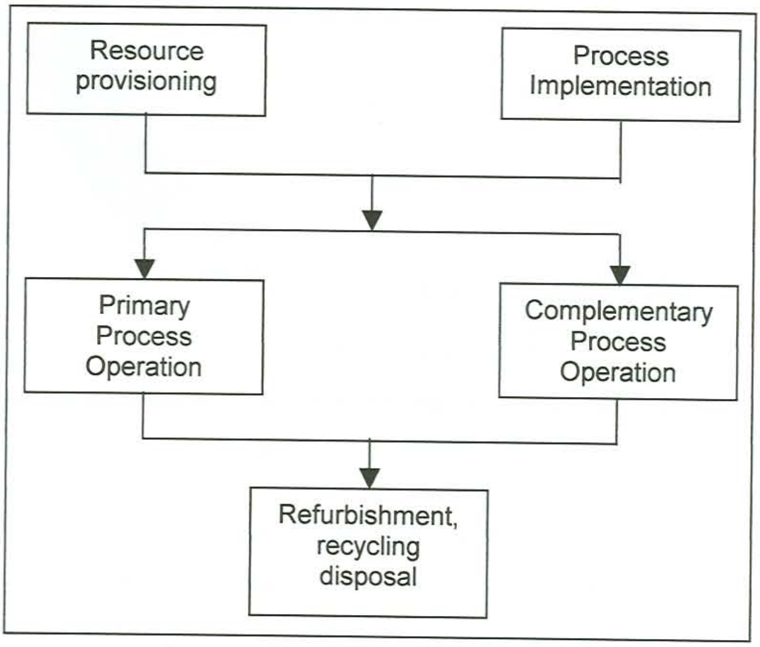


Figure 3.9: Process Life Cycle Model

Source: Graedel, 1998.

Intergraph Process, Power & Offshore[1], define a process life cycle that consist of six phases as shown in Figure 3.10.

[1] A company with 23 years experience in providing value to customers engaged in the design, construction and operation of plants by delivering software, services and solutions to achieve breakthroughs in efficiency.

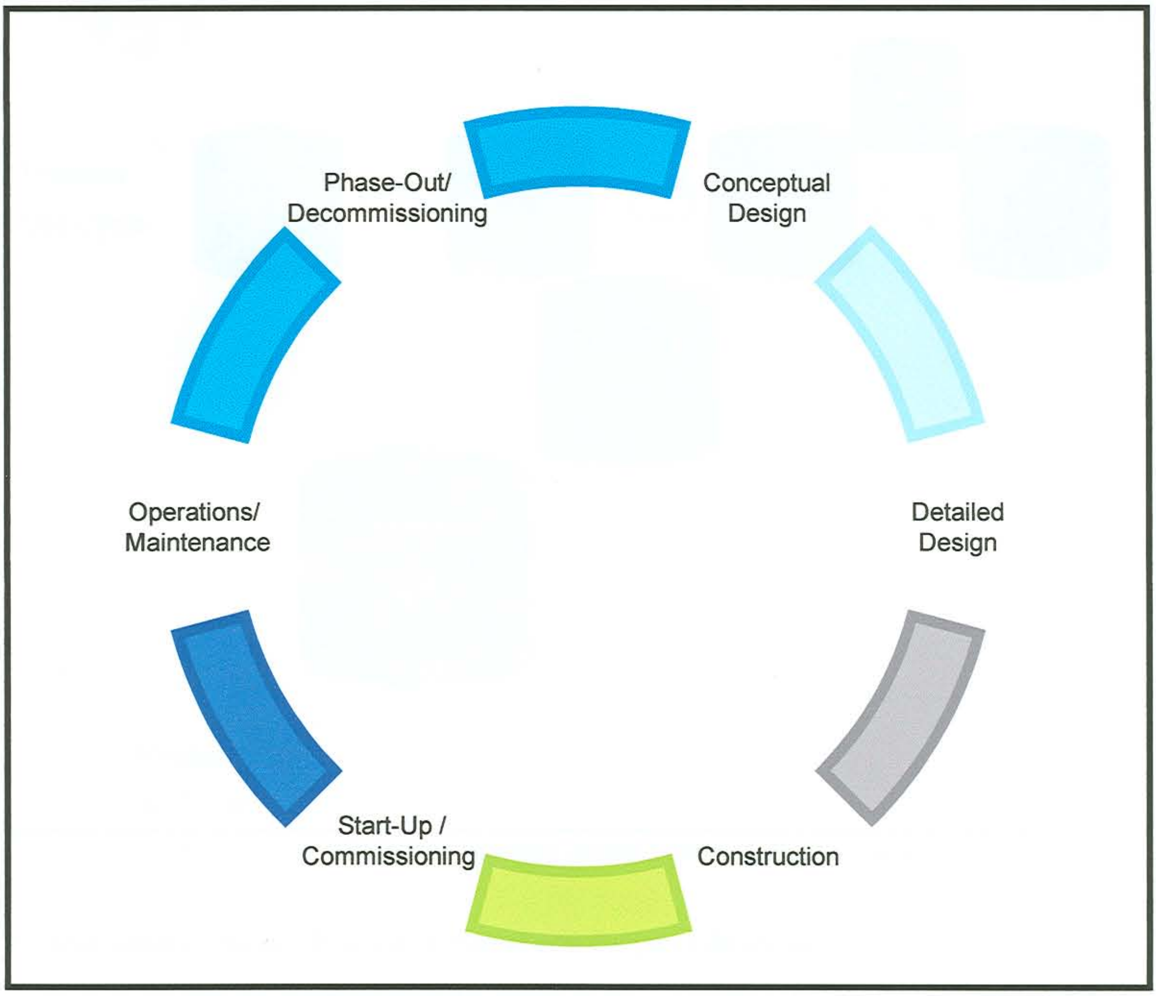


Figure 3.10: Process Life Cycle

The process life cycle of Graedel (1998) and the Integraph life cycle are combined and simplified into the four-phase process life cycle, shown in Figure 3.11.

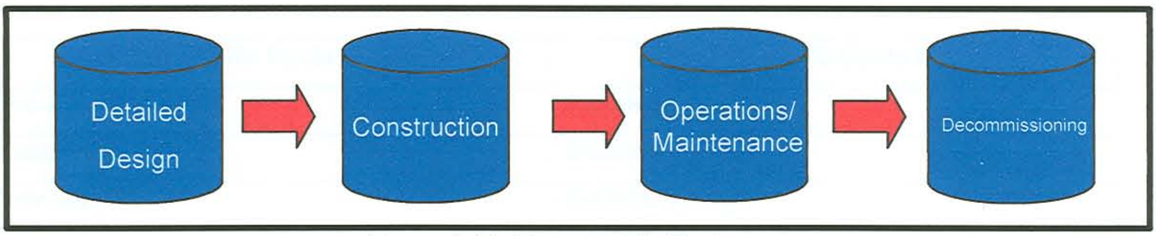


Figure 3.11: Process Life Cycle

c) Interaction between Product and Process Life Cycle

A process is defined as *"a series of actions, changes, or functions bringing about a result or a series of operations performed in the making or treatment of a product"* (The American Heritage® Dictionary of the English Language). The "result" is a product of some kind. The operation phase of the process is thus the manufacturing or production phase of the product. The relationship is depicted in Figure 3.12.

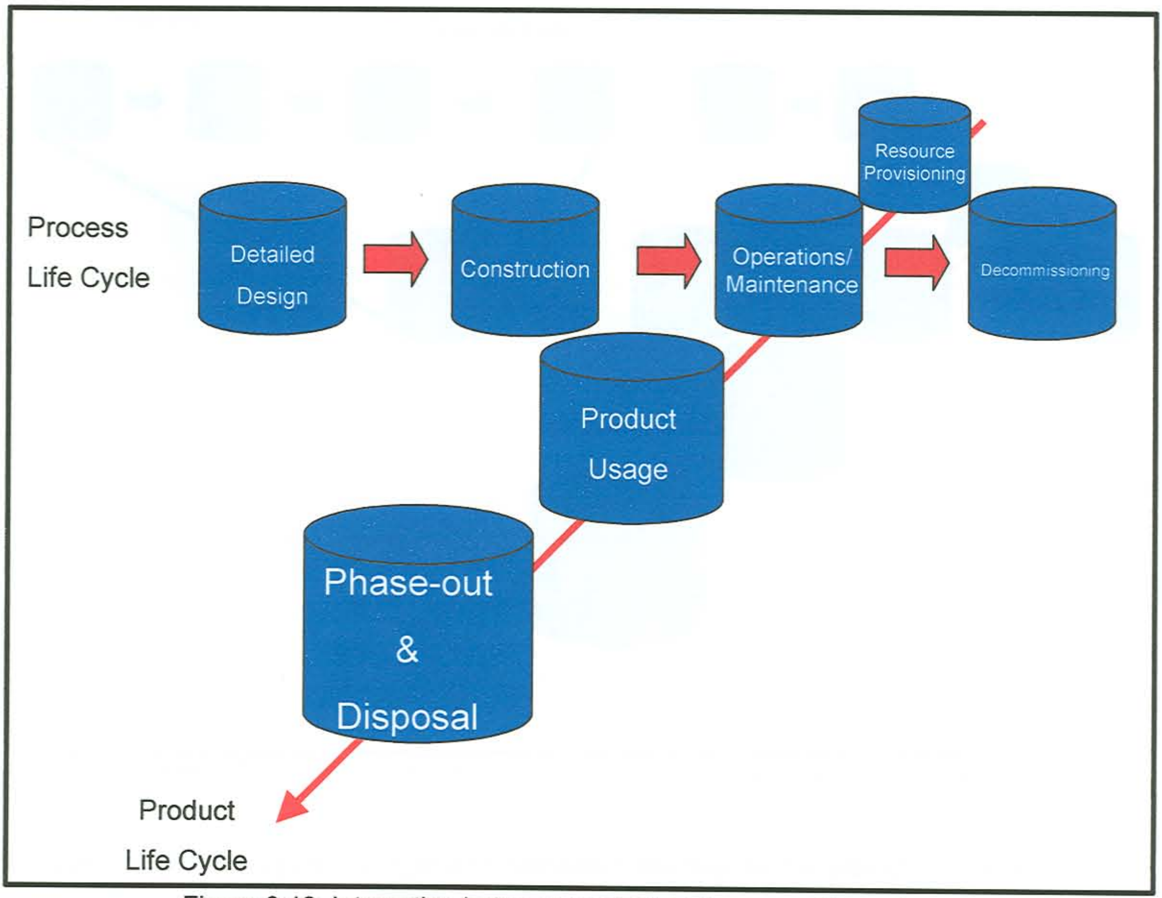


Figure 3.12: Interaction between product and process life cycles

d) Interaction between Process, Product and Project Life Cycle

Since projects that are undertaken in the South African process industry usually deliver a new or improved process that can produce products to fulfill the market's demand, the interaction between the project life cycle and the product and process life cycles must also be analysed. The process and the project and process life cycles are mapped in Table 3.4 and the interaction between the project, process and product life cycles is shown in Figure 3.13.

Project Life Cycle Phase	Process Life Cycle Phase
Pre-Feasibility	Detailed Design
Feasibility	Detailed Design
Development	Detailed Design
Execution & Testing	Detailed Design – Testing of Pilot Plant
Launch	Construction

Table 3.4: Mapping of the Project and Process Life Cycles

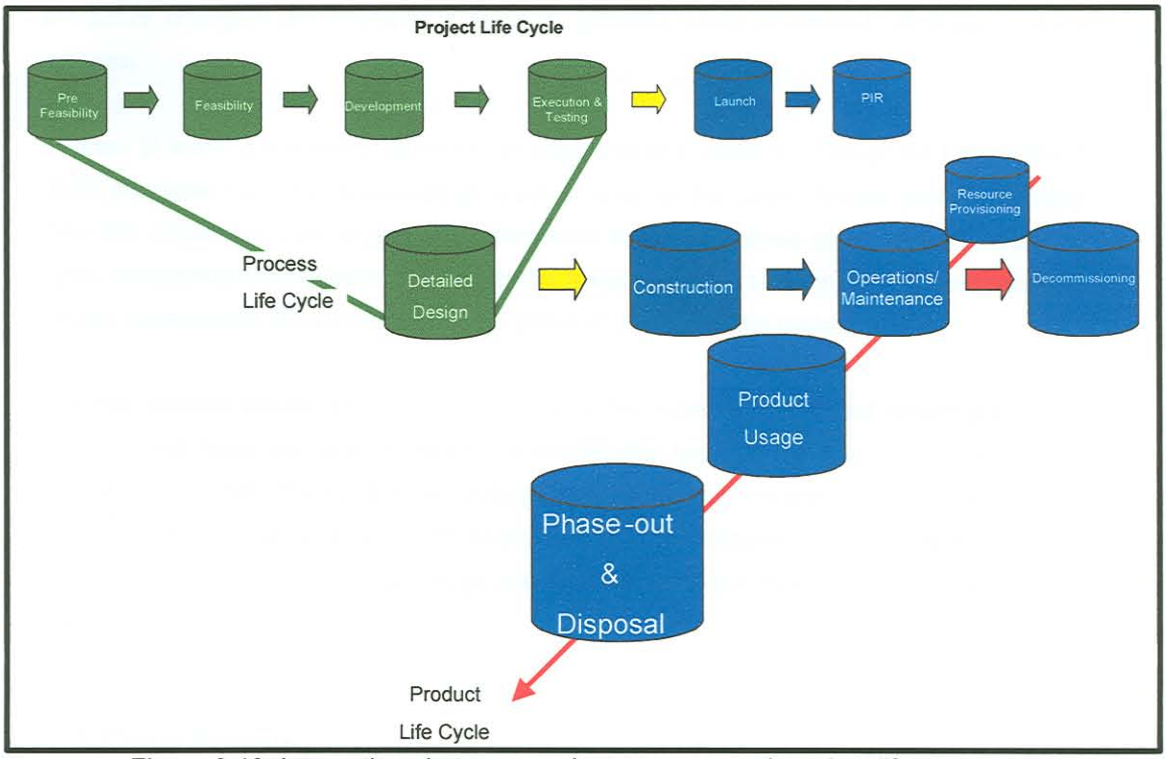


Figure 3.13: Interactions between project, process and product life cycles

A staged project life cycle management framework focuses on the project life cycle, but all environmental studies conducted during a project life cycle focus on possible environmental impacts resulting from the process or product life cycle. The remainder of this dissertation will therefore focus on all three life cycles and especially the interaction between the three, although changes are proposed to the project life cycle management framework only.

3.3.3 Proposed Changes to the Project Life Cycle Management Framework

a) Project Appraisal:

Environmental criteria will only receive the same attention as economic criteria if specific questions are developed to address environmental factors at the decision gates. Figure 3.4 clearly indicates that this is not currently the case. A whole new set of criteria dealing specifically with environmental factors must thus be developed for each gate of the project life cycle management framework.

b) Project Life Cycle Phase Activities and Deliverables:

Environmental criteria cannot only be addressed during project appraisal. Additional environmental related activities and deliverables must be added to the various project life cycle phases. Most projects in the process industry involve the development and implementation of a new or improved process. The design phase of a new process influences a significant portion of the total overall cost and it is also the only phase in which pro-active changes can be made to minimize possible future environmental impacts of the process.

In order to follow a pro-active approach an additional tool based on "Design for Environment" (DfE) principles must be developed at strategic level for the South African process industry. This tool should be used to generate information for the first three gates of the process life cycle management framework. Applied in this manner the tool can support the Environmental Impact Assessment conducted in the third phase of the project life cycle.

It is the process resulting from the project, and the subsequent product resulting from the process, that have the largest possible environmental impacts associated with the project. The strategic tool should assess possible environmental impacts of the Construction, Operations/Maintenance and Decommissioning life cycle phases of the process. Possible environmental impacts of product usage and product phase-out must be considered as part of the Operations/Maintenance phase.

3.4 Conclusion

Hobbs and Miller, 1998 stated that projects could no longer be treated as static undertakings due to the fact that a project is subjected to uncertainty, risks and both internal and external pressures through its life cycle and dynamic change is hence expected (as cited in Jaafari, 2000). The project management philosophy and – framework must therefore be adapted to ensure maximum flexibility and innovation throughout the life of a project.

In order to achieve sustainable project life cycle management it will be necessary to address all three pillars of sustainable development i.e. economic, environment and social during all aspects of project life cycle management. Current business management frameworks typically do not support this approach and must thus be altered to incorporate all sustainability criteria.

Changes have been suggested to the project life cycle management framework to ensure that environmental criteria are effectively considered. This involves an additional set of project appraisal criteria, the development of a strategic tool to bridge the gap between decision makers and designers, and the promotion of other environmental management tools within the project life cycle management framework.

Chapter 4: Environmental Indicators for the development of a corporate strategic decision tool

4.1 Environmental Concerns

The environmental problems faced by the world today are the consequence of the economic and social paradigms that existed in society since the late eighteenth century (Chapter 1). The scarcity of natural resources has been an issue since the beginning of time and is not a contributing factor to the immensity of the experienced environmental crisis. This is best summarized by Helm 1991 (as cited in Blignaut 1995):

"Growing population and the development of modern industrial economics have resulted in a process of environmental degradation. Human behaviour must change if the damage is to be contained."

In order to align strategic business practices to address the environmental concerns of the global society, decision makers should have a basic understanding of what these concerns imply.

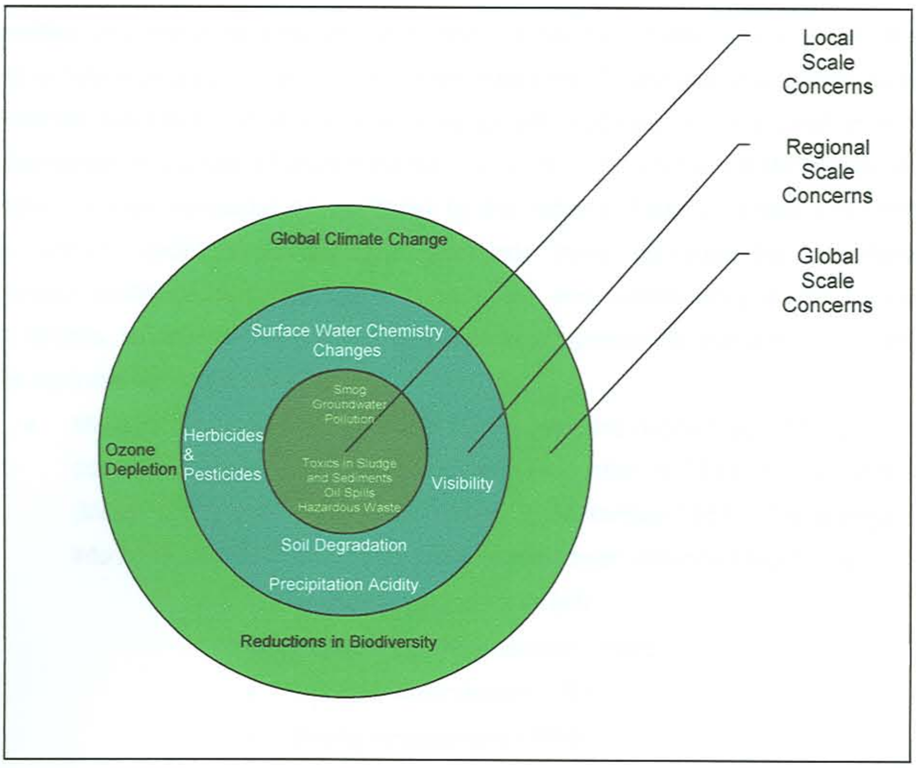


Figure 4.1: Classification of Environmental Concerns

Source: Graedel & Allenby, 1995.

As is shown in Figure 4.1, it is possible to distinguish between environmental concerns by spatial scale of impact, whereby the specific environmental impact categories can be grouped. Detailed descriptions of some of the major environmental concerns are given in Appendix D and include:

- Global climate change
- Ozone depletion
- Reduction in biodiversity
- Surface water chemical changes
- Soil degradation
- Precipitation acidity
- Visibility
- Herbicides and pesticides
- Smog
- Groundwater pollution
- Toxics in sludge
- Oil spills
- Hazardous waste sites

4.1.1 Reaction to Environmental Concerns

The identified environmental problems and concerns can be classified as impacts on either Land, Air or Water or a combination of the three resources. Businesses and governments use environmental checklists and sustainable development indicators in an attempt to minimize their contribution to causes of environmental concerns. The environmental degradation in South Africa is also measured or monitored by the national State of Nation Environmental Reports (DEAT, 2002). Governments worldwide have indicated the importance of environmental problems by committing their countries, and subsequently their business and industry sectors, to various international protocols and agreements that aim to address and minimize environmental problems, e.g.:

- Montreal Protocol on substances that deplete the ozone layer: This protocol laid down a schedule for cutting the use and production of CFCs, HCFCs and halons (Moss, 2000) and was agreed upon on 16 September 1987. The protocol came into force on the 1st of January 1989 and has been amended four times:
    - London Amendment –1990
    - Copenhagen Amendment – 1992
    - Montreal Amendment – 1997
    - Beijing Amendment –1999

- Kyoto Protocol: The protocol contains a political agreement by which industrial nations undertake to reduce gaseous emissions affecting the climate by 5.2% by the year 2012. It was signed in December 1997 in Japan.

4.2 Sustainable Development Indicators to address environmental concerns

Since the popularisation of the concept of Sustainable Development in 1987, society has been seeking for ways to measure its performance with regards to sustainability. In support of this effort various "indicators for sustainable development" have been developed focusing on different aspects of sustainable development. Veleva, Hart, Greiner and Crumbley (2001) define indicators as *"typical numerical measures that provide key information about a physical, social or economic system"* and identify three key objectives of indicators as:

- To raise awareness and understanding
- To inform decision-making
- To measure progress towards established goals.

4.2.1 United Nation's Indicators of Sustainable Development

The United Nations has developed a theme indicator framework to address sustainable development issues as defined by Agenda 21. The framework addresses the four aspects of sustainable development: Social, Environmental, Economic, as well as Institutional. Each of the aspects is divided into themes with sub-themes and indicators were developed for the sub-themes. The breakdown for Environmental Aspects is shown in Figure 4.2 and Table 4.1.

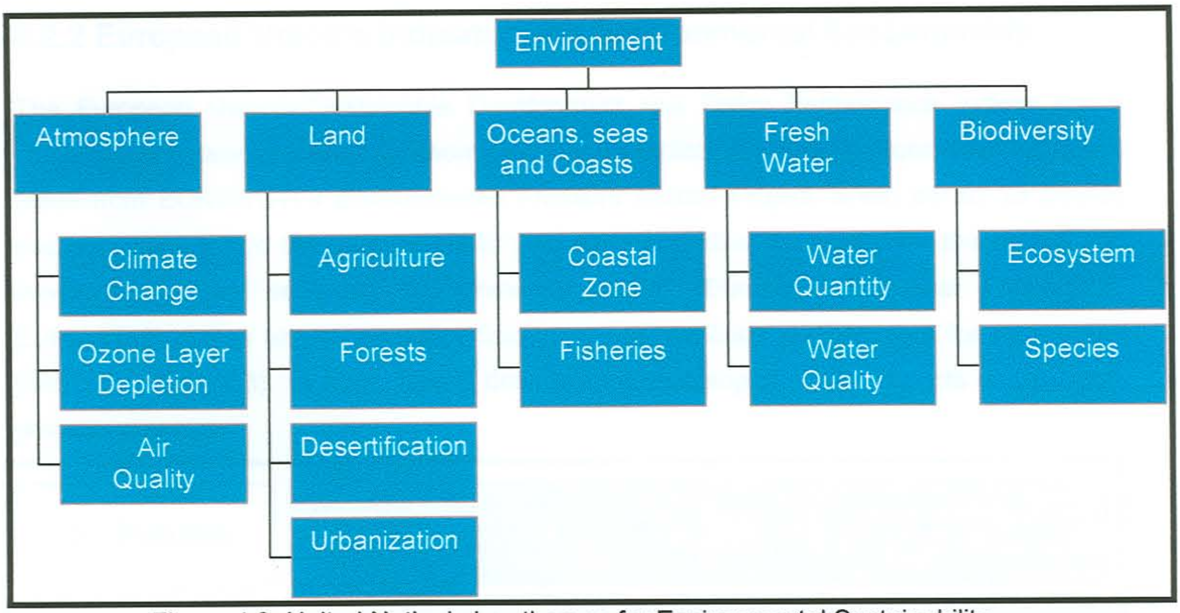


Figure 4.2: United Nation's key themes for Environmental Sustainability

Source: United Nations, 2002.

ENVIRONMENTAL		
Atmosphere (9)	Climate Change	Emissions of Greenhouse Gas
	Ozone Layer Depletion	Consumption of Ozone Depleting Substances
	Air Quality	Ambient Concentration of Air Pollutants in Urban Areas
Land (10)	Agriculture (14)	Arable and Permanent Crop Land Area
		Use of Fertilizers
		Use of Agricultural Pesticides
	Forests (11)	Forest Area as a percent of Land Area
		Wood Harvesting Intensity
	Desertification (12)	Land affected by desertification
	Urbanization (7)	Area of Urban Formal and Informal Settlements
Oceans, Sea and Coasts (17)	Coastal Zone	Algae Concentration in Coastal Waters
		Percent of Total Population Living in Coastal Areas
	Fisheries	Annual Catch by Major Species
Fresh Water (18)	Water Quantity	Annual Withdrawal of Ground and Surface Water as a percent of Total Available Water
	Water Quality	BOD in Water Bodies
		Concentration of Faecal Coliform in Freshwater
Biodiversity (15)	Ecosystem	Area of selected key ecosystems
		Protected area as a percentage of total area
	Species	Abundance of selected key species
*Numbers in brackets indicate relevant Agenda 21 chapters.		

Table 4.1: United Nation's Theme Indicator Framework for Environmental Sustainability

Source: United Nations, 2002.

Appendix E contains the complete theme indicator framework. Various countries are participating with the United Nations and have developed or are developing national sustainable development indicators.

4.2.2 European Union's Indicators for Environmental Sustainability

The European Union's Sustainable Development and Policy Performance Indices are a combination of environmental, economic and social indicators. The environmental indicators result from EUROSTAT's *Environmental Pressure Indices Project,* which aimed *"to provide decision makers and the general public with the information necessary for the design and monitoring of an adequate environmental policy"* (European Statistical Laboratory). EUROSTAT makes use of ten policy fields and has identified six indicators for each policy field (see Figure 4.3). A policy field is defined as a grouping of similar impacts or an overall problem pressure.

Air Pollution	Emissions of nitrogen oxides (NOx)	Emissions of non-methane volatile..	Emissions of sulphur dioxide (SO2)	Emissions of particles	Consumption of gasoline & diesel oil by road..	Primary energy consumption
Climate Change	Emissions of carbon dioxide (CO2)	Emissions of methane (CH4)	Emissions of nitrous oxide (N2O)	Emissions of chloro-fluoro-carbons..	Emissions of nitrogen oxides (NOx)	Emissions of sulphur oxides (SOx)
Loss of Biodiversity	Protected area loss, damage and..	Wetland loss through drainage	Agriculture intensity: area used for..	Fragmen-tation of forests & landscapes..	Clearance of natural & semi-natural..	Change in traditional land-use practice
Marine Environment & Coastal Zones	Eutrophi-cation	Overfishing	Develop-ment along shore	Priority habitat loss	Discharges of heavy metals	Oil pollution at coast & at sea
Ozone Layer Depletion	Emissions of bromo-fluoro-carbons..	Emissions of chloro-fluoro-carbons..	Emissions of hydro-chloro-fluoro..	Emissions of carbon dioxide (CO2)	Emissions of nitrogen oxides (NOx)	Emissions of chlorinated carbons
Resource Depletion	Water consumption per capita (incl...	Use of energy per capita	Increase in territory permanently occupied by	Nutrient-bala of the soil (nutrient input/..	Electricity production from fossil fuels..	Timber balance (new growth/..
Dispersion of Toxic Substances	Consumption of pesti-cides by agriculture	Emissions of persistent organic..	Consumption of toxic chemicals	Index of heavy metal emissions..	Index of heavy metal emissions..	Emissions of radioactive material
Urban Environmental Problems	Energy consumption	Non-recycled municipal waste	Non-treated wastewater	Share of private car transport	People endangered by noise emissions	Land use (change from natural to..
Waste	Waste landfilled	Waste incinerated	Hazardous waste	Municipal waste	Waste per product during a number of..	Waste recycled/ material recovered
Water Pollution & Water Resources	Nutrient (nitrogen & phosphorus - N + P) use..	Ground water abstraction	Pesticides used per hectare of agriculture..	Water treated/ water collected	Index of heavy metals emissions	Emissions of organic matter as biochemical..

Figure 4.3: European Union's framework for Environmental Sustainability Indicators

Source: http://esl.jrc.it/envind/

Each one of the six indicators contributes to the overall problem, and all six should be measured to ensure that enough information is provided to make an informed decision.

4.2.3 South Africa's Indicators for Environmental Sustainability

South Africa's Department of Environmental Affairs and Tourism (DEAT) has developed a core set of environmental indicators for national State of the Environmental reporting purposes (DEAT, 2002). The process involved the selection of priority environmental issues for reporting purposes and grouping these issues into themes (DEAT, 2002). Figure 4.4 shows the eight themes and the specific issues that are addressed under each theme.

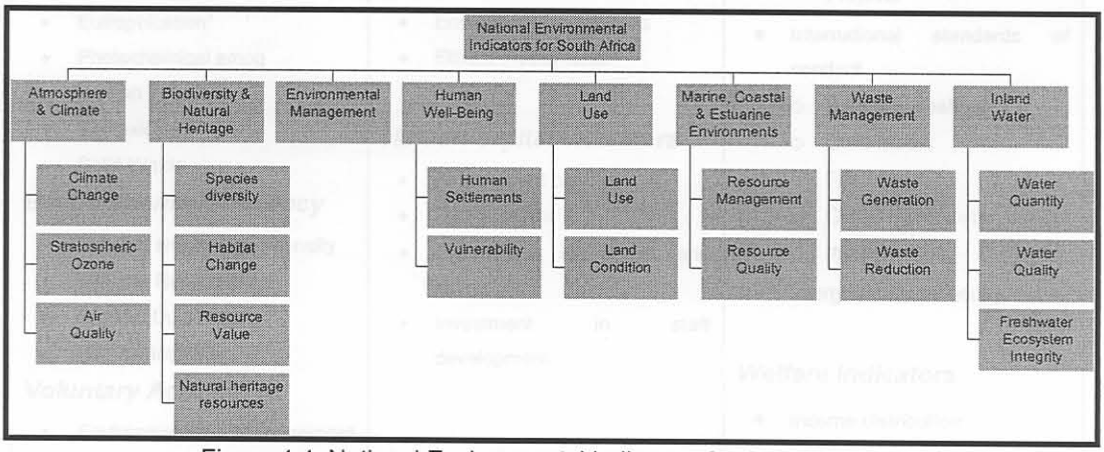


Figure 4.4: National Environmental Indicators for South Africa.

Source: DEAT, 2002

Indicators to measure each issue have been developed and a complete list of the indicators is attached in Appendix E.

4.2.4 Indicators of Sustainable Development for Industry

a) Azapagic & Perdan's Framework

The above-mentioned indicators, however, only address the sustainability of a region, country or continent and cannot be directly applied to business practices. Azapagic and Perdan, 2000 have suggested a sustainable development indicator framework for industry (Table 4.2) but states that *"...not all of them (indicators) will be appropriate for all companies and types of analysis"* and that *"more specific indicators for different sectors have to be defined separately"*.

ENVIRONMENTAL INDICATORS	ECONOMIC INDICATORS	SOCIAL INDICATORS
Environmental Impacts • Resource Use • Global Warming • Ozone Depletion • Acidification[1] • Eutrophication[2] • Photochemical smog • Human Toxicity • Ecotoxicity • Solid Waste ***Environmental Efficiency*** • Material and energy intensity • Material Recyclability • Product Durability • Service Intensity ***Voluntary Actions*** • Environmental Management Systems (EMS) • Environmental improvements above the compliance levels • Assessment of suppliers	***Financial Indicators*** • Value Added • Contribution to GDP • Expenditure on environmental protection • Environmental Liabilities • Ethical Investments ***Human-capital indicators*** • Employment contribution • Staff turnover • Expenditure on health and safety • Investment in staff development	***Ethics Indicators*** • Preservation of cultural values o Stakeholder inclusion o Involvement in Community Projects • International standards of conduct o Business dealings o Child labour o Fair prices o Collaboration with corrupt regimes • Intergenerational equity ***Welfare Indicators*** • Income distribution • Work Satisfaction • Satisfaction of social needs

Table 4.2: Indicators of sustainable development for industry: a general framework

Source: Azapagic & Perdan, 2000

Although these indicators can assist in measuring a company's sustainable performance, it cannot be applied directly to measure the sustainability of a project. The indicators do, nonetheless, show what must be taken into consideration when the environmental, economic and social performance of a project is measured.

b) Global Reporting Initiative

The Global Reporting Initiative (GRI) is a joint initiative between the non-government organisation Coalition for Environmentally Responsible Economics (CERE) and the United Nations Environment Programme (UNEP). It was launched in 1997 with the goal of *"enhancing the quality, rigour and utility of sustainability reporting"* (GRI, 2002). The mission of the organisation is to *"develop and disseminate globally applicable sustainability reporting guidelines"* (GRI, 2002). Businesses worldwide are using these reporting guidelines when

[1] Process whereby the concentration of free hydrogen ions increase in the ambient water resources.
[2] *A lack of accessible oxygen due to excess biological activity triggered by an oversupply of nitrogen and phosphorus"* Graedel & Allenby (1995).

reporting on corporate sustainability. Five companies in South Africa namely: ESKOM, SASOL, SAB, Umgeni Water and Hillside Aluminium are currently supporting the initiative.

The GRI divides the environmental category of sustainability into 10 aspects. Core and additional environmental performance indicators are suggested for each aspect (see Table 4.3).

Aspect	Core Indicators	Additional Indicators
Materials	• Total material used other than water by type • Percentage of material used that are wastes from sources external to the reporting organisation	
Energy	• Direct energy use segmented by primary source • Indirect energy use	• Initiatives to use renewable energy sources and to increase energy efficiency • Energy consumption footprint of major products • Other indirect energy use and implications
Water	• Total water use	• Water sources and related ecosystems/ habitats significantly affected by use of water • Annuals withdrawals of ground and surface water as a percent of annual renewable quantity of water available from the sources • Total recycling and reuse of water
Biodiversity	• Location and size of land owned, leased or managed in biodiversity-rich habitats • Descriptions of the major impacts on biodiversity associated with activitiesbitat and/or products and services in terrestrial, freshwater and marine environments	• Total amount of land owned, leased or managed for production activities and extraction use • Amount of impermeable surface as a percentage of land purchased or leased • Impacts of activities and operations on protected and sensitive areas • Changes to natural habitats resulting from activities and operations and percentage of habitat protected or restored • Objectives, programmes and targets for protecting and restoring native ecosystems and species in degraded areas • Number of IUCN Red List species with habitats in areas affected by operations • Business units currently operating or planning operations in and around protected or sensitive areas
Emissions, effluents and waste	• Greenhouse gas emissions • Use and emissions of ozone-depleting substances • NOx, SOx, and other significant air emissions by type	• Other relevant indirect greenhouse gas emissions • All production, transport, import or export or any waste deemed "hazardous" under the terms of the Basel Convention Annex I, II, III

	• Total amount of waste by type and destination • Significant discharges to water by type • Significant spills of chemicals, oils and fuels in terms of total number and total volume	and VIII
Suppliers		• Performance of suppliers relative to environmental components of programmes and procedures as described by GRI
Products and services	• Significant environmental impacts of principal products and services • Percentage of the weight of products sold that is reclaimable at the end of the products' useful life and percentage that is actually reclaimed	
Compliance	• Incidents and fines for non-compliance with all applicable international declarations/conventions/treaties, and national, sub-national, regional and local regulations associated with environmental issues	
Transport		• Significant environmental impacts of transportation used for logistical purposes
Overall		• Total environmental expenditure by type

Table 4.3: GRI's Environmental Performance Indicators

Source: GRI, 2002.

4.3 Environmental Checklists

Environmental checklists are mostly used to identify impacts on the environment or key environmental factors for further analysis. It is often used as part of an environmental impact assessment or to determine whether a project justifies an environmental impact assessment. The advantages of checklists are its straightforwardness and user-friendliness as well as the fact that it can easily be amended. Although checklists provide a convenient summary of proposed activities and potential impacts, it does not consider the scale of impacts and cumulative impacts are often ignored. Examples of environmental checklists are attached in Appendix F.

The study of environmental checklists gives a clear indication of what the key environmental concerns or factors are that can be affected by industrial activities as well as the industrial actions that cause the effects. Table 4.4 summarizes the factors the different checklists focus on.

Canter & Karmath (1995).
• Physical environmental landform
• Air/Climatology
• Water
• Solid Waste
• Noise
• Hazardous Waste
• Biological Environmental flora
• Fauna
• Recreation
• Aesthetics
• Archeological sites
• Health & Safety
• Cultural Patterns
• Local services
• Public Utilities
• Population
• Economic
• Transportation
• Natural Resources
	California Environmental Checklist (http://ceres.ca.gov/topic/env_law/ceqa/guidelines/appendices.html
	• Aesthetics
	• Agriculture Resources
	• Air Quality
	• Biological Resources
	• Cultural Resources
	• Geology/Soils
	• Hazards & Hazardous Materials
	• Hydrology/Water Quality
	• Land Use/Planning
	• Mineral Resources
	• Noise
	• Population/Housing
	• Public Services
	• Recreation
	• Transportation Traffic
	• Utilities/Service Systems
	• Mandatory Findings of Significance
		Washington State: Department of Ecology (http://www.ecy.wa.gov)
		• Earth
		• Air
		• Water
		  o Surface
		  o Ground
		  o Water Runoff
		• Plants
		• Animals
		• Energy & Natural Resources
		• Environmental Health
		• Land and Shoreline Use
		• Housing
		• Aesthetics
		• Light and glare
		• Recreation
		• Historic and Cultural Preservation
		• Transportation
		• Public Services
		• Utilities

US General Service Administration (http://hydra.gsa.gov/) • Subsurface Conditions • Hydrology • Landforms • Wildlife • Land Use • Natural Hazards • Cultural Resources • Utilities/Services • Transportation • Hazardous Materials	***US Department of Energy (http://www.id.doe.gov/doeid)*** • Air Emissions • Asbestos • Work Force Adjustments • Excess Noise levels • Utility Modification • Soil Disturbance • Water Treatment • Water/Well Use • Water Course Modification • Pesticide Use • Chemical Use/Storage	• Petroleum Storage • Solid Waste • PCBs • Hazardous Waste • Radioactive Waste • Mixed Waste • Radiation Exposure • Liquid Effluent • Sensitive Resources • CERCLA/RCRA Site

Table 4.4: Focus Areas of Environmental Checklists

The Environmental Checklists provides guidance in formulating the relevant type of questions that a gate review (as discussed in Chapter 3) should typically address. It gives a clear indication that a framework for environmental factors is necessary to provide structure to typical gate review questions.

4.4 Framework to evaluate Environmental Impacts within Projects

Based on the study of environmental concerns, environmental checklists, sustainable development indicators and environmental performance indicators, four main environmental factors or themes were chosen: Land, Air, Water and Mined resources. The themes are used to configure a framework to classify possible environmental impacts of projects (Figure 4.5).

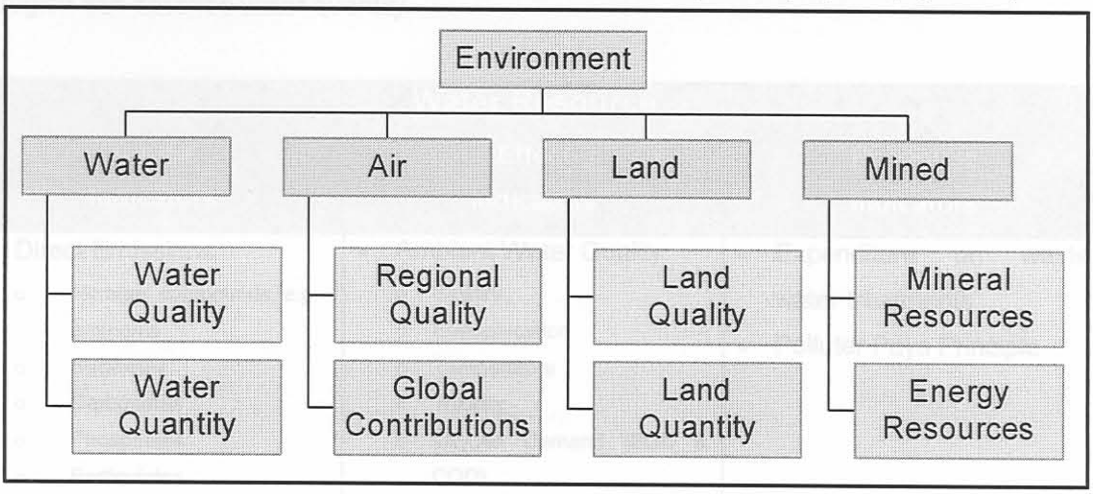


Figure 4.5: Framework to classify possible environmental impacts of projects

Possible measurable causes of environmental effects for each main factor are determined, and in addition, suitable indicators are identified to measure these environmental effects. The framework focuses on direct environmentally measurable effects and possible responses to these environmental effects are listed in the form of response indicators. It must be noted that only anthropogenic causes, i.e. human induced, typical of the process industry have been considered, i.e. natural or other human activities are not included in the framework.

Environmental impacts can have an end-point effect on either human health quality or ecosystem quality (see cause-effect chain of environmental impacts in section 2.3.2b). The framework does not focus on end-point of impacts such as economic costs, which are often paid for by society and not the company. The possibility of specific end-point impacts sometimes justifies response expenses. The focus of the following tables are on specific environmental effects of the process industry and economic and social consequences of end-point effects are not taken into consideration.

4.4.1 Water

The availability of adequate water resources in a region is a function of the quality and quantity of these resources. Water quality is described by the physical characteristics of the water resources, e.g. pH, concentration of key pollutants in water, the actual smell, the appearance of the water, etc. In turn, the groundwater levels and surface water availability in a region can describe water quantity.

Water Resource		
Cause Indicators	**Effect Indicators**	**Response Indicators**
• Direct Emissions : o Nitrogen compounds, e.g. ammonia o Sulphates o Carbonates o Phosphates o Particulates o Organics, differentiated as CxHy, aromatics, halogen aromatics (AOX), etc. o Metals, e.g. Hg, Pb, Ni, etc. • Indirect Emissions: o Leachate from Waste Material discharged into ground o Accidental Spills o Air emissions with final impact on water quality, e.g. nitrogen oxides, sulphur dioxide (see air resources table) • Water Use: o Annual withdrawal of ground water supplies o Annual withdrawal of surface water	• Ambient Water Quality o Salinity o Eutrophication o Temperature o Toxicity o Oxygen Demand (BOD & COD) o Acidification (acid drainage or acid rain) o Total dissolved solids (TSS) • Ambient Water Quantity o Change in surface flow pattern o Water table depth	• Expenditure on waste water treatments • Polluter Pays Principle

Table 4.5: Indicators for Water Resource

4.4.2 Air

As a resource, air impacts can be divided in terms of regional air quality effects i.e. visibility, smell, noise levels and pollution concentrations in air, and global effects which are concerned with environmental problems such as global warming and ozone depletion.

Air Resource		
Cause Indicators	**Effect Indicators**	**Response Indicators**
• Direct Emissions i.e. gas residues(point source and fugitive): o Nitrogen oxides o Methane o Non-methane volatile organic compounds o Metals o Sulphur oxides o Reduced Sulphur Compounds o Ammonia o Carbon oxides o Chlorofluorocarbon-type compounds • Indirect Emissions o Accidental spills o Long term emissions from waste disposal facilities • Non-material emissions: o Noise	• Regional Air Quality effects: o Summer smog (Photochemical ground level ozone formation) o Noise levels o Winter smog (particle concentration) o Smell o Acidification o Toxicity • Global effects o Stratospheric ozone Depletion o Global Warming	• Expenditure on air pollution impact abatement options • Expenditure on climate change impact abatement options

Table 4.6: Indicators for Air Resource

4.4.3 Land

Land resources can be described as a function of land quality and land quantity. Land quantity is described by characteristics such as soil degradation, natural forests area as a percentage of land area, area of urban formal and informal settlements as well as arable and permanent cropland area. In turn, the reduction in biodiversity and soil conditions can be used to describe land quality.

Land		
Cause Indicators	Effect Indicators	Response Indicators
• Direct emissions: ○ Organics ○ Metals • Indirect emissions: ○ Solid waste ○ Accidental spills • Land use: ○ Occupied land ○ Contaminated land ○ Topsoil removed	• Land Quality ○ Heavy metal concentration in topsoil ○ Organics concentration in topsoil ○ Nutrient concentration ○ Biodiversity • Land Quantity ○ Land conversion/transformation ○ Loss of topsoil	• Percentage of designated protected areas

Table 4.7: Indicators for Land

4.4.4 Mined Resources

Mined resources focus on mineral and energy resources. Renewable options are preferred and therefore mined resources can be described by the reserve or availability of non-renewable mineral and energy resources.

Mined Resources		
Cause Indicators	Effect Indicators	Response Indicators
• Consumption of non-renewable mineral resources • Consumption of renewable energy resources • Intensity of energy use	• Minerals reserve/availability • Fuels reserve/availability	• Capital expenditure to increase materials and energy efficiency

Table 4.8: Indicators for Mined Resources

4.5 Conclusion

Four main environmental factors that can be affected by projects have been identified. A framework of possible environmental impacts has been constructed by focusing on each resource separately using the following methodology:

- Determining causes of possible impacts on the various resources
- Identifying effect indicators to monitor the resulting impacts
- Listing possible responses that can minimize the impacts.

This framework provides guidance in identifying impacts for each one of the three critical phases of the process being implemented, as identified in Chapter 3 (Construction, Operation and Decommissioning). The environmental feasibility of the project should be evaluated at each gate review and the information in the framework provides the basis from which questions for the gate reviews with regards to the specific themes can be formulated.

The environmental framework is the basis from which the scoring guidelines used in the corporate strategic decision-making tool, proposed in this document, are developed and thus forms an integral part of the methodology.

Chapter 5: Environmental Matrix Evaluation for Corporate Decision Purposes

5.1 Process industry activities causing environmental impacts

The main activities, of the process industry, center around processes manufacturing products (see Figure 5.1 for the process- and product life cycles). In each one of the phases, of the product and process life cycle, there are specific activities that have cross boundaries with nature and that can consequently cause environmental impacts. The activities together with the nature constituents form the cause of an environmental impact (see cause indicators in Chapter 4).

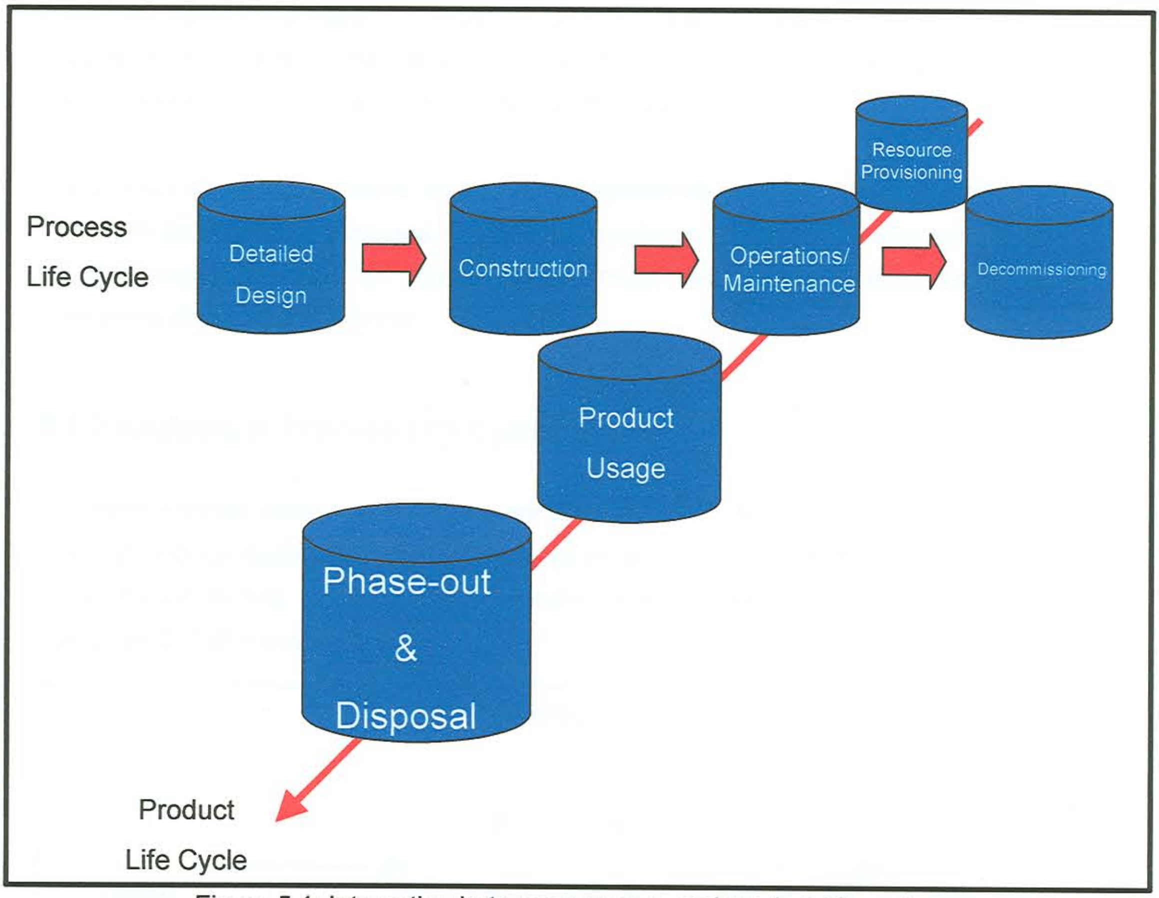


Figure 5.1: Interaction between process- and product life cycle

Environmental impacts in each one of the phases have an associated intensity as well as probability of occurrence. The three critical phases in the process life cycle with regards to possible environmental impacts and future liabilities have been identified in Chapter 3 as: Construction, Operations and Decommissioning Phases. The reason for this is that impacts associated with the process design phase have a low intensity and it is believed that the design phase should be proactively used to minimize future liabilities by applying Design for Environment principles. Sharratt & Choong (2002) agree that to a large extent environmental impacts of a process is determined by its design, *"decisions taken during process design include not only decisions that affect on-site environmental performance, but also, through the selection of feedstocks, suppliers, energy sources and transport systems, the indirect environmental impacts are determined."*

5.1.1 Products of the Process Industry

The process a project implements produces products, therefore the product life cycle must also be taken into consideration when evaluating the environmental impacts resulting from the project. The principles of "Product Stewardship" also known as "Extended Product Responsibility" force companies to consider the environmental footprint of their products. Producer Responsibility Laws are also gaining prominence (United States' Environmental Protection Agency webpage). Companies have the greatest responsibility to reduce the environmental impacts of their products since they possess the greatest ability to do so (United States' Environmental Protection Agency webpage).

The product life cycle is viewed as part of the operations phase in order to minimize the complexity for evaluation purposes. The environmental impacts of the project can therefore be evaluated by focussing on only the three process development phases: Construction, Operations and Decommissioning.

5.1.2 Analysis of Process Life Cycle Phases

The three process development phases are analysed by applying the IDEFØ methodology. The methodology applies "box and arrow" graphics to show the inputs to a process/function; output from it as well as the enabling mechanisms and controls (KBSI, 2002). The basic syntax for IDEFØ is shown in Figure 5.2.

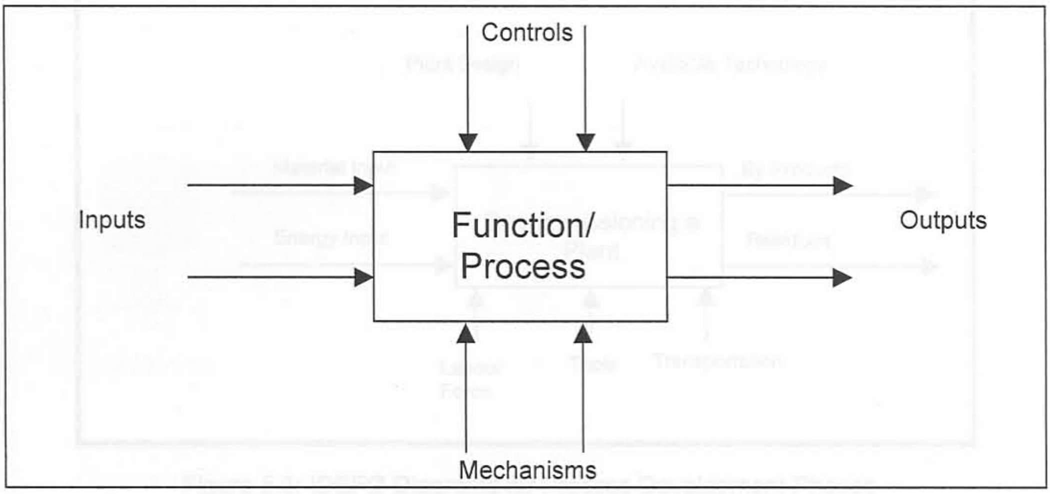


Figure 5.2: Basic Syntax of IDEFØ

Source: KBSI, 2002

The diagrams for the three phases, which are based on the IDEFØ methodology, are shown in Figure 5.3.

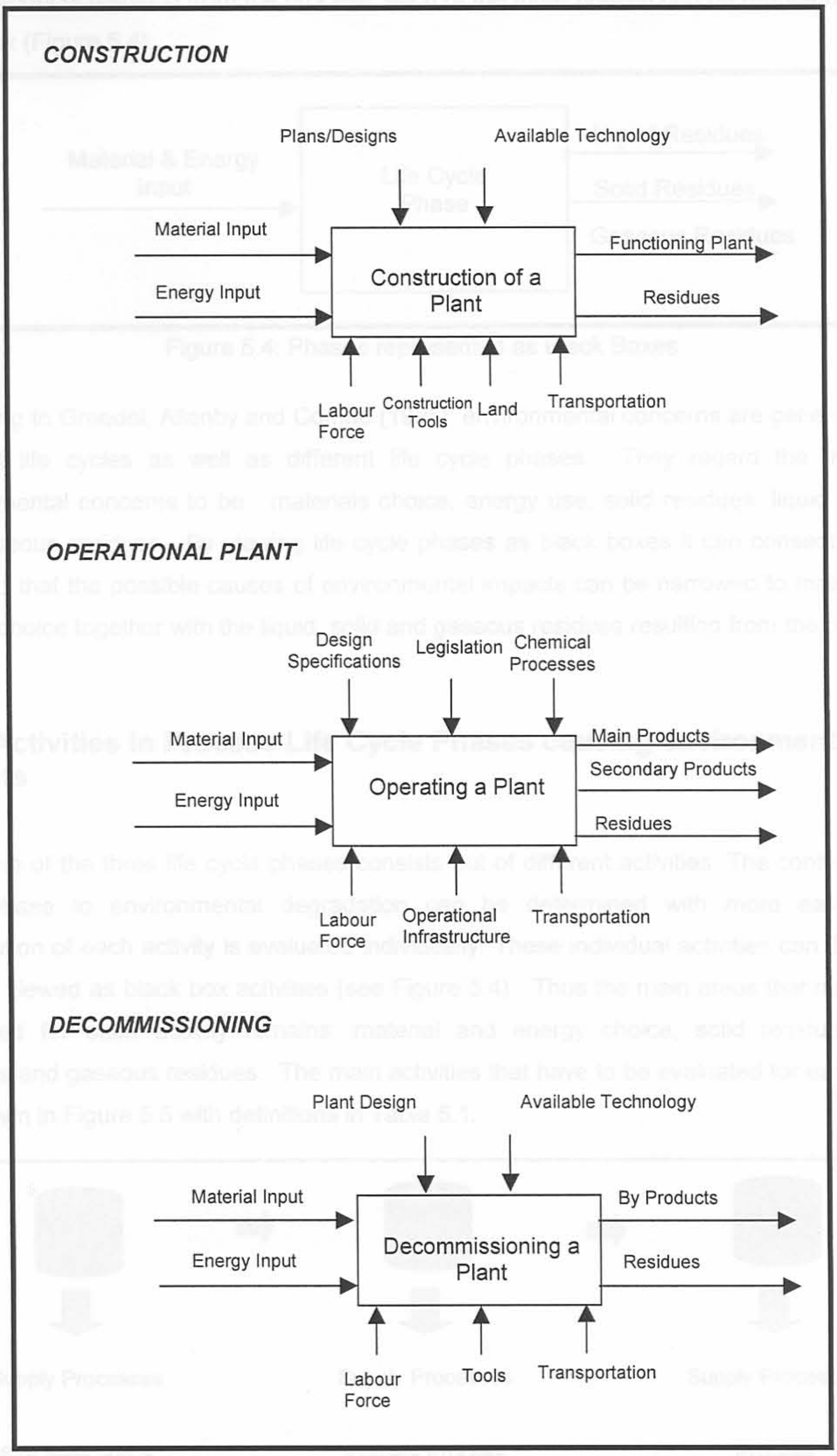


Figure 5.3: IDEFØ Diagrams for Process Development Phases

If a black box is drawn around the process, the controlling and enabling mechanisms, as well as the products resulting from the process, each of the three phases can be represented as a black box (Figure 5.4).

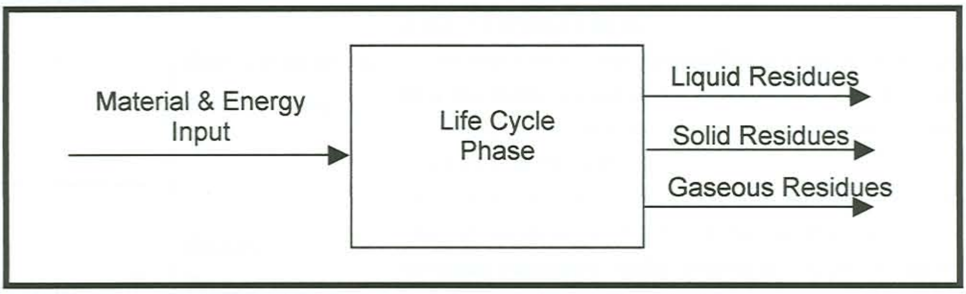


Figure 5.4: Phases represented as Black Boxes

According to Graedel, Allenby and Comrie (1995), environmental concerns are generic across different life cycles as well as different life cycle phases. They regard the five main environmental concerns to be: materials choice, energy use, solid residues, liquid residues and gaseous residues. By viewing life cycle phases as black boxes it can consequently be deduced that the possible causes of environmental impacts can be narrowed to material and energy choice together with the liquid, solid and gaseous residues resulting from the phases.

5.1.3 Activities in Process Life Cycle Phases causing environmental impacts

Each one of the three life cycle phases consists out of different activities. The contribution of each phase to environmental degradation can be determined with more ease if the contribution of each activity is evaluated individually. These individual activities can, however, also be viewed as black box activities (see Figure 5.4). Thus the main areas that need to be evaluated for each activity remains: material and energy choice, solid residues, liquid residues and gaseous residues. The main activities that have to be evaluated for each phase are shown in Figure 5.5 with definitions in Table 5.1.

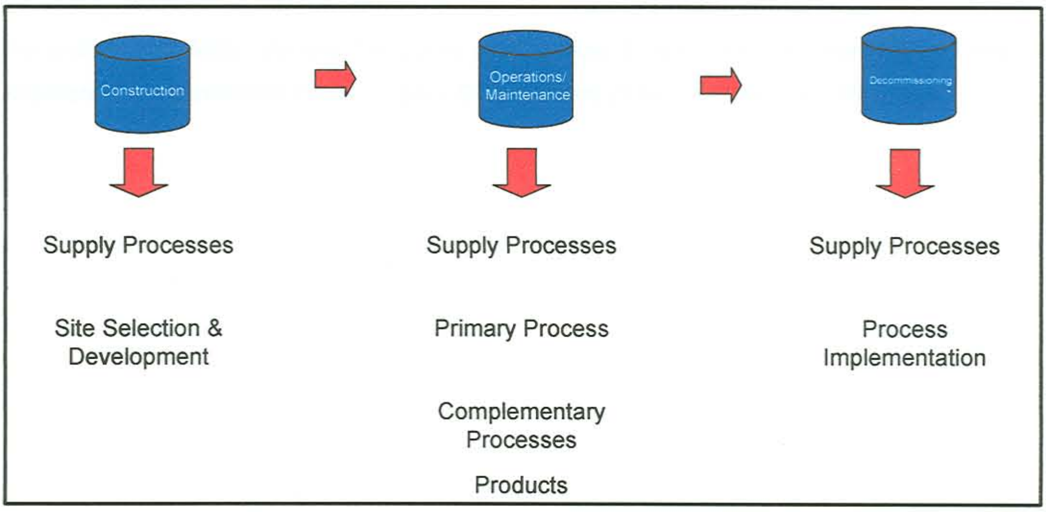


Figure 5.5: Main activities in each phase

Phase	Activity	Definition
Construction	Supply Processes	All processes involve with the supply of all material, energy and any other consumables required for the completion of the construction phase of a process's life cycle.
	Site Selection & Development	All processes involve with the selection of a specific site or location for a new facility; as well as the selection of construction materials and methods as well as all processes involve in the final construction of the facility.
Operation	Supply Processes	All processes involve with the supply of all material, energy and any other consumables required for normal operation i.e. raw material extraction, transport to facility, process to prepare raw material for process; packaging of raw material; packaging material sourced for finished product. (Pre Gate focus)
	Primary Process	All steps essential to manufacture product/All value adding steps that leads to the final product excluding supply and complementary processes.
	Complementary Process	All support processes excluding supply processes; i.e. transport and storage of product; waste management. (Post Gate focus)
	Products	A post gate focus that looks at the possible environmental impacts of product use and product end-of life (recycling; re-use or disposal)
Decommissioning	Supply Processes	All processes involve with the supply of all material, energy and any other consumables required for the completion of the decommissioning process.
	Process Implementation	All steps essential to disassembly the plant and recycle equipment as well as all processes needed to restore the original landside.

Table 5.1: Definitions of main activities

5.2 Environmental Matrix Evaluation

5.2.1 Purpose of the Matrix

The corporate decision-making tool that is developed and proposed in this dissertation is based on the Design for Environment (DfE) Matrix evaluation approach that was introduced by Allenby in 1992 (as cited in Allenby 2000). The tool is to be applied proactively in the Idea Generation, Pre-feasibility and Feasibility phases and thus before the Environmental Impact Assessment is performed in the Detailed Development phase (see Figure 5.6).

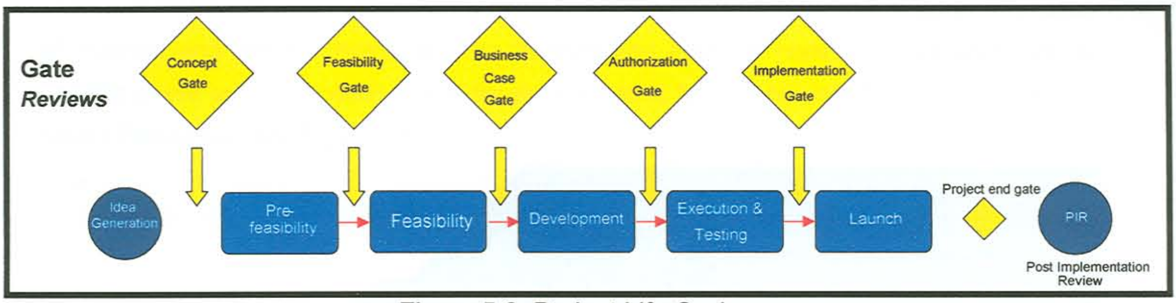


Figure 5.6: Project Life Cycle

The environmental matrix tool that is proposed in this document aims to assist designers and enforce DfE principles as the phases in which it is applied correspond with the design phase of the process (Figure 3.13) The matrix can be viewed as a bridge between the decision makers and the designers as illustrated in Figure 5.7.

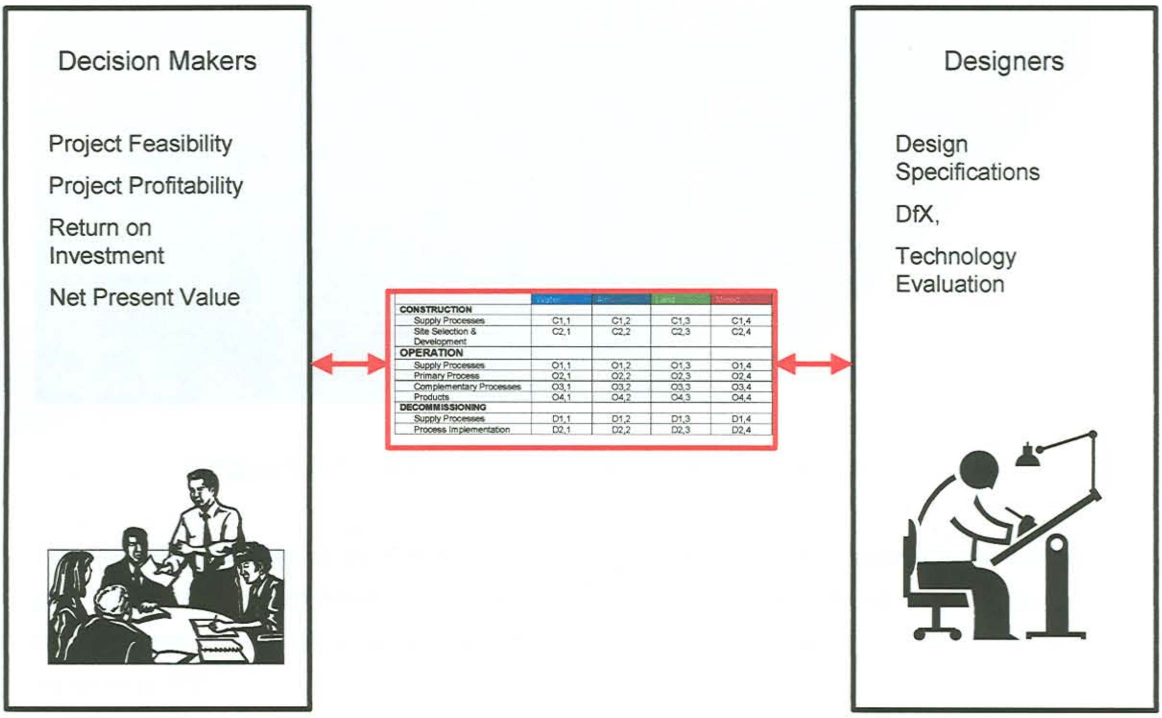


Figure 5.7: The "bridge" between designers and decision makers

5.2.2 Structure of the Matrix

In order to determine the possible environmental impacts associated with a process industry project, the contribution of the individual activities (performed in different phases) to the cause indicators (identified in Chapter 4) need to be evaluated. To ensure efficient evaluation of possible environmental impacts resulting from project activities, the influence of material and energy choice, and liquid, solid and gaseous residues of each activity on the four environmental factors identified in Chapter 4 must be assessed.

The ideal matrix will consequently be a three-dimensional matrix that can evaluate the impact of material and energy choice, and liquid, solid and gaseous residues associated with a specific phase activity on each one of the environmental factors, namely Water, Air, Land and Mined Resources (see Figure 5.8).

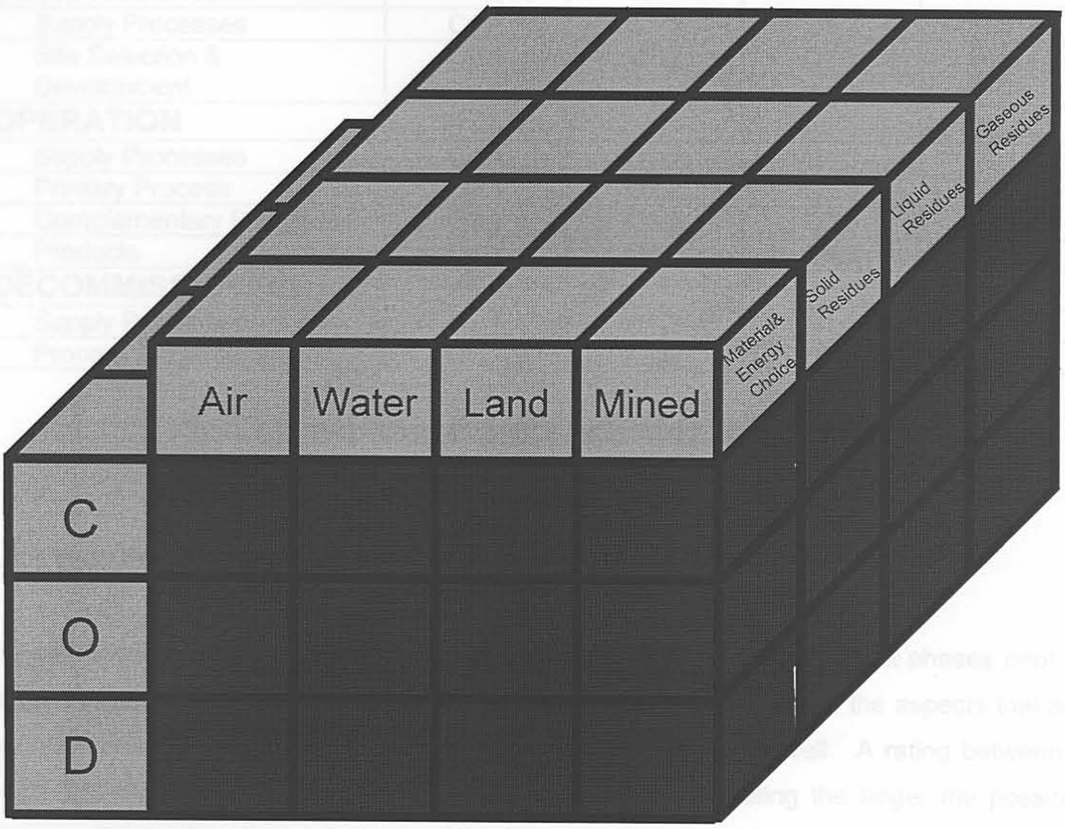


Figure 5.8: Three-dimensional Environmental Evaluation Matrix

The main disadvantage of such a matrix is that on a phase only level there are already 48 cells of interaction that need to be evaluated. If the matrix is adapted to evaluate the environmental impacts on an activity level the number of cells that needs to be evaluated will increase to 128.

An alternative approach is to evaluate the impacts of the activities of each phase on the four environmental factors and to ensure that the scoring guidelines for each cell (interaction) incorporates the possible impacts resulting from material and energy choice, solid residues, liquid residues and gaseous residues. The matrix is then reduced to a two dimensional matrix with 32 cells of interaction that need to be evaluated (Figure 5.9)

	Water	Air	Land	Mined
CONSTRUCTION				
Supply Processes	C1,1	C1,2	C1,3	C1,4
Site Selection & Development	C2,1	C2,2	C2,3	C2,4
OPERATION				
Supply Processes	O1,1	O1,2	O1,3	O1,4
Primary Process	O2,1	O2,2	O2,3	O2,4
Complementary Processes	O3,1	O3,2	O3,3	O3,4
Products	O4,1	O4,2	O4,3	O4,4
DECOMMISSIONING				
Supply Processes	D1,1	D1,2	D1,3	D1,4
Process Implementation	D2,1	D2,2	D2,3	D2,4

Figure 5.9: Two dimensional Environmental Evaluation Matrix

5.2.3 Scoring Method

The matrix shown in Figure 5.9 is used for evaluation purposes in the project phases prior to Gates 1 to 3. Although the same matrix is used in each project phases, the aspects that are evaluated change and therefore the scoring guidelines change as well. A rating between 1 and 5 is assigned for each cell of interaction; the higher the rating the larger the possible effect on the environmental factor. The lowest value of one is chosen as any industrial operation has an effect on the environment to some extent; it is only the intensity of that effect that differs, *"all economic activity contributes to the net entropy through the continuous dissipation of free energy and matter"* (Rees, 1988).

A rating is assigned by completing the scoring guidelines. For gates 1 and 2 the scoring method follows the approach introduced by Graedel & Allenby (1995) and refined by Graedel (1998). The scoring guidelines for Gate 1 and 2 are a set of YES/NO questions. At Gate 1 only one question is asked and examples of worst-case scenarios are listed.

At gate 2 a set of questions must be completed for each cell of interaction in order to rate the possible impact. Only planned impacts, i.e. impacts that will occur on a continuous basis after implementation are therefore known to the designers, are evaluated at gate 2. Gate 3 considers planned as well as unplanned impacts, e.g. accidental spills, and a risk factor for each question is determined from a scoring grid (Figure 5.10). A value of High, Medium or Low is assigned to the probability of occurrence, as well as the intensity of impact. The risk factor for each cell (interaction) is determined by adding the risk factors of each question in the cell's question set (see section 5.3 and refer to Appendix G). The highest possible rating for gates 1 and 2, is thus 160, and for gate 3 800.

		Intensity of occurrence		
		High	Medium	Low
Probability of occurrence	High	5	4	2
	Medium	4	3	1
	Low	2	1	1

Figure 5.10: Scoring Grid to determine risk factor

5.3 Scoring Guidelines

Scoring guidelines for each element are provided for gates 1 to 3. The questions asked in the scoring guidelines should focus on the following aspects namely:

- Design – questions to verify that an optimal environmental friendly design, that meets the specifications, has been achieved. These questions must ensure that all alternatives have been investigated. Design incorporates the design of the process, maintenance as well as planned maintenance shutdowns.
- Planned Impacts – question that address the quantity and intensity of direct and indirect impacts as well as ways to minimize these impacts.
- Unplanned impacts – under this aspect questions addressing accidental releases are included.

All three of these aspects are not applicable to all activities. The level of detail in the questions addressing these aspects varies between the gates. The questions compiled from the environmental checklists (Table 5.3, Table 5.5 and Table 5.7) together with the questions developed by Graedel and Allenby (1995), Graedel (1998) and Yarwood & Eagan (1998), served as a basis for the questions used in the scoring guidelines. A complete set of scoring guidelines and protocols are attached in Appendix G.

5.3.1 Construction Phase

The construction phase has two main activities: Supply Processes and Site Selection and Development. Table 5.2 shows which aspects the scoring guidelines should address for each interaction between the activities and the environmental factors.

	Water	Air	Land	Mined
Supply Processes	• Design • Planned Impacts	• Design • Planned Impacts	• Design • Planned Impacts	• Design • Planned Impacts
Site Selection & Development	• Design • Unplanned Impacts • Planned Impacts	• Design • Unplanned Impacts • Planned Impacts	• Design • Unplanned Impacts • Planned Impacts	• Design

Table 5.2: Aspects scoring guidelines should focus on for Construction phase

Table 5.3 shows the questions of concern for the Construction Phase, which are compiled from the various environmental checklists that have been studied (see Appendix F).

CONSTRUCTION PHASE			
Water	**Air**	**Land**	**Mined**
• Will the river flows be altered due to construction? • Will the construction alter the existing drainage patterns of the site or area? • What type of emissions will be discharged into water system? • Will the construction result or contribute towards an increase in water temperature? • Will the quality and/or quantity of groundwater be threatened at any time? • Does the construction endanger a wetland or inland floodplain? • How much surface water will be withdrawn during construction?	• Will the construction result in fugitive dust and particulates? • Will the construction increase ambient noise levels and/or expose people or wildlife to excessive noise? • Will the construction cause vibrations? • Objectionable odors? • What type of emissions to air would result from the construction? Hazardous or greenhouse gasses?	• Landslides and landsubsidence ? • Will the construction result in erosion of soil due to increase winds or removal of vegetation? / Could erosion occur as a result of clearing or construction? • Will the construction result in substantial loss of topsoil? • Will the construction have an impact on land classified as farmland or substantially alter existing or proposed land use of an area? • How will construction debris be disposed off? • Will the construction substantially degrade the existing visual character or quality of the site and its surroundings? • Will the construction have a substantial adverse effect on biodiversity?	• What kinds of energy will be used to meet the energy needs of the construction phase?

Table 5.3: Questions of concern for Construction Phase

5.3.2 Operation Phase

Four activities have been identified for the operation phase. Table 5.4 shows which aspects the scoring guidelines should address for each interaction between the activities and the environmental factors during this phase.

	Water	Air	Land	Mined
Supply Processes	• Design • Planned Impacts	• Design • Planned Impacts	• Design • Planned Impacts	• Design • Planned Impacts
Primary Processes	• Design • Unplanned Impacts	• Design • Unplanned Impacts • Planned Impacts	• Design • Unplanned Impacts	• Design • Unplanned Impacts
Complementary Processes	• Design • Unplanned Impacts • Planned Impacts	• Design • Unplanned Impacts • Planned Impacts	• Design • Unplanned Impacts • Planned Impacts	• Design • Unplanned Impacts
Product	• Design • Unplanned Impacts • Planned Impacts	• Design • Unplanned Impacts • Planned Impacts	• Design • Unplanned Impacts • Planned Impacts	• Design • Unplanned Impacts

Table 5.4: Aspects scoring guidelines should focus on for Operation phase

Waste or residues (Solid and Liquid) generated by the primary process are addressed under the complementary processes as waste management processes. Table 5.5 shows the questions of concern for the Operation Phase, which are again compiled from the various environmental checklists that have been studied (see Appendix F).

OPERATION PHASE			
Water	**Air**	**Land**	**Mined**
• What type of emissions will be discharged into water system? • Will water or emissions be discharged into the ground water? • Will the operational process result in an increase in water temperature? • Is there a probability that waste streams will be	• Will the operational process increase ambient noise levels and/or expose people or wildlife to excessive noise? • Will the operational process cause: o Vibrations? o Objectionable odors? o Emissions of a hazardous air pollutant	• Will the operational process result in excessive magnetic fields and/or radiation? • Will the process generate significant solid waste? If yes, what impact will this waste have on the existing landfill capacity? • Will the operational process have a	• Will the operational process result in extensive use of existing mineral resources (mining, oil, gas, etc)? • What kinds of energy will be used to meet the energy needs of the process? • Will the process result on the loss of availability of a known mineral

stored in underground tanks (thus making ground water vulnerable to contamination) or that waste material could enter ground waters? • How much water will be needed for the operational process? (Determine additional burden on water resources)	and/or greenhouse gas? • Do any proposed air emissions require new air control systems or upgrading of existing systems?	substantial adverse effect on biodiversity?	resource or locally-important mineral resource?

Table 5.5: Questions of concern for Operation Phase

5.3.3 Decommissioning Phase

The Decommissioning Phase consist of two activities and Table 5.6 shows which aspects the scoring guidelines should address for each interaction between the activities and the environmental factors.

	Water	Air	Land	Mined
Supply Processes	• Design • Planned Impacts	• Design • Planned Impacts	• Design • Planned Impacts	• Design • Planned Impacts
Process Implementation	• Design • Unplanned Impacts • Planned Impacts	• Design • Unplanned Impacts • Planned Impacts	• Design • Unplanned Impacts • Planned Impacts	• Design

Table 5.6: Aspects scoring guidelines should focus on for Decommissioning phase

Table 5.7 shows the questions of concern for the Decommissioning Phase, which are also compiled from the various environmental checklists that have been studied (see Appendix F).

DECOMMISSIONING PHASE			
Water	**Air**	**Land**	**Mined**
• What type of emissions will be discharged into water system? • Can the decommissioning result or contribute towards an increase in water temperature? • Will the quality and/or quantity of groundwater be threatened at any time?	• Will the decommissioning increase ambient noise levels and/or expose people or wildlife to excessive noise? • Will the operational process cause: o Vibrations? o Objectionable odours? • Will the decommissioning result in fugitive dust and particulates?	• Will the decommissioning result in erosion of soil due to increase winds or removal of vegetation?	• What kinds of energy and material will be used to meet the specific needs of the decommissioning phase?

Table 5.7: Questions of concern for Decommissioning Phase

5.4 Interpretation of Results

The completed matrix shows a rating for the impact of each phase on every environmental factor, as well as a rating for the total impact on each of the environmental factors. Figure 5.11 illustrates an example of completing the Environmental Evaluation Matrix.

Gate 1:

	Water	Air	Land	Mined
CONSTRUCTION (10)	***6***	***2***	***2***	***6***
Supply Processes	5	1	1	5
Site Selection & Development	1	1	1	1
OPERATION (20)	***12***	***12***	***8***	***4***
Supply Processes	5	1	1	1
Primary Process	1	5	1	1
Complementary Processes	5	5	1	1
Products	1	1	5	1
DECOMMISSIONING (10)	***2***	***6***	***6***	***2***
Supply Processes	1	1	1	1
Process Implementation	1	5	5	1
(40)	**20**	**20**	**16**	**12**

Gate 2:

	Water	Air	Land	Mined
CONSTRUCTION (10)	***7***	***5***	***5***	***7***
Supply Processes	5	2	3	5
Site Selection & Development	2	3	2	2
OPERATION (20)	***15***	***14***	***12***	***9***
Supply Processes	5	2	3	2
Primary Process	4	5	2	2
Complementary Processes	5	5	2	2
Products	1	2	5	3
DECOMMISSIONING (10)	***5***	***8***	***7***	***3***
Supply Processes	2	3	2	1
Process Implementation	3	5	5	2
(40)	**27**	**27**	**24**	**19**

Gate 3:

	Water	Air	Land	Mined
CONSTRUCTION (50)	***21***	***18***	***12***	***33***
Supply Processes	15	8	8	25
Site Selection & Development	6	10	4	8
OPERATION (100)	***57***	***58***	***41***	***26***
Supply Processes	25	8	6	10
Primary Process	15	15	8	3
Complementary Processes	12	18	14	8
Products	5	17	13	5
DECOMMISSIONING (50)	***16***	***32***	***34***	***20***
Supply Processes	5	7	9	11
Process Implementation	11	25	25	9
(200)	**94**	**108**	**87**	**79**

Figure 5.11: Example of a completed matrix at each gate

The matrix determines whether the interaction between a specific activity and specific resource can be viewed as a possible area of environmental concern. Possible areas of environmental concern are referred to as hotspots. Environmental hotspots and potential liabilities are identified based on the rating of the matrix element during a specific gate review:

- Gate 1: Hotspots are elements with a rating of 5
- Gate 2: Hotspots are elements with a rating of 3 or higher
- Gate 3: Hotspots are elements with a rating of 9 or higher

The information about hotspots must be communicated to the decision-making process and it must therefore be incorporated into this process. Methods to utilize the information in the decision-making process are discussed in Chapter 7. The hotspot information must also be communicated to the next project phase as points to consider or reconsider during the design. Thereby, it is ensured that process designers adequately address potential environmental liabilities, and gate reviewers consider the implications before proceeding with the project.

5.5 Conclusion

A Environmental matrix Evaluation tool is introduced to bridge the gap between the designers and decision-makers. The tool is based on Design for Environment (DfE) principles. The potential impact that can result from the interaction between various identified activities in each critical phase (Chapter 3) with the environmental factors (Chapter 4) has been evaluated. Scoring guidelines are provided for each interaction to guide the user during the evaluation process. The tool is best applicable before Gates 1 to 3 in the staged project management framework.

A completed matrix provides identifies potential areas of environmental concern, also called "hotspots". This information must be communicated to the designers in order for the matrix to fully support DfE, but the information must also be integrated into the decision-making process. Various methodologies to ensure the integration will be discussed further (see Chapter 7). A practical case study in the South African process industry will determine the useability of the Environmental Evaluation Matrix for designers, and establish whether the tool will contribute to existing project management frameworks.

Chapter 6: Case Study

6.1 Goals of Case Study

The aim of the Environmental Evaluation Matrix tool that has been developed is to identify possible areas of environmental concern. The tool has been applied to a project in the South African process industry as a case study. The goals with the case study was to determine:

- The relevance of the tool by evaluating the environmental impacts relevant to the process industries,
- The amount of value added to the decision-making process or knowledge base and
- The ease with which the tool could be applied and used.

The aim with the case study was thus to identify strengths of the tool as well as areas for improvement and to build a business case to support the application of the tool.

6.2 Background to Case Study Project

The tool was applied to a project that was identified by an industry partner. The industry partner is an international company within the South African process industry that focuses on chemical and petrochemical products. Technical experts that were involved with the project were identified and completed the scoring guideline questions of the Environmental Evaluation Matrix (EEM) tool. Technical reports were used to determine what information was available when the project moved through gates 1 to 3.

The project aimed to increase the production capability of an existing plant by 15% by upgrading, removing bottlenecks and installing new equipment. The expansion would have enabled the company to supply the expected increase in product demand in the global marketplace of 4% (at the commencement of the project). In order to increase the production capability, the company had to increase its raw material input and three alternatives options to achieve this were identified. The project investigated all three alternatives, which were:

- Alternative A: Use of coal from existing or future coal mines
- Alternative B: Use of natural gas (a new input that has not been used before)
- Alternative C: A combination of the above

The project was, however, stopped before it entered Gate 3 due to changing market conditions. Figure 6.1 indicates the dates the specific project moved through gate 1 and gate 2. The Draft Environmental Impact Report was nevertheless finished, and it was later used as a basis for a similar project the company undertook.

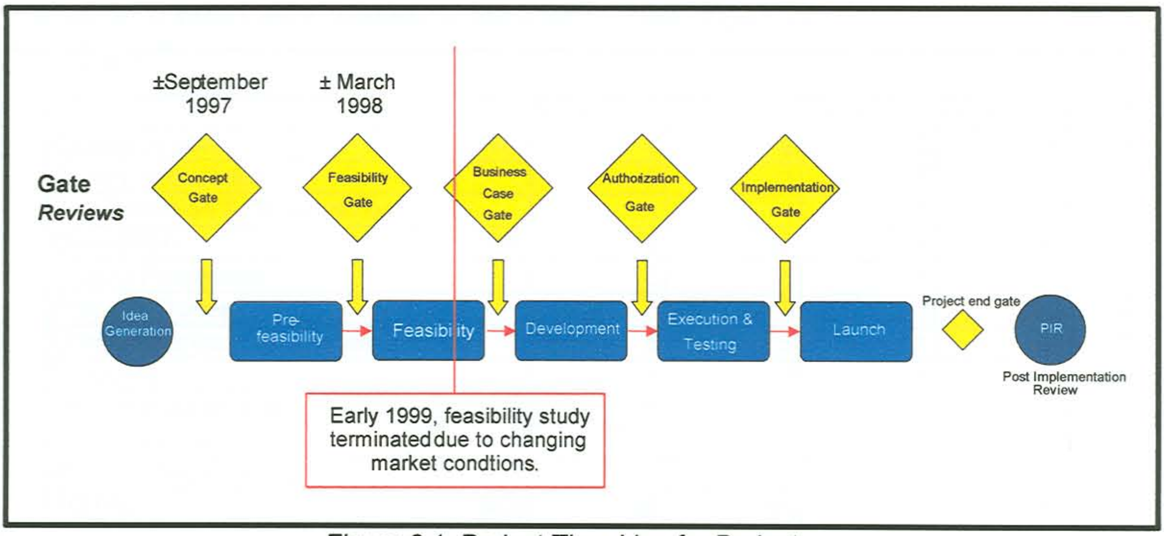


Figure 6.1: Project Time Line for Project

The same systems boundaries that were applied for the Environmental Impact Assessment (EIA) were used for purposes of the case study. Therefore, the EEM tool was only applied for the proposed 15% expansion and the environmental effects of this production increase. The technical expert regarded the environmental impacts after mitigation action to be similar for alternatives A and B. Due to the fact that the combination alternative entered the feasibility phase the scoring guidelines were only completed for alternative C.

6.3 Results

6.3.1 Values obtained from the Environmental Evaluation Matrix

The following values were obtained for the different gates (Figure 6.2):

Gate 1:

		Water	Air	Land	Mined
Construction	**(10)**	**6**	**2**	**2**	**6**
Supply Processes		5	1	1	5
Site Selection & Development		1	1	1	1
Operation	**(20)**	**16**	**12**	**4**	**12**
Supply Processes		5	1	1	5
Primary Process		5	5	1	5
Complementary Processes		5	5	1	1
Products		1	1	1	1
Decommissioning	**(10)**	**6**	**2**	**2**	**2**
Supply Processes		1	1	1	1
Process Implementation		5	1	1	1
TOTAL	**(40)**	**28**	**16**	**8**	**20**

Gate 2:

		Water	Air	Land	Mined
Construction	**(10)**	**7**	**7**	**7**	**10**
Supply Processes		4	3	3	5
Site Selection & Development		3	4	4	5
Operation	**(20)**	**10.5**	**9**	**7**	**4**
Supply Processes		4	3	3	3
Primary Process		2	1	1	1
Complementary Processes		1.5	2	3	0
Products		3	3	0	0
Decommissioning	**(10)**	**5**	**5**	**5**	**6.5**
Supply Processes		0	0	2	1.5
Process Implementation		5	5	3	5
TOTAL	**(40)**	**22.5**	**21**	**19**	**20.5**

Gate 3:

		Water	**Air**	**Land**	**Mined**
Construction	**(50)**	**15**	**19**	**22**	**10**
Supply Processes		10	9	9	5
Site Selection & Development		5	10	13	5
Operation	**(100)**	**47**	**28**	**34**	**32**
Supply Processes		21	11	11	17
Primary Process		16	7	11	5
Complementary Processes		5	5	5	5
Products		5	5	7	5
Decommissioning	**(50)**	**20**	**10**	**11**	**10**
Supply Processes		13	5	6	5
Process Implementation		7	5	5	5
TOTAL	**(200)**	**82**	**57**	**67**	**52**

Hotspots

Figure 6.2: Environmental Evaluation Matrices for Gate 1 to 3.

The percentage of cells that are hotspots follows no specific pattern, as 32% of the cells are hotspots at Gate 1, 59% of the cells are hotspots at Gate 2 and only 38% of the cells are hotspots at Gate 3. Since the three gates follows different evaluation methods the progress of four specific cells through the three gates were analysed on a similar scale of 0-100% (Figure 6.3). The scores for the cells at different gates were thus expressed as percentages (Table 6.1). The four cells are:

- Operation: Supply Processes: Water
- Operation: Supply Processes: Air
- Operation: Complementary Process: Land
- Operation: Supply Processes: Mined

	Operation: Supply Processes: Water		Operation: Supply Processes: Air		Operation: Complementary Process: Land		Operation: Supply Processes: Mined	
Gate 1	5	100%	1	20%	1	20%	5	100%
Gate 2	4	80%	3	60%	3	60%	3	60%
Gate 3	21	84%	11	44%	5	20%	17	68%

Table 6.1: Expressing scores as percentages

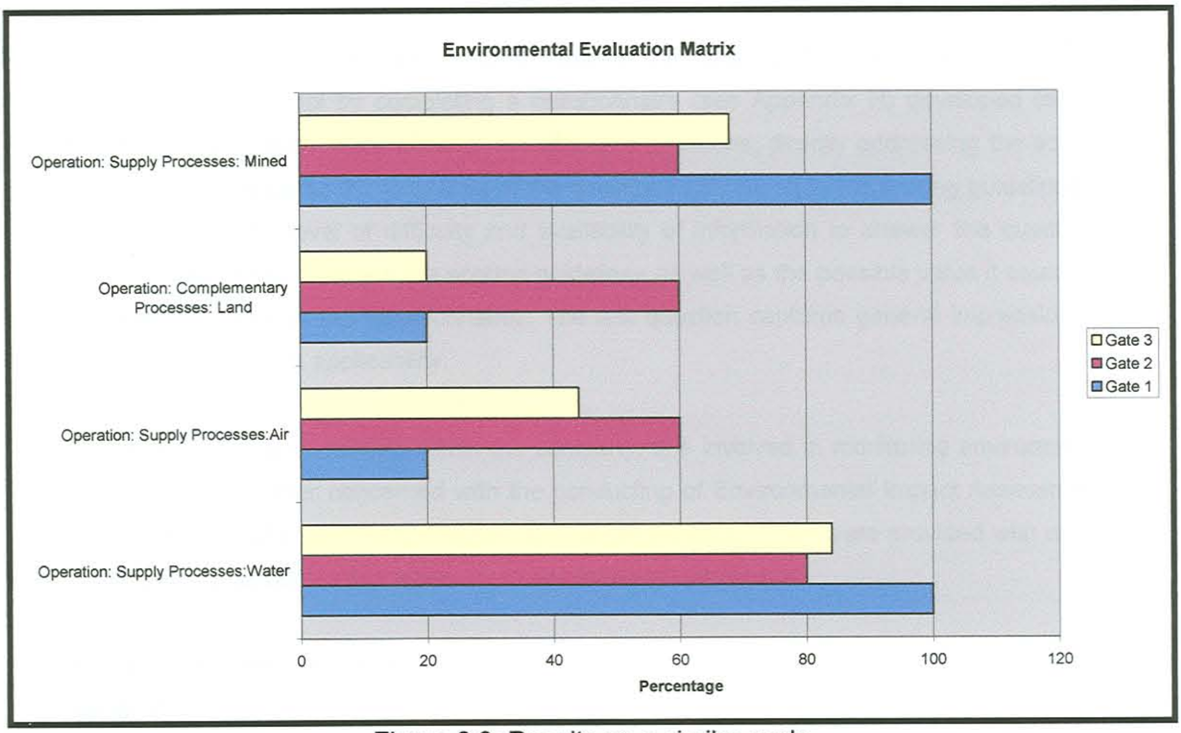


Figure 6.3: Results on a similar scale

It can be concluded that the evaluation processes at the three gates are independent from each other and that a prediction of other gate outcomes cannot be made at preceding gates. The conclusion will nevertheless have to be confirmed with more case studies. The conclusion is based on the fact that scores for individual cells follow no pattern between the various gates. Various patterns were identified, some which are followed by more than one cell e.g. for the cell "Operation: Supply Processes: Water" as well as for "Operation: Supply Processes: Mined" the score decreased between Gate 1 and 2 and then increases between Gate 2 and 3. This is however not the case for "Operation: Supply Processes: Air" where the score first increases and then decreases. Further case studies can be used to analyse the various patterns and to attempt to find correlation between them.

It is not possible to truly interpret the results of the EEM applied to the case study since there is nothing to measure it against. The conclusion was thus reached that completed projects should be used as case study to determine matrix values to measure results against. That would also improve the interpretation of the results since the environmental effects of completed projects can be compared with the projects' matrix evaluations.

6.3.2 Feedback on application of environmental evaluation matrix tool

The goals with the feedback sessions were to obtain opinions on the scoring guidelines and to determine who, inside the organisation, should complete the scoring guidelines. Feedback was obtained from the process engineers who managed the technical aspects of the project and who completed the scoring guidelines as well as from environmental specialists within the company.

The project technical experts provided feedback on the nature of the questions as well as the applicability of the tool by completing a questionnaire (see Appendix H) developed for this purpose. The questionnaire consists out of seven questions, directly addressing the scoring guidelines. It evaluates the relevance of the questions addressed in the scoring guidelines as well as the clarity, level of difficulty and availability of information to answer the questions. The time needed to complete the scoring guidelines as well as the possible value it could add are also evaluated in the questionnaire. The last question captures general impressions of the matrix tool and its applicability.

Two environmental specialists within the company, one involved in monitoring environmental impacts and the other concerned with the conducting of Environmental Impact Assessments (EIA), were identified as environmental responsible persons. They were provided with copies of the scoring guidelines and asked to complete the questionnaire.

a) Project technical experts

General:

The project technical experts note the scoring guidelines' "pre-gate" focus, taking the environmental effects and impacts of the extraction, purification and/or conversion of raw materials into consideration as part of supply processes of all three phases. This aspect of the scoring guidelines is highlighted as extraordinary, especially in the construction phase since the current models within the company do not consider the environmental friendliness of raw material manufacturing for construction purposes. It only focuses on total life cycle cost and the safety of use of a material. This highlights the priorities of the process industry, i.e. safety and costs over the plant life cycle. At this stage, it seems that environmental issues are not considered at all during the phase of plant construction. The environmental impacts of raw material manufacturing are thus ignored as long as the chosen raw material is bought from an approved vendor.

The "Yes/No" nature of the questions is criticised by the project technical experts. They feel answers or alternative options must be provided in quantitative terms in order to minimize emotional and subjective judgements. They are also of the opinion that more detail on the intensity of occurrence or quantity of occurrence should be provided at Gate 2, since there is a vast difference between for example 1000 litres of water and 1 million litres of water being used.

The project technical experts identified certain questions for which the information is not available at the specific gates. For example, supplier agreements with regards to packaging material are not in place at Gate 2 although specific design philosophies, which guide processes that are only finalized post Gate 4, exist.

It is noted that for some questions one of the answers is impossible to occur e.g. C 2.1 question one *"Is the construction process designed to avoid the use of water?"* where a positive answer is impossible since all construction processes need water. The project technical experts also feel that some of the questions are "Not Applicable" to the specific project e.g. C 2.1 question three *"Is the site such that it can be made operational with minimal production of residues with high water pollution potential?"*

Construction:

Certain questions in the scoring guidelines address the design of the construction phase. The project technical experts are of the opinion that although the impacts of construction should be taken into consideration, the design of the construction process fell outside company boundaries and is the responsibility of the contractor. The company does specify to the contractor that the safe disposal of waste and chemical residue, etc. is responsibility of the contractor. Questions addressing the design of the construction process are thus regarded as irrelevant.

The project technical experts note the difference between optimised and minimised solutions. Many questions asked whether certain possible impacts have been minimized, e.g. transportation of construction materials. An optimised solution is found, mostly centred around cost-effectiveness, which is not always the optimal environmental solution.

Operation

The relevance of questions, with regards to design considerations focused on energy use, is questioned by the project technical experts since *"any plant is designed to strike a balance between OPEX (cost of energy) and CAPEX vs available technology vs legislation"*.

Decommissioning

The project technical experts note that the decommissioning process has not been designed at Gate1, 2 or 3 of the project life cycle. Therefore all questions related to the design of the process must be negative. Decommissioning is apparently not considered when a process is being designed and implemented.

b) Environmental experts

Environmental Specialist A:

The first environmental expert is of the opinion that the scoring guidelines address too many aspects, with a lack of emphasis on detailed analysis. The project technical experts' view that the rating is too subjective is supported. The environmental expert do, however, rate the clarity as good but hold the opinion that the scoring guidelines must provide more examples and be more company specific. The availability of the information to answer the questions identified as a main problems. It is noted that the scoring guidelines included a focus on products, packaging material and the decommissioning phase, which is not currently included in analyses.

The environmental specialist states that the current scoring guidelines could not be applied in the company and suggests that perhaps scoring guidelines of this nature should only focus on fewer aspects, in the region of ten aspects for example, and should apply a quantitative scoring system.

Environmental Specialist B:

The second environmental expert also notes that the scoring guidelines address decommissioning, products as well as a "pre-gate" focus which is not currently part of the evaluation process. This environmental expert shares the project technical experts' views on "pre-gate" focus inclusion in such a document as well as the fact that some questions are "Not Applicable" to all projects (see section 6.3.2b). The environmental expert is especially concerned about whether the answers to the questions should take mitigation actions into consideration or not. The opinion was expressed that the design team must be involved in completing the scoring guidelines since so many questions address design decisions.

6.4 Conclusions & Recommendations

The following strengths and weaknesses are identified based on the feedback received (Table 6.2):

Strengths	Weaknesses
The scoring guidelines address aspects currently ignored such as products, decommissioning and "pre-gate" activities.	The questions are too general, not detailed enough and with inadequate examples, descriptions and quantitative measures.
It forces the design engineer to consider environmental aspects often not considered.	Lack of available information to answer the questions.
	Subjective rating system.

Table 6.2: Strengths and Weaknesses of Scoring Guidelines

The scoring guidelines' approach to consider the environmental aspects of "pre-gate" operations is in line with *greening the supply chain* or *supply chain environmental management* initiatives. This concept of supply chain environmental management is observed as a recent and novel managerial principle, especially in South East Asia (Rao, 2002). Since this part of the EEM tool was met with scepticism, it is recommended that the concept be introduced into industry practices through additional environmental criteria to evaluate suppliers against. Table 6.3 lists examples of environmental questions that can be used to evaluate suppliers' environmental performance (Yarwood & Eagan, 1998). Companies can even assign rating values to the answers thereby rating approved suppliers.

	Yes/No
Does the supplier have an Environmental Management System (EMS) in place?	
Does the supplier have formal energy conservation practices in place?	
Does the supplier have ISO 9000 in place?	
Does the supplier have ISO 14000 in place?	
Does the supplier publish an environmental report regularly? Annually Bi-annually	
Does the supplier have a water conservation program in place?	
Does the supplier have a formal program in place for minimizing air emissions?	
Does the supplier have adequate operational procedures in place to address unplanned environmental impacts?	

Table 6.3: Examples of questions to address environmental performance of suppliers

Source: Adapted from Yarwood & Eagan, 1998.

It is evident that the generic scoring guidelines cannot be applied directly within a specific company. The scoring guidelines will have to be adapted according to the company-specific needs and priorities, so that a quantitative rating system can be used. A generic quantitative rating system cannot be developed since there are no agreement on what quantity of impact is regarded as negligible and what as a project terminator. Based on the feedback that information is not available at the various phases, it is questionable whether quantitative environmental information will be available before Gate 3. The only threat in adapting the scoring guidelines for a specific company, is that certain aspects the company do not focus on might be ignored although these may be very relevant and of concern.

It is true that the scoring guidelines address many aspects and do not focus on detailed analysis. The original concept, however, was that the scoring guidelines should provoke environmental considerations in the design phase and inform decision makers of potential environmental concerns. Detailed analysis can be done during the Environmental Impact Assessment.

One case study cannot be entirely conclusive. It is recommended that the scoring guidelines must be applied in a "real-time" project, as it moves through the phases and gates, since only then a reliable conclusion on the impact of the scoring guidelines on the design and decision making phases can be drawn.

The scoring guidelines do add value, even if it only highlights aspects currently ignored. No conclusion could, however, be reached on whether the value added justify the time consumption of the scoring guidelines. It is furthermore concluded that the scoring guidelines of the EEM tool should be completed by a team of project and environmental responsible persons with different viewpoints and expertise.

Chapter 7: Methodologies to incorporate environmental sustainability into the project appraisal process

7.1 Introduction

In the staged project management framework, project performance and key deliverables are reviewed at the end of each phase. These gate-reviews serve as decision points where the project continuation is determined (see Chapter 3.2.2). Environmental sustainability criteria can only be incorporated into the appraisal process if it manifests in the two key aspects of a gate review, namely:

- Information presented to the decision gate meeting, also referred to as decision documentation, which include the status of project deliverables, project plan, technological feasibility, financial feasibility, etc.
- Typical criteria addressed by the meeting (see Figure 3.4)

The Environmental Evaluation Matrix tool provides information about potential areas for environmental concerns. The tool can therefore provide inputs to the information presented to the decision gate meeting. There are, however, different methodologies that can be used to incorporate the output of the tool into the gate review information. The methodologies can be divided into two main categories or schools of thought (Figure 7.1).

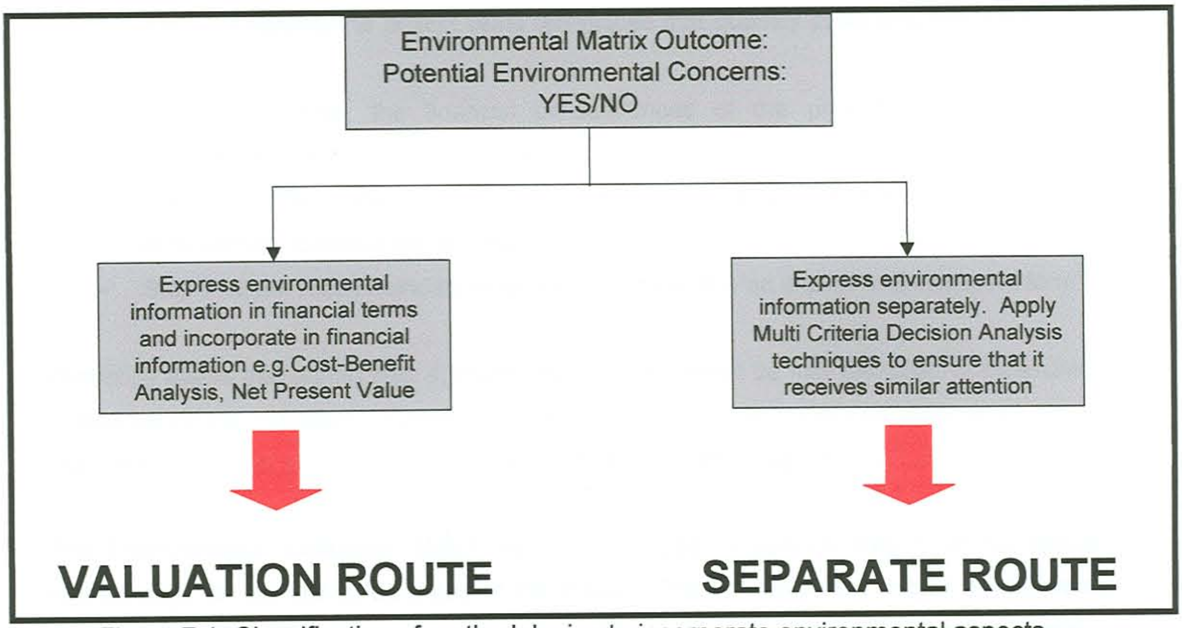


Figure 7.1: Classification of methodologies to incorporate environmental aspects

Criteria for the gate reviews are developed from environmental checklists, scoring guidelines and other environmental management tools' checklists and are addressed in Chapter 8.

7.2 Incorporating environmental sustainability into decision documentation: Valuation Route

The World Bank: Environment Department (1998) regards incorporating environmental aspects into project analysis as a two-step process:

- Understand *what* the impacts are.
- Determine the economic importance of the impacts by estimating the monetary value thereof.

7.2.1 Ecological Economics

Valuation refers to *"the placing of monetary values on environmental goods or services or the impacts of environmental quality changes"* (Dixon, Scura, Carpenter & Sherman, 1994). Environmental valuation, also referred to as environmental economic appraisal, can be incorporated into a decision-making framework by pursuing the following methodology (Winpenny, 1991):

- Step 1: Identify major environmental problems and their causes.
- Step 2: Analyse main potential environmental impacts of the project. Environmental impacts that form an absolute constraint and that will result in project termination can be identified by the analysis.
- Step 3: Review possible alternative solutions or responses to accommodate the identified impacts.
- Step 4: Appraise the project using techniques that quantify costs and benefits as far as possible.
- Step 5: Consider the financial consequences of the project. Also consider externalities resulting from the project.
- Step 6: Draw together implications for policy and institutional building e.g. enforcement, compliance, tax, etc.
- Step 7: Make recommendations to decision-makers in an explicit and intelligent form.

Winpenny states that during step 4, major impacts that cannot be fully identified or measured should be clearly indicated. Furthermore benefits can also be measured qualitatively on a scale from extremely positive (+++) to very negative (---) (see paragraph 7.2.1.c).

The Environmental Evaluation Matrix tool can be used to perform step 1 of the above methodology for the first three gates of the model. The environmental impact assessment (EIA) can be used for the remaining gates. The outcome of the environmental matrix identifies the areas of concern and from the scoring guidelines the problems in each area can be identified. The resource tables (Chapter 4) list possible responses to mitigate the environmental effects. The costs of these responses must be appraised as well.

Dixon and Sherman (1990) developed a flowchart (see Figure 7.2), which guides the appraisal of environmental impacts. The input to this flowchart is the identified and analysed environmental impact of a project. The flowchart provides a simplified guide to *"choosing an appropriate technique for a given situation"* (The World Bank: Environment Department, 1998).

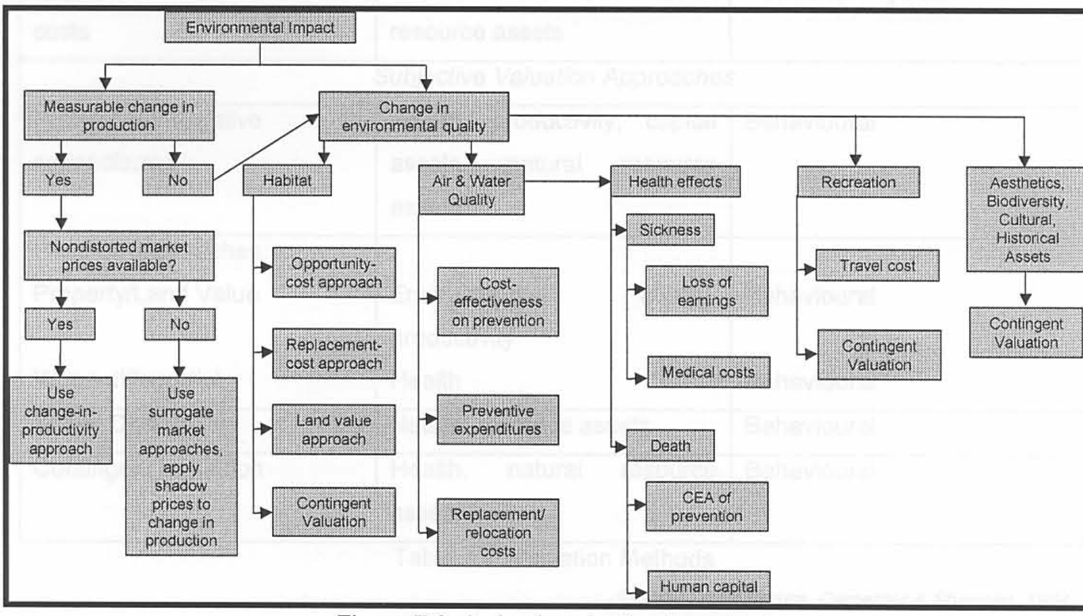


Figure 7.2: A simple valuation flowchart

Source: Dixon, Scura, Carpenter & Sherman, 1994.

The valuation methods, which are mentioned in Figure 7.2, follow either an objective or a subjective valuation approach. Objective valuation approaches aims to describe the cause-effect relationships, which can then be used to provide an objective measure of the damage resulting from certain causes. This approach relies on *"damage functions which relate the level of offending activity (e.g. level and type of air pollutants) to the degree of physical damage to a natural or man made asset (e.g. soiling of buildings) or to the degree of health impact (e.g. incidence of respiratory disease)"* (Dixon, Scura, Carpenter & Sherman, 1994).

Subjective valuation approaches on the other hand is based on *"subjective assessments of possible damage expressed or revealed in real or hypothetical market behaviour"* (Dixon, Scura, Carpenter & Sherman, 1994). Examples of the two approaches, the types of effects that can be valued, and the underlying basis for the valuation is shown in Table 7.1 (Dixon, Scura, Carpenter & Sherman, 1994).

Valuation Method	Effects Valued	Underlying Basis for Valuation
	Objective Valuation Approaches	
Changes in Productivity	Productivity	Technical/Physical
Cost of illness	Health (morbidity)	Technical/Physical
Human Capital	Health (morbidity)	Technical/Physical
Replacement/Restoration costs	Capital assets, natural resource assets	Technical/Physical
	Subjective Valuation Approaches	
Preventive/mitigative expenditures	Health, productivity, capital assets, natural resource assets	Behavioural
Hedonic approaches: Property/Land Value	Environmental quality, productivity	Behavioural
Wage differential	Health	Behavioural
Travel Cost	Natural resource assets	Behavioural
Contingent Valuation	Health, natural resource assets	Behavioural

Table 7.1: Valuation Methods

Source: Dixon, Scura, Carpenter & Sherman, 1994.

The valuation methods are discussed in more detail in Appendix I. The specific project and the type of environmental effect will determine the choice of technique. Also, it is often necessary to use more than one technique to address all the aspects of a project. The applicability of all valuation methods on the project evaluation process does, nevertheless, differ. Dixon, Scura, Carpenter & Sherman (1994) classified the methods into three categories, namely:

- Generally Applicable: Standard and Straightforward approaches
- Selectively Applicable: Approaches that require more data or stronger assumptions
- Potentially Applicable: More data intensive and difficult approaches

Examples of each category are given in Table 7.2.

Generally Applicable Methods	Selectively Applicable Methods	Potentially Applicable Methods
• Approaches that use market values of goods and services: o Changes-in-productivity o Cost-of-illness o Opportunity-cost • Cost-side approaches that use the value of actual or potential expenditure: o Cost-effectiveness o Preventive expenditures o Replacement costs o Relocation costs o Shadow-project	• Surrogate Market Techniques: o Travel-cost o Marketed goods as environmental surrogates • Contingent Valuation Methods: o Bidding games o Take-it-or-leave-it experiments o Trade-off games o Costless choice o Delphi technique	• Hedonic Methods: o Property and other land-value approaches o Wage-differential approach • Macroeconomic models: o Linear programming o Natural resource accounting o Economy-wide impacts

Table 7.2: Classification of valuation methods based on applicability

Source: Dixon, Scura, Carpenter & Sherman, 1994.

The information of the environmental valuation is eventually incorporated into the broader economic analysis of the project (The World Bank: Environment Department, 1998). The most common methods used for project appraisal tend to be a Cost-Benefit Analysis (CBA) and a Cost-Effect Analysis (CEA). The three main decision criteria, also referred to as project evaluation indicators, used in the two methods are:

- Net present value (NPV): Determines the present value of net benefits by discounting all benefits and costs back to the beginning of the base year.
- Internal rate of return (IRR): IRR is defined as the discount rate that will result in a zero NPV for a project.
- Benefit-cost ration (BCR): The ratio between discounted benefits and discounted costs. A BCR should be greater than 1 for the project to generate benefits.

Incorporating the environmental valuation into the economic analysis do not change any of the methods of analysis or decision criteria. However, setting the boundaries for the analysis needs special consideration as the environmental impacts could have effects that extend beyond the temporal and spatial boundaries of the project itself.

a) Temporal Boundaries

The temporal boundary of a project refers to the time horizon that is considered for analysis purposes. The choice of a time horizon is further complicated by the choice of an appropriate discount rate. For example a discount rate of 10% would imply that most costs and benefits become inconsequential after 20 years (Dixon, Scura, Carpenter & Sherman, 1994), while certain environmental impacts could have an end-effect for far longer. There are two approaches to handle the time horizon and accommodate long-term environmental impacts in the analysis:

- Choose a time horizon long enough to include all effects of environmental impacts. This implies extending the cash-flow analysis beyond the normal end-of-project period.
- Add a capitalized value of net costs (or benefits) of future environmental impacts (positive or negative) at the normal end-of-project period. The same approach that one will use for a residual value estimate for a long-lasting capital good is thus applied.

b) Spatial Boundaries

The spatial boundary refers to the area that is influenced by the environmental impacts of the project, and it can extend far beyond the geographical boundaries of the project. In choosing a spatial boundary it is important to be transparent in the assumptions that are made.

7.2.2 Total Cost Assessment Methodology

The American Institute of Chemical Engineers' Centre for Waste Reduction Technologies (AIChE CWRT) has developed a standardised, yet flexible, approach to understanding and managing the environmental and health costs associated with products and processes. The approach, "Total Cost Assessment Methodology" (TCA Methodology), can assist in internal managerial decision-making. The TCA Methodology supports a life-cycle thinking approach and is thus regarded by some as a Life Cycle Cost Analysis technique (see Appendix C for more information on the methodology). AIChE CWRT intends for the TCA Methodology to assist in bridging the gap between hard and soft financial values and the current non-monetized concepts of business sustainability goals (AIChE CWRT, 1999).

The Ecological Economics valuation methods conduct a separate economic analysis on environmental impacts and then incorporate these into a broader economic analysis of the project. In contrast, the TCA Methodology incorporates environmental and health costs from the start and have a complete cost inventory that includes all costs necessary to determine whether a project is profitable (Washington State: Department of Ecology, 2000). This is achieved by applying the unique cost classification used in the TCA Methodology. The methodology distinguishes between five types of costs (see Table 7.3).

Cost Type	Definition
Type I: Direct costs for the manufacturing site	Direct costs of capital investment, labor, raw material and waste disposal. Includes both recurring and non-recurring costs as well as both capital and operations and management (O&M) costs.
Type II: Potentially hidden corporate and manufacturing site overhead costs	Indirect costs not allocated to the product process. May include both recurring and non-recurring costs. Includes capital and O&M costs as well as outsourced services.
Type III: Future and contingent liability costs	Liability costs include fines and penalties caused by non-compliance and future liabilities for forced clean-up, personal injury and property damage.
Type IV: Internal intangible costs	Costs paid by the company and includes difficult to measure cost entities such as worker wellness, worker morale, customer loyalty, corporate image, estimates of avoided costs, etc.
Type V: External costs	Costs for which the company does not pay (see definition of externalities in Glossary).

Table 7.3: Costs included in TCA Methodology

Source: AIChE CWRT, 1999.

Information with regards to Type I and Type II costs can be derived from a company's internal cost accounting system. Completing various checklists and obtaining information from cost databases, can determine Type III, IV and V costs. According to AIChE CWRT (1999) the methodology can be applied in various phases of a project life cycle where it can provide a basis for an improved decision (Figure 7.3)

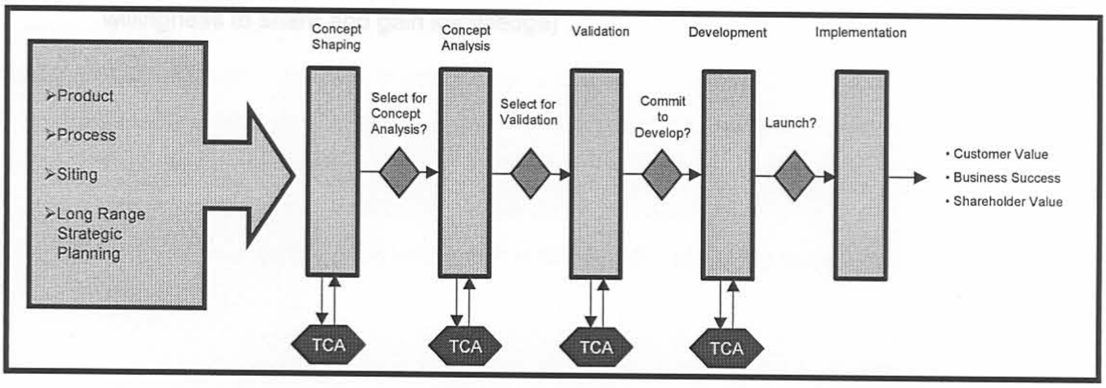


Figure 7.3: Phases where TCA can be applied in an overall Project Management Framework

Source: AIChE CWRT, 1999.

TCA can be performed manually by using spreadsheets and checklists developed by the AIChE CWRT. Two TCA software packages are, however, available for companies to use:

- P2Finance: Spreadsheet Software developed by Tellus Institute (http://www.tellus.org)
- TCAce™: A software package developed for the AIChE CWRT by Sylvatica (http://www.sylvatica.com/tools.htm)

7.3 Incorporating environmental sustainability into decision documentation: Separate Route

The separate route approach proposes two methods to deal with environmental aspects in a project management appraisal framework.

7.3.1 Balanced Scorecard Approach

a) History of Balanced Scorecards

Robert Kaplan first proposed the Balanced Scorecard (BSC) approach in 1992. The traditional balanced scorecard approach looks at four key business aspects, namely:

- Financial perspective (earnings per share, revenue growth, profit growth etc)
- Customer perspective (market share, customer satisfaction, referral rate, customer retention)
- Internal business process perspective (cycle time, cost of service, speed of services, job safety)
- Learning and growth perspective (effectiveness of change to technology and processes, speed and frequency of changes-adaptability, employee satisfaction, willingness to share and gain knowledge)

The scorecard is centred about the vision and strategy of the company (Figure 7.4) and it suggests the use of non-financial performance measures via the three additional perspectives to supplement the traditional financial measures (Sim & Koh, 2001).

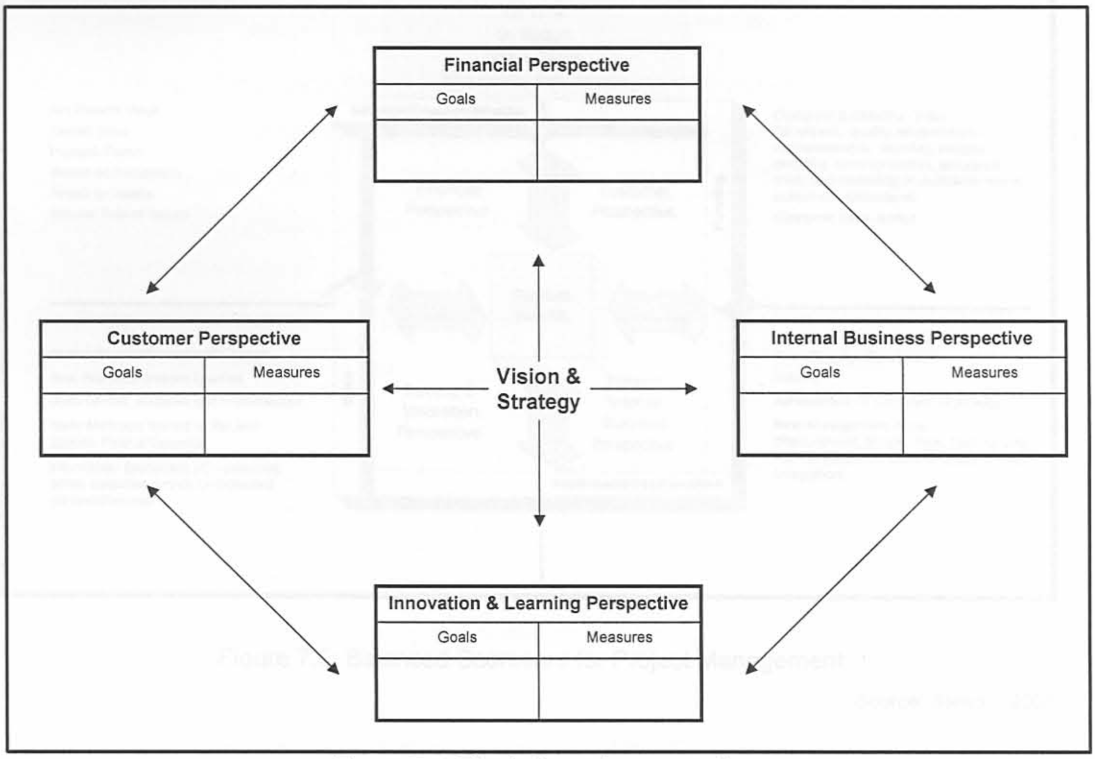


Figure 7.4: The balanced scorecard

Source: Sim & Koh, 2001.

b) Balanced Scorecards for Project Management

Stewart (2001) proposes a BSC approach to *"better manage the project"* and states that the approach can be used to *"perform health checks through the project life cycle"*. The proposed BSC model for projects (Figure 7.5) uses a "stoplight" colour scheme to visually express the status and identified areas of improvement. The colour scheme consist of:

- Green: Project performance agrees with project plans and stakeholder expectations.
- Yellow: Deficiencies in project performance have been noted, are being monitored and corrective action will be implemented in the near future.
- Red: Serious deficiencies have been noted and the project is in a crisis.

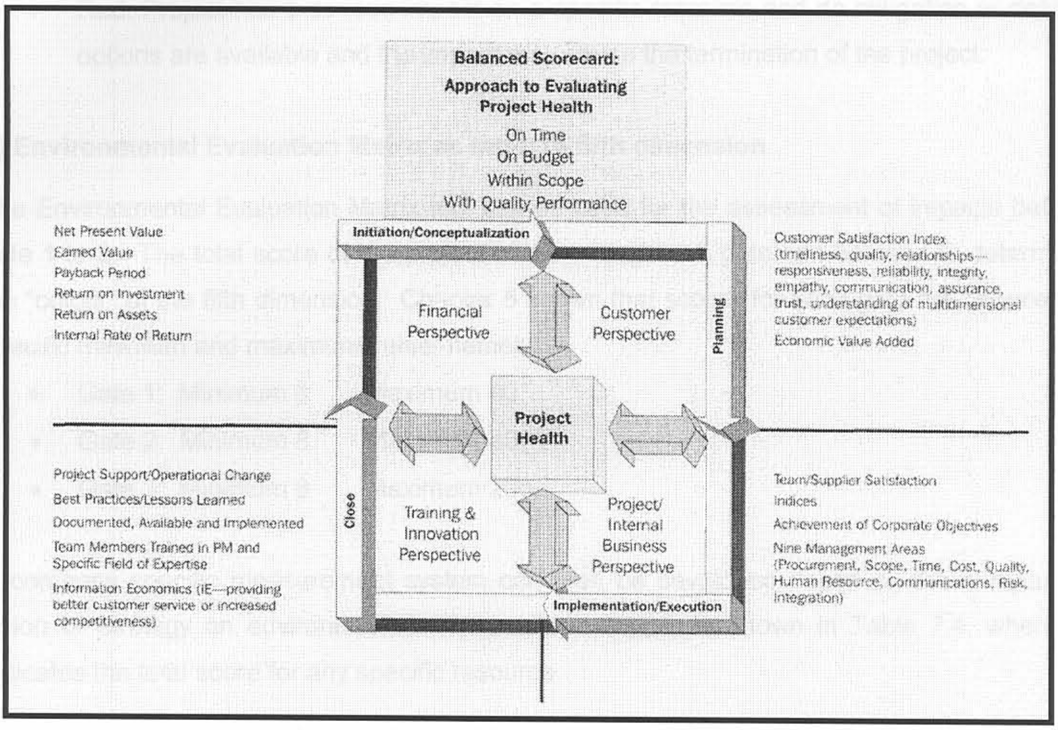


Figure 7.5: Balanced Scorecard for Project Management

Source: Stewart, 2001

c) Approach to include Environmental Sustainability into Balanced Scorecard for Project Management

It is proposed that a fifth perspective be added to the balanced scorecard for a project, i.e. *Environmental Management of Project*. A "*Without harming the environment*" view must then subsequently be added to the Project Health Evaluation Approach (Figure 7.5). In line with the balanced scorecard methodology, goals and measures must be set for this perspective. It is proposed that companies set goals in terms of the four environmental factors identified in the framework in Chapter 4 (Figure 4.5) namely: Air, Water, Land and Mined Resources. The goals should be set in terms of environmental impacts resulting from the project on these resources and will be company specific. Previous projects can be used to set a baseline for the goals.

The colour scheme (rating system) for the proposed fifth perspective, as applied to gates 1 to 3, is as follows:

- Green: Project has minimal impacts on the specific resource.
- Yellow: Project has an impact on a specific resource but mitigation options are available, the impact is still within compliance level, or the subsequent design phase could possibly address the impact.

- Red: Project has a serious impact on a specific resource and no mitigation or design options are available and the impact may cause the termination of the project.

d) Environmental Evaluation Matrix as input to fifth dimension

The Environmental Evaluation Matrix tool can be used for the assessment of impacts before gate 1 to 3. The total score of the project at the end of each gate can be used to determine the "colour" of the fifth dimension. Chapter 5 shown that scores for each gate are between a specific minimum and maximum value, namely:

- Gate 1: Minimum 8 Maximum 40
- Gate 2: Minimum 8 Maximum 40
- Gate 3: Minimum 8 Maximum 200

A company specific measurement system can then be developed based on the company's vision or strategy on environmental affairs. An **example** is shown in Table 7.4, where X indicates the total score for any specific resource.

	Red	Yellow	Green
Gate 1	X > 21	20 < X < 10	X < 10
Gate 2	X > 21	20 < X < 10	X < 10
Gate 3	X > 75	75 < X < 25	X < 25

Table 7.4: **Example** of a measurement system deducted from the Environmental Matrix Evaluation Tool

For purposes of Gate 4 the Environmental Impact Assessment (EIA) can be used to determine the measurement and from Gate 5 onwards the actual impacts should be measured against planned impacts. The goals must also be communicated to the Environmental Management System.

7.3.2 Environmental Indicators for Project Appraisal

a) The World Bank Approach

Segnestam (1999) proposes an approach based on a set of environmental indicators for projects supported by the World Bank. The approach suggests the following classification of indicators:

- Input Indicators that monitor the project-specific resources that are provided.
- Component Outcome/Output Indicators that should relate to stated goals and objectives of the component. The indicators measure the immediate or short-term results of the project as well as goods and services provided by the project.

- Project Impact Indicators that should relate to possible effects of the project on the environment and that should also measure possible externalities related to the environment.

The World Bank (2002) states that the two levels of indicators most useful in tracking project performance are the component outcome/output indicators and the project impact indicators (see Figure 7.6).

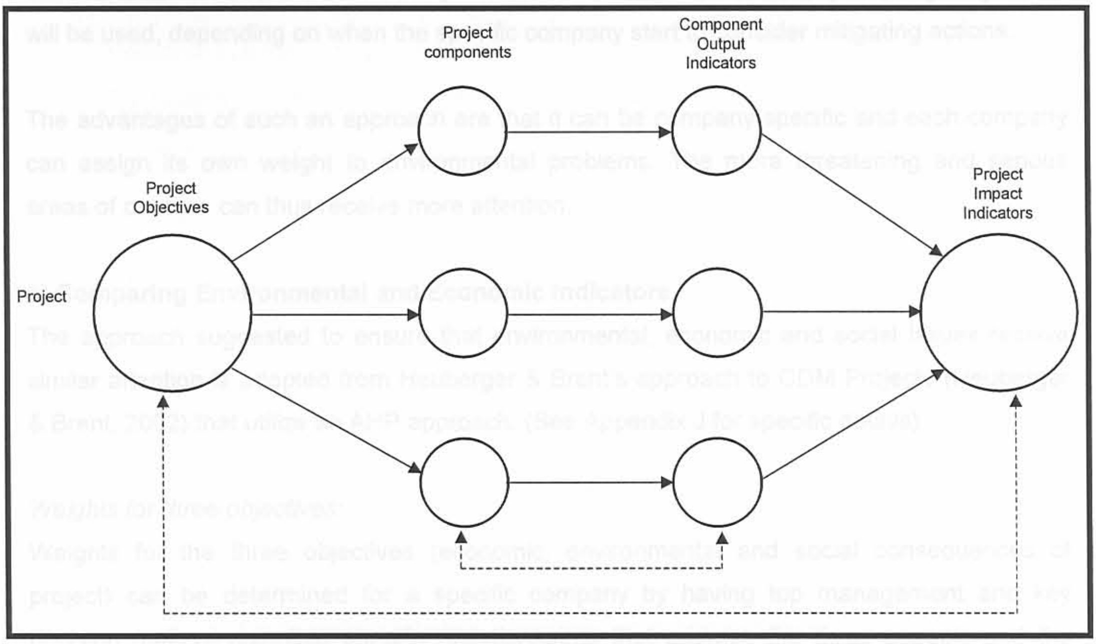


Figure 7.6: Project and component-level indicators

Source: Segnestam (1999) and World Bank (2002)

The World Bank is currently developing various types of impact indicators, which addresses different environmental concerns and aspects. However, it has been noted by the Bank that it is difficult to determine a project's impact on an environmental problem or concern using the indicators.

b) Proposed Use of the methodology

It is proposed that a similar indicator approach is used for project appraisal purposes. Specific indicators with regards to the different aspects of the identified resources can be used to monitor the project impacts (list of indicators in Table 4.6 to 4.9). Financial indicators such as Net Present Value (NPV), Internal Rate of Return (IRR) or Return on Investment (ROI) are used to express the financial feasibility of the project. The environmental feasibility can then be expressed in terms of one indicator value for the different environmental aspects, which can be determined from the Environmental Evaluation Matrix tool.

Multi criteria decision analysis techniques (see Appendix J) such as Analytic Hierarchy Method or Weighted Summation can be used to determine the overall value score from all the project environmental indicators (Heuberger & Brent, 2002). The score can then be presented to the decision-makers at the gate review meetings. Since the accuracy and availability of environmental information also increases through the project life cycle, the indicator can be updated in the different project phases as is the case with NPV, ROI and IRR. It will thus happen that in certain phases an environmental indicator pre mitigating action will be calculated and in other phases an environmental indicator post mitigating action will be used, depending on when the specific company start to consider mitigating actions.

The advantages of such an approach are that it can be company specific and each company can assign its own weight to environmental problems. The more threatening and serious areas of concern can thus receive more attention.

c) Comparing Environmental and Economic Indicators

The approach suggested to ensure that environmental, economic and social issues receive similar attention is adopted from Heuberger & Brent's approach to CDM Projects (Heuberger & Brent, 2002) that utilize an AHP approach. (See Appendix J for specific details).

Weights for three objectives:

Weights for the three objectives (economic, environmental and social consequences of project) can be determined for a specific company by having top management and key decision makers complete specific questionnaires that address the three aspects and the perceived importance thereof (see Appendix J). These weights can then be standarized for the application of AHP to all projects. For purposes of the section social consequences of projects are not considered.

Scores for each objective for a specific project:

A different approach to scoring is suggested by Heuberger and Brent (2002). Heuberger and Brent (2002) define base conditions as the situation that would have occurred in the absence of the project and assign a score of either 1, 0 or –1 to each objective based on the following:

- Project improve base conditions for specific objective: 1
- Project has no effect on base conditions for specific objective: 0
- Project has a negative effect on base conditions for specific objective: -1

An overall score is then calculated for a project and the project can only continue if it has a positive score.

Project Score= $W_{economic}{}^{*}S_{economic} + W_{environmental}{}^{*}S_{environmental} + W_{social}{}^{*}S_{social}$

W = weight of factor *S= score for factor*

It is proposed that the company determine a baseline value for the specific economic indicator it uses for example a baseline value for ROI can be 15%. An environmental baseline can be established for each gate by using the Environmental Evaluation Matrix tool.

d) Example

Scenario:

- Company XYZ is a company in the process industry.
- Project Q is a new project currently at Gate 2.
- The Environmental Matrix Evaluation Tool has been applied to the project (see Figure 7.7) and it is known that the ROI is 22%

	Water	Air	Land	Mined
CONSTRUCTION (10)	***7***	***5***	***5***	***7***
Supply Processes	5	2	3	5
Site Selection & Development	2	3	2	2
OPERATION (20)	***15***	***14***	***12***	***9***
Supply Processes	5	2	3	2
Primary Process	4	5	2	2
Complementary Processes	5	5	2	2
Products	1	2	5	3
DECOMMISSIONING (10)	***5***	***8***	***7***	***3***
Supply Processes	2	3	2	1
Process Implementation	3	5	5	2
(40)	**27**	**27**	**24**	**19**

Figure 7.7: Environmental Matrix for Project Q

Weights for the triple bottom line:

- Company XYZ does not currently include social aspects in its project appraisal.
- Company XYZ regards economic aspects of a project two times more important than environmental aspects.
- Using the Web-HIPRE Multi Criteria Decision Analysis software (http://www.hipre.hut.fi/WebHipre/) the following weights can be assigned to the economic and environmental aspects:
    - Economic: 0.67
    - Environmental: 0.33

Weights for the four environmental factors

Company XYZ has serious problems with the environmental impacts of their process on water resources. They believe that impacts on water resources are four times more important than impacts on other resources. Impacts on the remaining three categories are of equal importance. Using the Web-HIPRE Multi Criteria Decision Analysis software (http://www.hipre.hut.fi/WebHipre/) the following weights can be assigned to the different environmental factors:

Environmental Factor	Weight
Water Resources	0.571
Air Resources	0.143
Land Resources	0.143
Mined Resources	0.143

Table 7.5: Weights for Environmental Factors

These weights can be used together with a completed Environmental Evaluation Matrix to determine the Environmental Indicator:

Environmental Indicator = $W_{water}*S_{water} + W_{air}*S_{air} + W_{land}*S_{land} + W_{mined}*S_{mined}$

W = weight of environmental factor *S= environmental matrix score for factor*

Baseline Values at Gate 2:

- Company XYZ has chosen a financial baseline value for Gate 2 as a 15% ROI
- A baseline value for environmental aspects is determined by calculating the Environmental Indicator for a completed Environmental Evaluation Matrix with all entries 3.

	Water	Air	Land	Mined
CONSTRUCTION (10)	***6***	***6***	***6***	***6***
Supply Processes	3	3	3	3
Site Selection & Development	3	3	3	3
OPERATION (20)	***12***	***12***	***12***	***12***
Supply Processes	3	3	3	3
Primary Process	3	3	3	3
Complementary Processes	3	3	3	3
Products	3	3	3	3
DECOMMISSIONING (10)	***6***	***6***	***6***	***6***
Supply Processes	3	3	3	3
Process Implementation	3	3	3	3
(40)	**24**	**24**	**24**	**24**

Figure 7.8; Environmental Baseline for Gate 2 (Example)

Environmental Indicator = $W_{water}*S_{water} + W_{air}*S_{air} + W_{land}*S_{land} + W_{mined}*S_{mined}$

W = weight of environmental factor *S= environmental matrix score for factor*

Environmental Baseline (Gate2) = 0.571*24 + 0.143*24 +0.143*24 + 0.143*24
= 24

If a project has an Environmental Indicator (EI) of higher than 24, it has a negative effect on environmental baseline conditions. A project has a positive effect on the financial baseline as long as it has a ROI that is higher than 15%.

Environmental Indicator for Project Q

Environmental Indicator (Project Q) = 0.571*27 + 0.143*27 +0.143*24 + 0.143*19
= 25.427

Project Score for Project Q:

In summary:

	Baseline	Project Q
Financial = ROI	15%	22%
Environmental = Environmental Indicator	24	25.427

Table 7.6: Project Q Information

Project Q thus has a positive effect on the economic baseline and a score of 1 is assigned, the environmental baseline is, however, affected negatively and thus a score of –1 is assigned. The total score for the project is:

$$\text{Project Score} = W_{economic} * S_{economic} + W_{environmental} * S_{environmental} + W_{social} * S_{social}$$

W = weight of factor *S= score for factor*

Project Score = 0.67 (1) + 0.33(-1)
= 0.34

The project score is higher than 0 and thus the project can continue.

7.4 Conclusion

Techniques to include environmental aspects into decision documentation in a way that is logical to decision-makers do exist. First, techniques are available to express environmental impacts in monetary terms and to present it at gate review meetings as part of the broader economic evaluation of a project. Advocates of monetisation of environmental impacts claim that as we are living in a "monetary" society, only aspects that can be expressed in monetary terms receive sufficient attention (Richter, 1991 as cited in Holub et al. 1999).

The critics of monetisation of environmental impacts lay emphasis on the inherent incompatibility between economic and ecological scales and highlight that expressing environmental impacts in monetary terms may give the impression that these impacts are easily comparable with other monetary values such as yields on economic investment. However, the complexity of the monetisation of environmental impacts extends beyond the actual monetary value, which should be communicated to decision makers. It has been proposed that the environmental impacts and effects that can be easily monetised should be express in monetary values, and the remaining effects and impacts should be expressed in non-monetary values (Winpenny, 1991).

Second, tools that can address and incorporate environmental effects into decision documentation without assigning monetary values to it, do exist and can assist the decision process. These tools are, however, not efficiently deployed by business, especially on project level. Advantages of multi criteria decision analysis are that each decision criteria receives due consideration without necessarily converting it to a common scale such as a monetary value. The value these techniques can contribute to strategic decision-making should not be ignored (Petrie, Basson, Stewart, Notten & Alexander, 2001).

The answer to the question of whether it should be by following an economic valuation method or not seems to depend on the type of project, impacts addressed as well as the company preference. The idea to incorporate both approaches into one evaluation has been proposed and supported by various people, i.e. Winpenny (1991) and Ron Janssen (1992), who developed a software package called "DEFINITE" that can assist in improving the quality of environmental decision-making. The software offers multiple approaches to evaluate projects (Table 7.5).

Methods	Transparency	Information type	Output
A) Presentation Methods			
Appraisal Table	Very Good	Quantitative	Overview
Graphic Display	Very Good	Quantitative/ Qualitative	Overview
B) Monetary Methods			
Cost Benefit Analysis	Reasonable	Monetary	Rate of Return
Cost-effectiveness Analysis	Very Good	Monetary	Ranking
C) Multi Criteria Analysis			
Weighted Summation	Good	Quantitative	Ranking
Electre Method	Reasonable	Quantitative	Ranking
Regime Method	Reasonable	Quantitative/Qualitative	Ranking
Expected Value Method	Good	Qualitative	Ranking
Evamix Method	Reasonable	Quantitative/Qualitative	Ranking

Table 7.7: Evaluation Methods in 'DEFINITE'

Source: Jansen, 1992.

The conclusion reached is that companies should apply the techniques they are the most at ease with as the important focus, though, remains the incorporation of environmental information regardless of the approach followed. It is nevertheless recommended that a balanced scorecard or environmental indicator approach are followed for Gate 1 and 2 due to the fact that not a lot of information is available at the early stages. From Gate 3 onwards an economic approach can be followed or the two approaches combined.

Chapter 8: Conclusions and Recommendations

8.1 Problem Statement & Methodology

8.1.1 Background

A company's project management framework must support the goals and objectives of sustainable development, as it is the driving force that implements new ventures and processes (Sunter & Visser, 2002). The project appraisal process should therefore focus on the environmental, economical as well as social consequences of the project. Economic aspects receive the most consideration in current project appraisal processes. The evaluation of a typical project management framework used in the South African process industry proved that environmental and social aspects are not addressed at the same level as economical aspects. Figure 8.1 illustrates the extent of current environmental considerations in project management in South Africa.

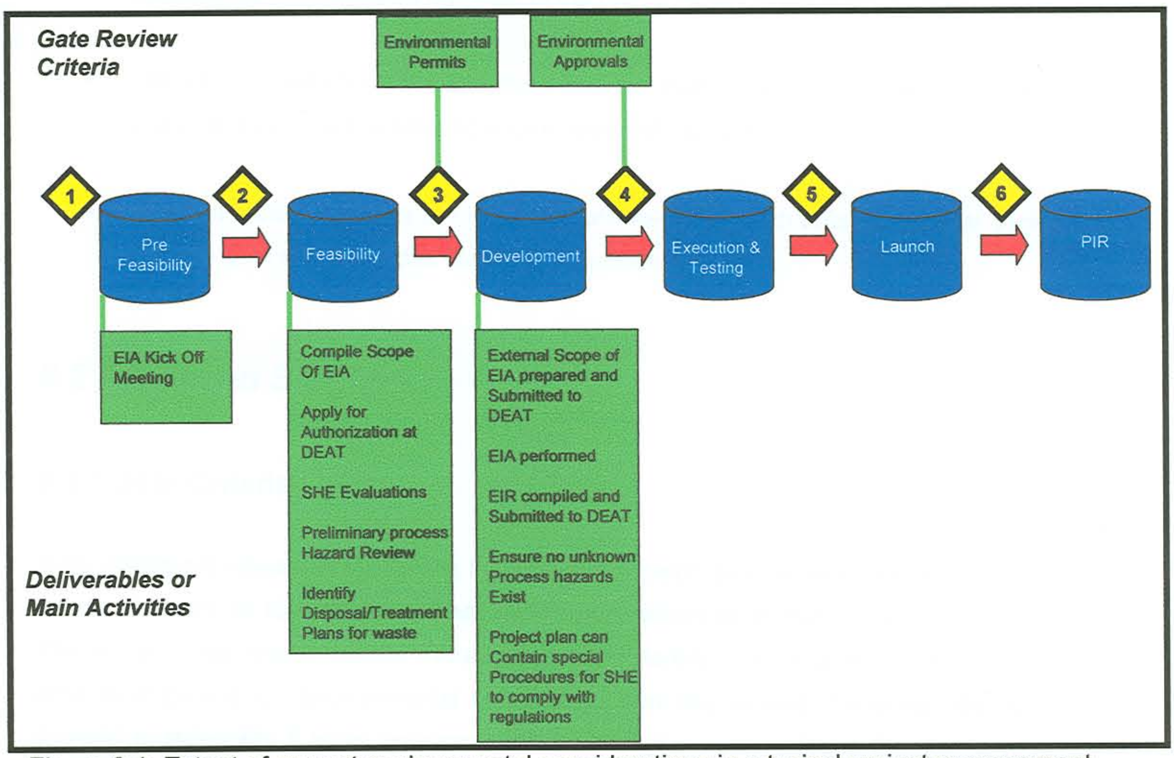


Figure 8.1: Extent of current environmental considerations in a typical project management framework.

8.1.2 Problem Statement

Businesses within the South African process industry will not truly support sustainable development until social and environmental aspects receive similar management attention as economic aspects. In this context the typical current project management framework is therefore not efficient and need to be adapted.

The focus of the dissertation excluded social and economical aspects. Economical aspects are efficiently addressed in the current project management framework. Social aspects are excluded since incorporation of sustainability into businesses has traditionally started by focusing on environmental aspects only (see section 1.2.2). The aim is thus to incorporate environmental sustainability into a project management framework.

8.1.3 Methodology

In order to ensure that environmental sustainability aspects are treated on a par with economic aspects the following areas of the current project management framework have been investigated:

- Gate criteria, which refer to the questions that must be answered about the progress, deliverables and expected outcome of the project at the different phase-ends.

- Deliverables, which define specific outcomes that must be achieved during every phase and which are measured and reviewed at the gate meeting.

- Decision-Making Process at the various phase-ends, which refer to the final decision at every gate about whether the project continue or not.

8.2 Proposed Solution

8.2.1 Gate Criteria

Gate criteria are viewed as the driving force behind decision gate meetings since it guides the decision-makers as to what the project should have achieved at that stage in its life cycle. The current gate review criteria include only two references to environmental aspects of projects (Figure 8.1). Environmental sustainability can only receive the same attention as financial sustainability if more environmental specific criteria are added to the staged project management framework.

Such criteria have been developed taking the following into consideration:

- Specific activities at certain stages of the project life cycle (Figure 3.3)
- Applicability of specific environmental management tools (Figure 3.6)
- Information that can be obtained from the developed Environmental Evaluation Matrix (EEM) tool or Environmental Impact Assessments (EIAs)

The criteria are gate specific and can be included as part of the technology management criteria (within the project management process) or separately as environmental management criteria. Figure 8.2 proposes how these criteria may be incorporated into the project management framework. This process will act as a driver to ensure that environmental aspects are adequately addressed in future business practices.

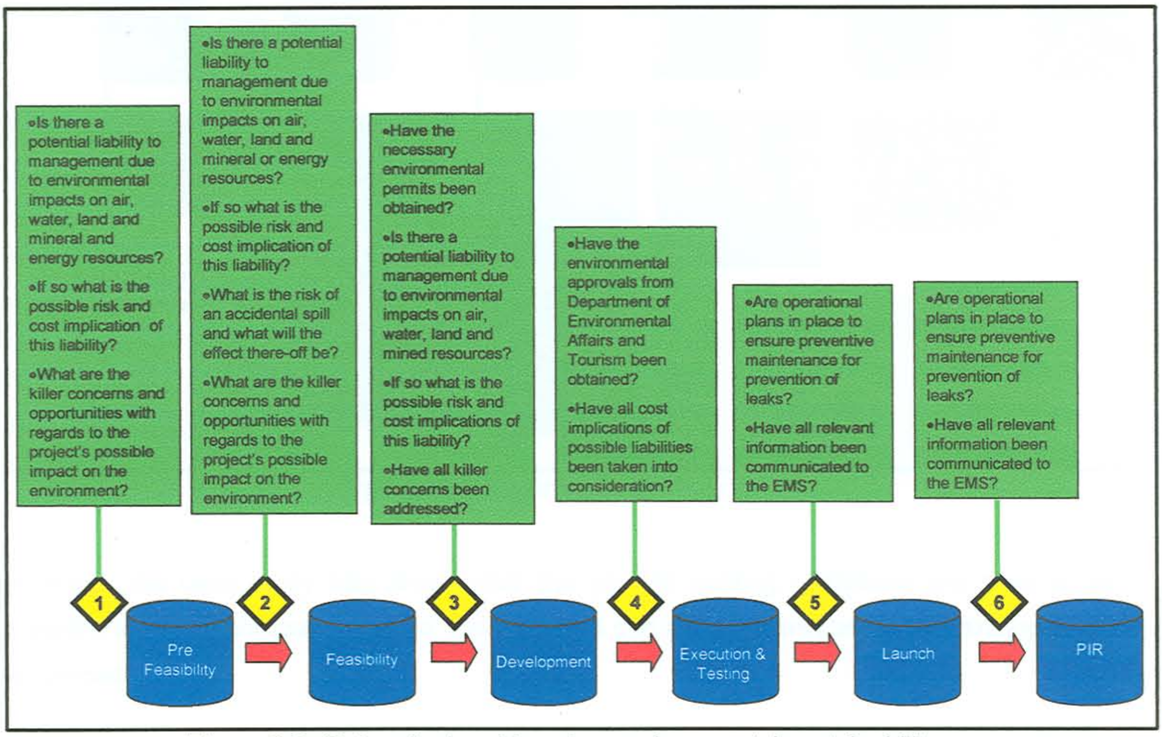


Figure 8.2: Gate criteria addressing environmental sustainability

8.2.2 Deliverables

Environmental information must be available to answer the questions related to environmental aspects incorporated in the gate criteria. It is concluded from Figure 8.1 that specific environmental deliverables are only documented in the project management framework up to the development phase. There are, however, certain environmental tools that should be applied after the development phase such as the implementation of an Environmental Management System (EMS) during the launch phase. Businesses within the process industry are incorporating these activities or tools, but it is not documented as part of the project management framework. These activities should specifically be mentioned as the outcomes thereof are measured by the gate criteria.

In the dissertation an Environmental Evaluation Matrix (EEM) tool to assist with the gathering of environmental information at Gates 1 to 3 was developed. The tool can assist decision-making processes as well as emphasise the importance of environmental aspects to designers and the project team. It is further proposed that the deliverables of the project management framework must be adapted to incorporate the use of the EEM tool as well as other environmental management tools that are used in later phases. The proposed environmental deliverables are shown in Figure 8.3.

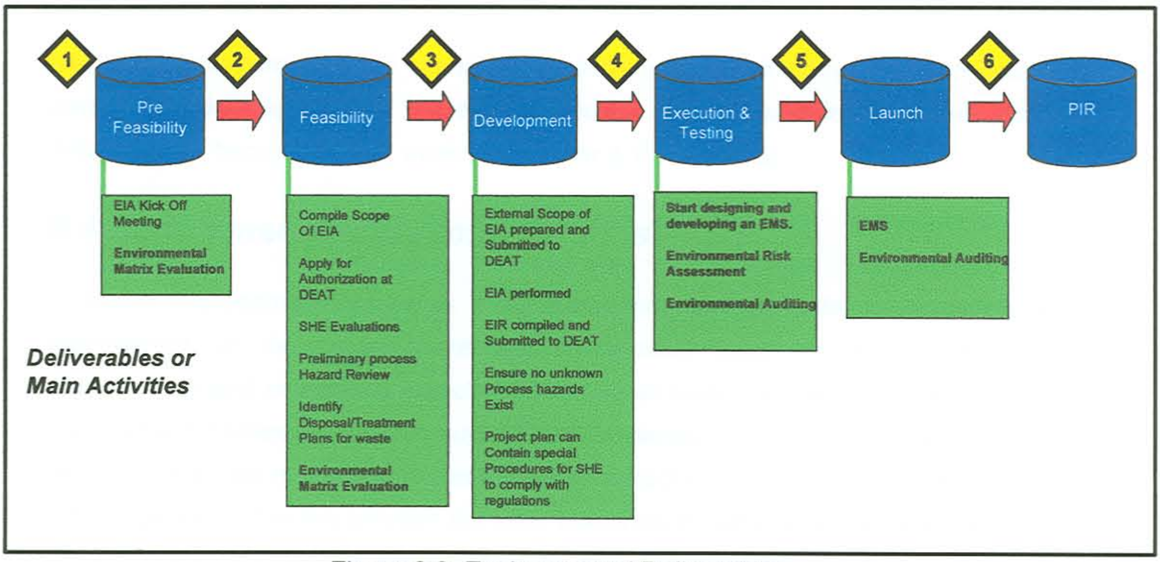


Figure 8.3: Environmental Deliverables

Although the case study has shown that the generic scoring guidelines will have to be adapted for to be company specific, the EEM tool can promote environmental thinking within a company.

8.2.3 Decision-Making Process

Environmental aspects can be incorporated into the decision-making process by either expressing it in financial terms or by using multi criteria decision analysis techniques to weigh environmental and economic aspects against each other (see Figure 7.1). It is recommended that companies utilize one, or both, of the separate techniques to incorporate environmental aspects into the decision-making processes at Gates 1 to 3.

8.3 Implementation Challenges

Implementing the changes to the project management framework within the company will be met with resistance. Many view sustainable development, and especially the environmental focus thereof, as a burden to growth and it is not easy to "sell" the concepts within the ranks of a company (Holliday, Schmidheiny & Watts, 2002).

The incorporation of environmental sustainability, or sustainability as a whole, requires a paradigm shift within the company. This will not be achieved if top management does not clearly indicate the support for sustainable development as part of the company's s, mission, vision and strategy i.e. at policy level.

Environmental sustainability should first be introduced by adapting the gate criteria. The second step can be to incorporate the proposed environmental deliverables in the project management framework. Finally the environmental information can be taken into consideration during the decision-making process.

Companies must embrace the opportunity to implement sustainability, as it can become a competitive advantage. If the challenge is ignored, sustainable development will remain a threat that can become a major weakness (Sunter & Visser, 2002).

8.4 Recommendations for future research

A project management framework that incorporates environmental sustainability is an improvement on the current state, but sustainability does not only consist out of environmental and economical aspects. Unless social aspects are also included, the project management framework will not support true sustainability. The incorporation of social aspects in a project management framework and project appraisal process therefore requires further research. The link between the three objectives of sustainability and the way in which impacts in the three different regions affect the other two aspects are another area that could benefit from future research. In South Africa, research directed towards a better economic valuation of environmental effects is currently undertaken. Figure 8.4 illustrates future research opportunities.

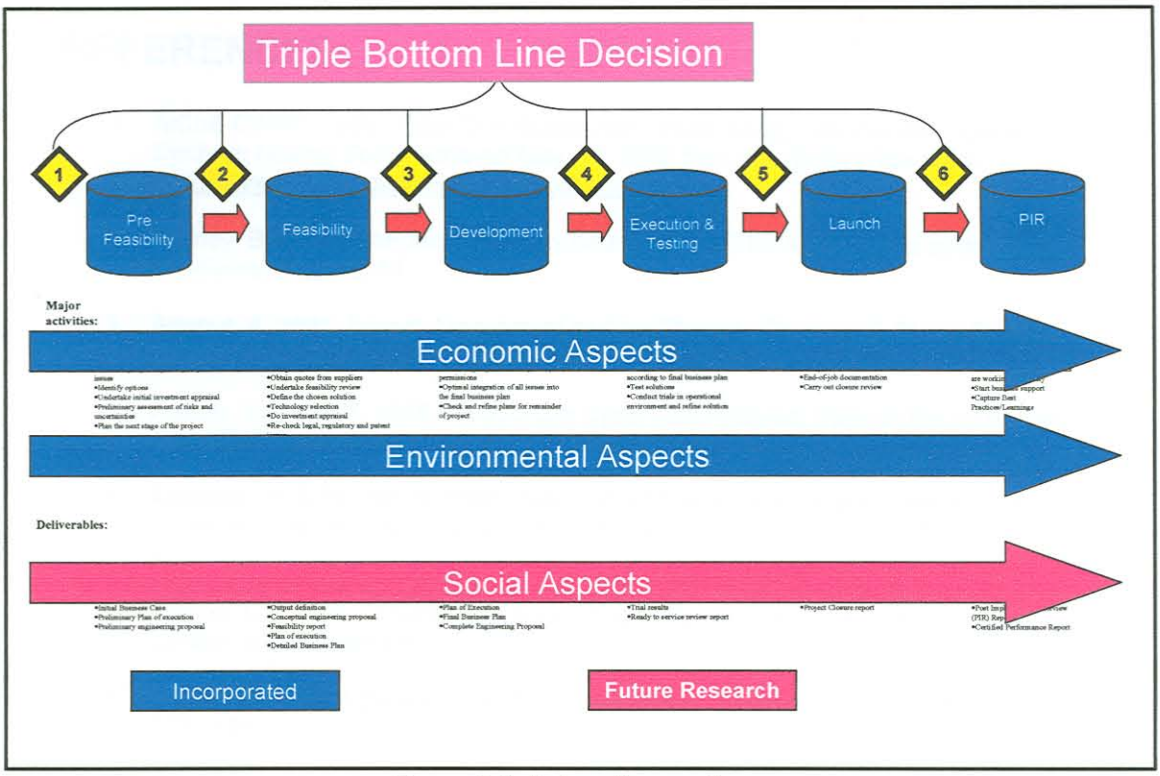


Figure 8.4: Future Research

8.5 Conclusion

Sustainable development is not a fixed state of harmony. It is rather a process of constant change, change in the way in which resources are used, change in the direction of investments, change in the orientation of technologies and even institutional changes. All these changes are, however, aligned and consistent with present and future needs (Holliday, Schmidheiny & Watts, 2002).

Inherently sustainable development is all about painful decisions and choices. The concept can only achieve its goals if society, government and business progress at the same speed in the same direction. In South Africa the economic climate is a major barrier to the incorporation of sustainable development into business activities (Holliday, Schmidheiny & Watts, 2002). Industry leaders should set an example by facing the challenge, only then a sustainable future might become a reality.

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108. South Africa: Department of Health:
Malaria & DDT: http://www.doh.gov.za/search/index.html

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http://www.unep.or.jp/ietc/Publications/TechPublications

110. US EPA
Ozone: http://www.epa.gov/ozone/
Global Warming: http://www.epa.gov/globalwarming/
Product Stewardship:
http://www.epa.gov/epaoswer/non-hw/reduce/epr/about/index.html

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Soil Degradation: http://www.igc.org/wri/trends/soilloss.html

112. WWF:
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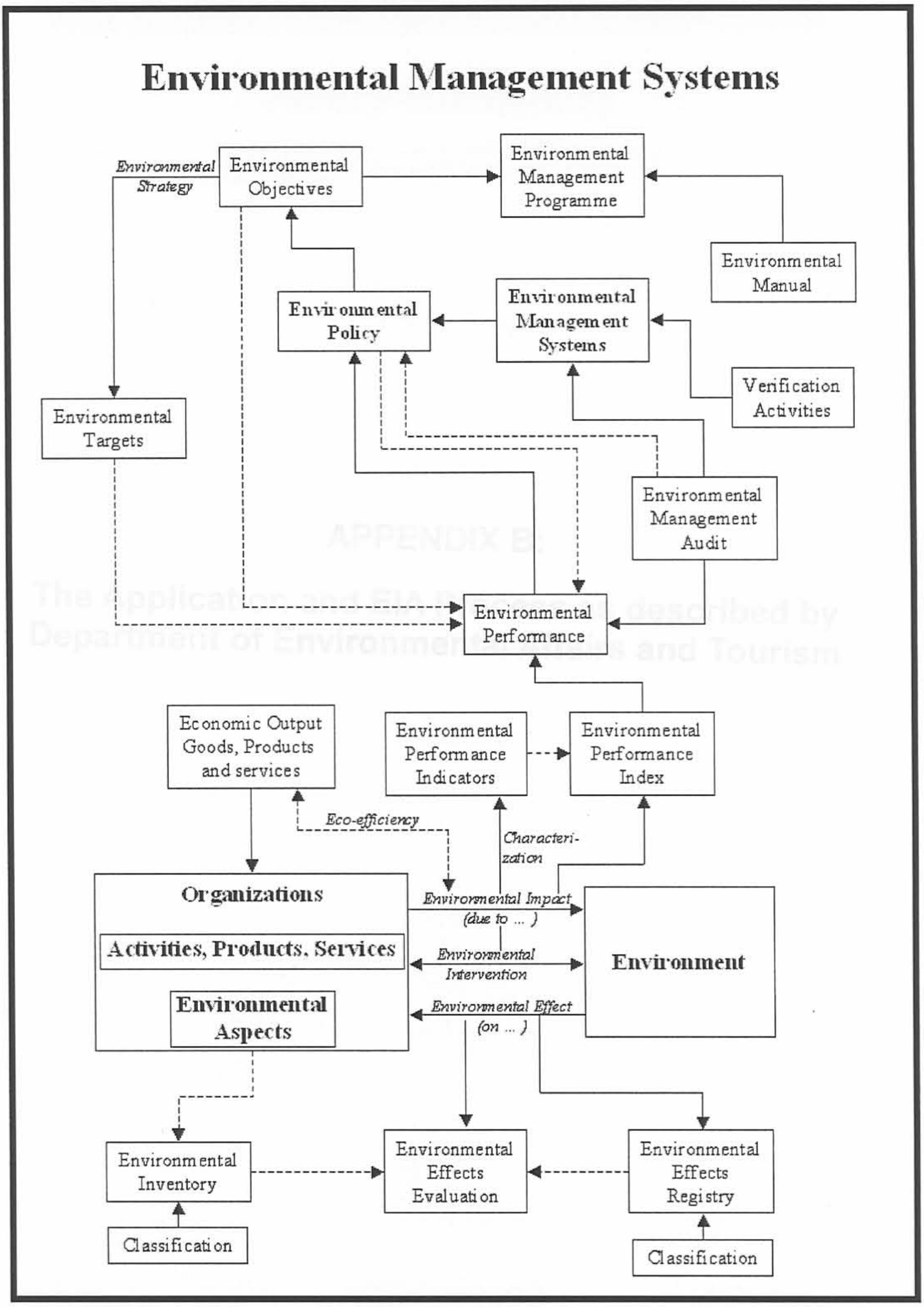
Biodiversity: http://www.panda.org/species/

APPENDIX A:

Interaction between EMS, organization and environment



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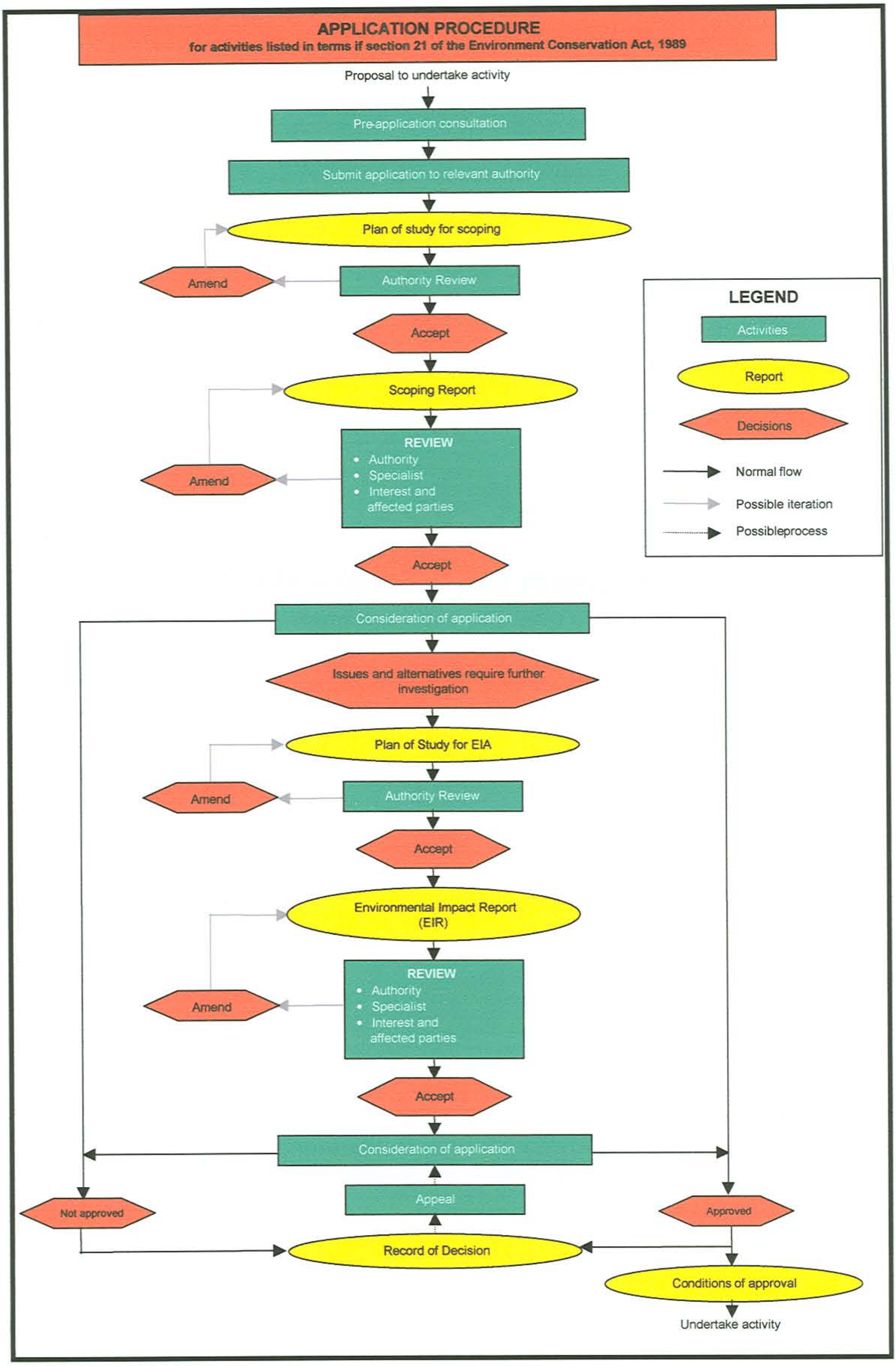
APPENDIX B:

The Application and EIA Process as described by Department of Environmental Affairs and Tourism

Appendix B: Environmental Impact Assessment Process



Source: DEAT, 1998.

APPENDIX C:

Life Cycle Cost Analysis Methodologies

C 1: LCCA Model of Fabrycky and Blanchard

Fabrycky and Blanchard's LCCA Methodology consist of 10 steps, as shown, in Figure C.1. The superiority of this methodology lies in the detail cost breakdown structure (CBS) it uses. Costs are first divided into one of four categories before it is sub-divided into relevant incremental costs (See Figure C.2). The four main cost categories are:

- Research & Development costs
- Production & Construction costs
- Operation & Maintenance costs
- Retirement & Disposal costs.

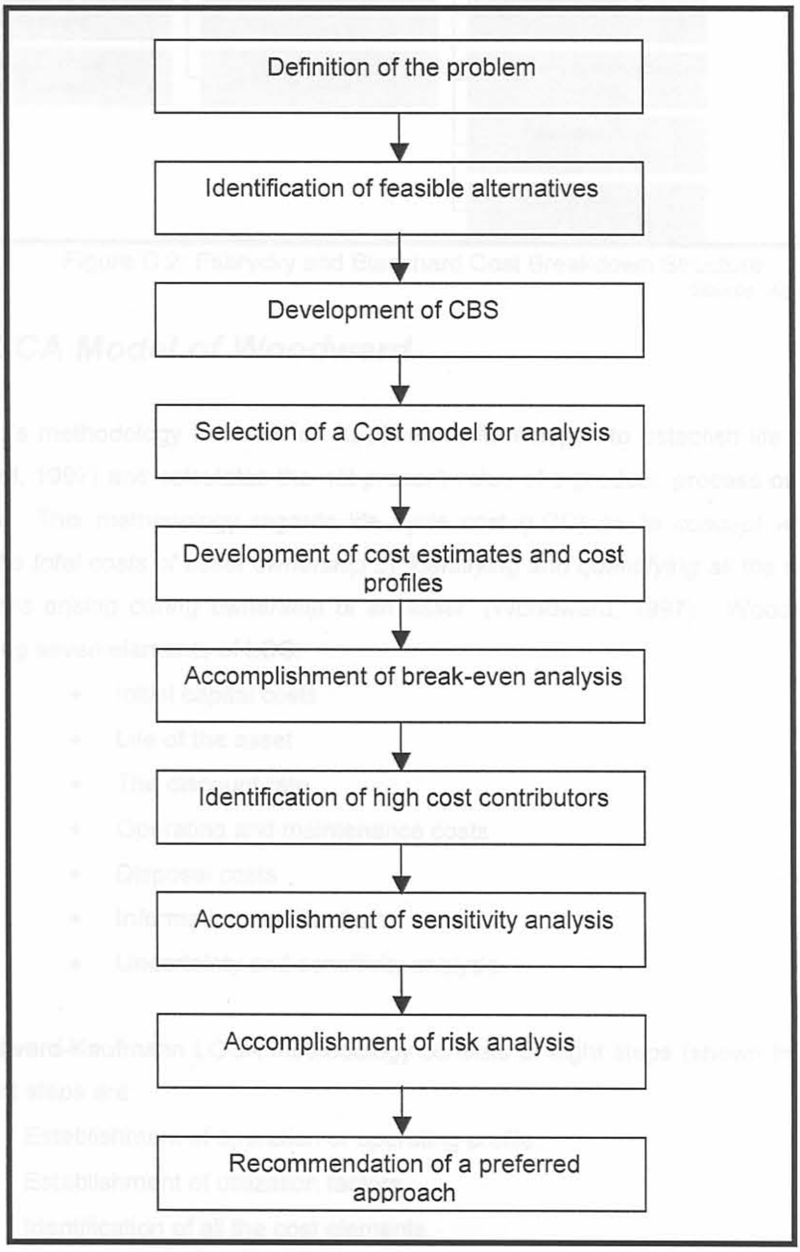


Figure C.2: Fabrycky and Blanchard LCCA Methodology

Source: Durairaj, Ong, Nee & Tan, 2002.

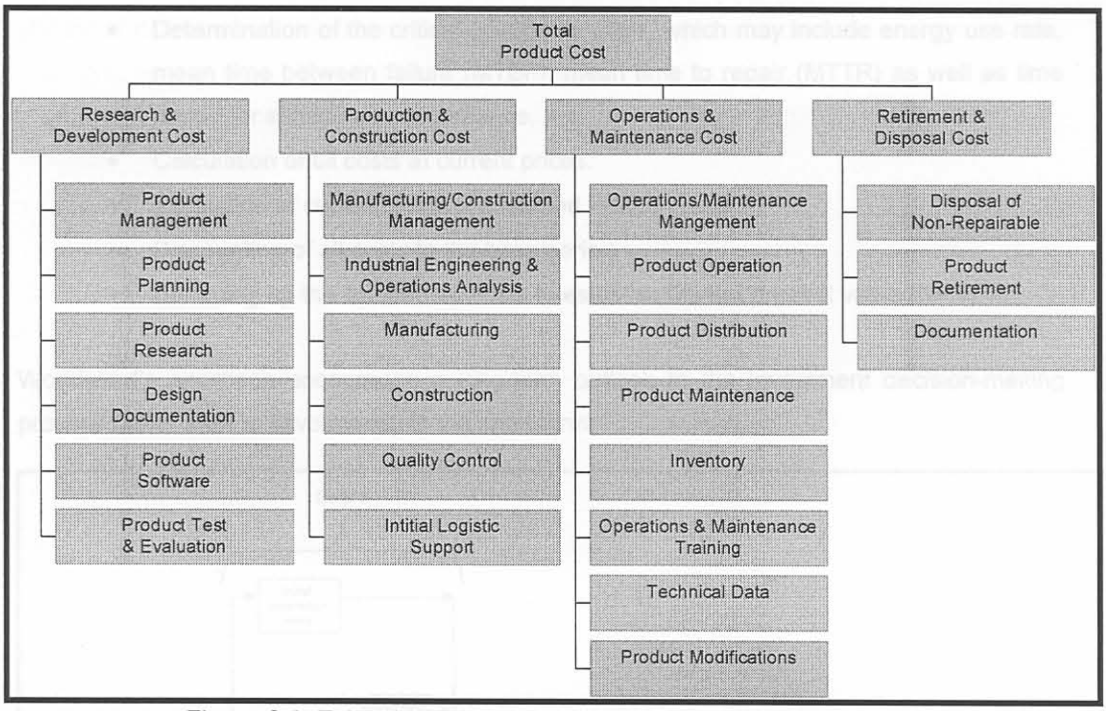


Figure C.2: Fabrycky and Blanchard Cost Breakdown Structure

Source: Asiedu & Gu, 1998

C 2: LCCA Model of Woodward

Woodward's methodology is based on Kaufmann's formulation to establish life cycle costing (Woodward, 1997) and calculates the net present value of a product, process or system's life cycle cost. This methodology regards life cycle cost (LCC) as *"a concept which aims to optimise the total costs of asset ownership by identifying and quantifying all the significant net expenditures arising during ownership of an asset"* (Woodward, 1997). Woodward identify the following seven elements of LCC:

- Initial capital costs
- Life of the asset
- The discount rate
- Operating and maintenance costs
- Disposal costs
- Information and feedback
- Uncertainty and sensitivity analysis

The Woodward-Kaufmann LCCA methodology consists of eight steps (shown in Figure C.3). These eight steps are:

- Establishment of operation or operating profile.
- Establishment of utilization factors.
- Identification of all the cost elements.

- Determination of the critical cost parameters, which may include energy use rate, mean time between failure (MTBF), mean time to repair (MTTR) as well as time period for scheduled maintenance.
- Calculation of all costs at current prices.
- Escalation of current costs at assumed inflation rates.
- Discounting of all costs to the base period.
- Summing up the discounted costs to establish the net present value (NPV).

Woodward's approach encourages a long-term outlook to the investment decision-making process rather than to save money in the short term.

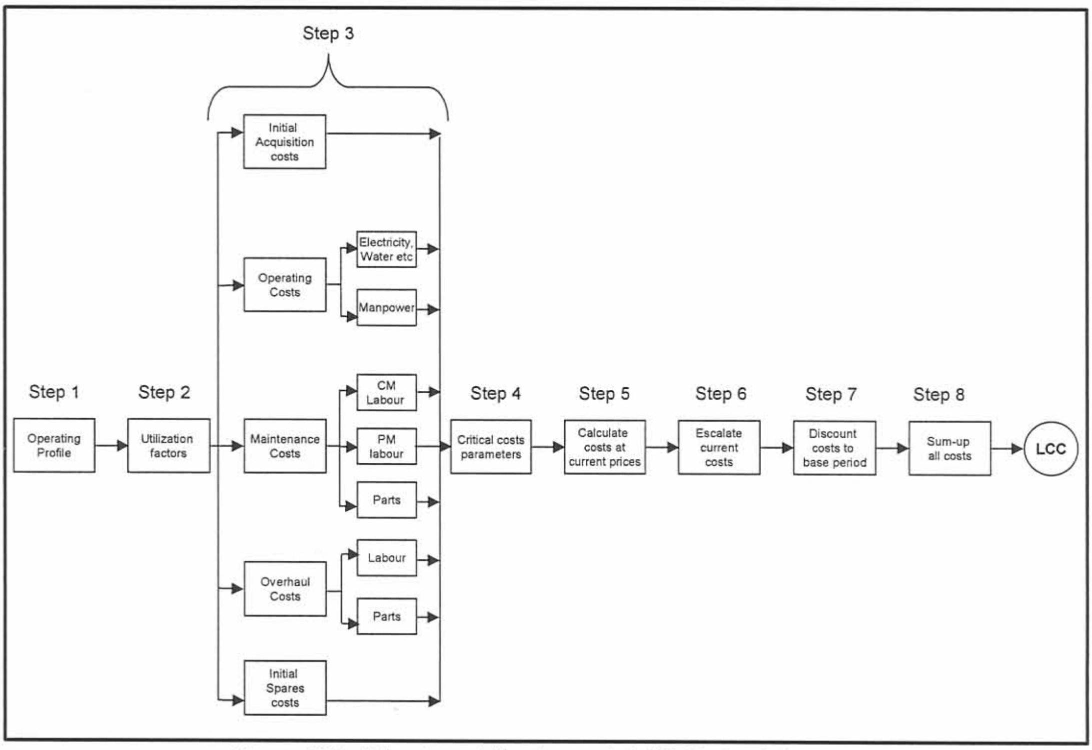


Figure C.3: Woodward-Kaufmann LCCA Methodology

Source: Woodward, 1997.

C 3: LCCA Model of Dahlen and Bolmsjo

Dahlen and Bolmsjo's methodology is often referred to as "Life cycle cost analysis of the labour factor" as it widens the field of application for LCC by focusing on the cost of an employee over the entire employment cycle, i.e. recruitment to retirement. One of parallels between traditional LCC graphs and the costs of an employee "life cycle" is the fact that in both cases the initial cost are high. In the case of the employee this is due to recruitment costs and the costs of training and introducing the employee into the company, while for processes and plants it is the initial construction costs that are high.

Dahlen and Bolsmjo (1996) distinguished between three types of labour cost categories, and also distinguish between sub-costs and elements of sub-costs (see Figure C.4). The inclusion of the labour-related costs in an LCC enables the methodology to assist with industrial decision such as:

- Who is to be employed?
- How much can be invested in education and training of a new employee?
- What is the correlation between costs and the shape of the work tasks and the working environment?
- What should the mix of the production factors capital and labour look like to achieve the most cost-effective production system?

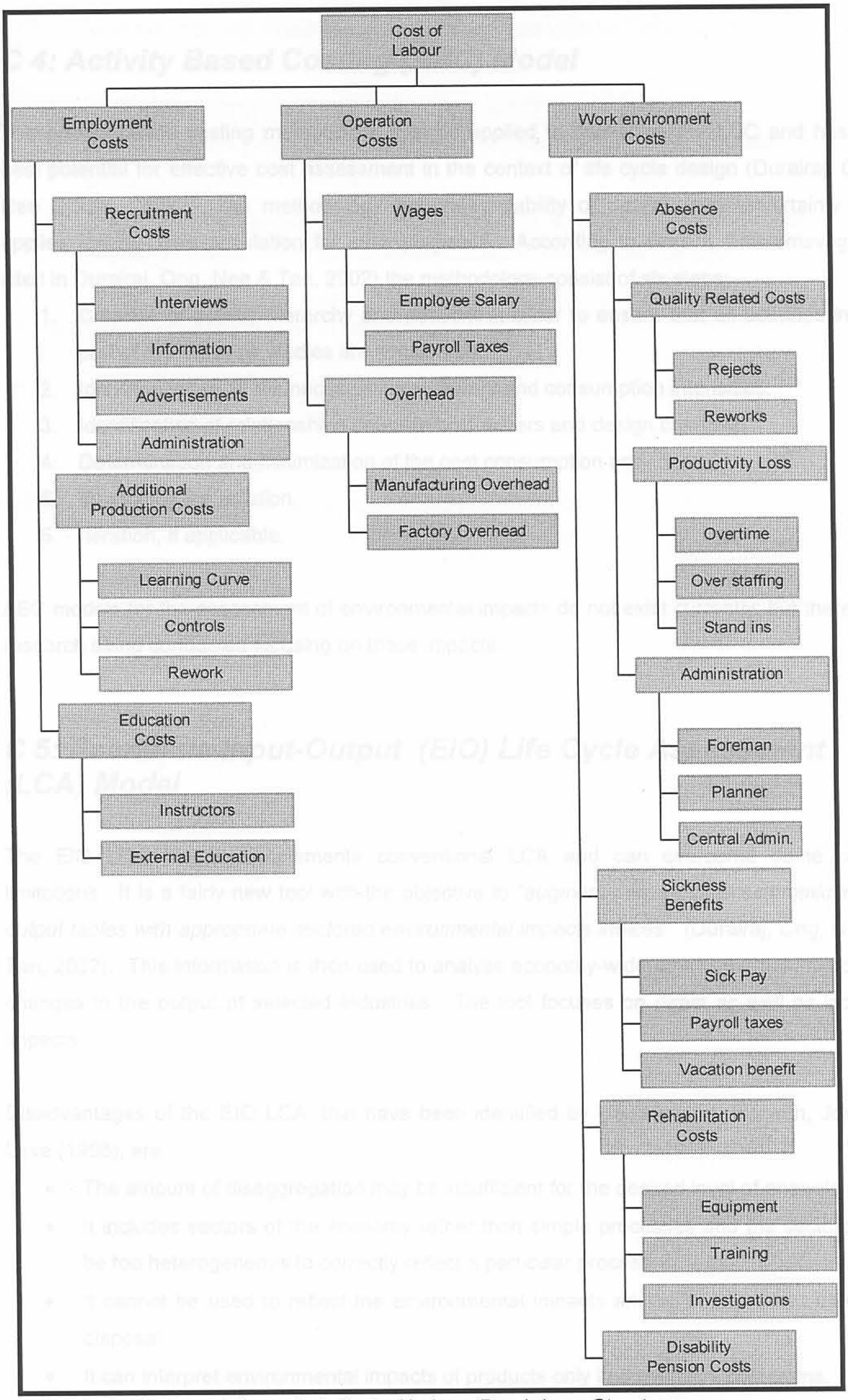


Figure C.4: Cost of Labour Breakdown Structure

Source: Dahlen &Bolsmjo, 1996.

C 4: Activity Based Costing (ABC) Model

The activity based costing methodology can be applied to determine the LCC and has the best potential for effective cost assessment in the context of life cycle design (Durairaj, Ong, Nee & Tan, 2002). The methodology has the capability of dealing with uncertainty and applies Monte Carlo simulation for such purposes. According to Bras & Emblemsvag (as cited in Durairaj, Ong, Nee & Tan, 2002) the methodology consist of six steps:

1. Creation of activity hierarchy and network in order to ensure that all activities in the part of the life cycle studies are considered.
2. Identification of all the necessary cost drivers and consumption intensities.
3. Identification of relationships between cost drivers and design changes.
4. Determination and minimization of the cost consumption activities.
5. Evaluating the solution.
6. Iteration, if applicable.

ABC models for the assessment of environmental impacts do not exist currently; but there are research being conducted focusing on these impacts.

C 5: Economic Input-Output (EIO) Life Cycle Assessment (LCA) Model

The EIO LCA Model complements conventional LCA and can overcome some of its limitations. It is a fairly new tool with the objective to *"augment conventional economic input-output tables with appropriate sectored environmental impacts indices"* (Durairaj, Ong, Nee & Tan, 2002). This information is then used to analyse economy-wide environmental impacts of changes in the output of selected industries. The tool focuses on direct as well as indirect impacts.

Disadvantages of the EIO LCA, that have been identified by Hendrickson, Horvath, Joshi & Lave (1998), are:

- The amount of disaggregation may be insufficient for the desired level of analysis.
- It includes sectors of the economy rather than simple processes and the sectors can be too heterogeneous to correctly reflect a particular process.
- It cannot be used to reflect the environmental impacts arising from product use and disposal.
- It can interpret environmental impacts of products only in cumulative cost terms.

Advantages of the EIO LCA Model have also been identified by Hendrickson, Horvath, Joshi & Lave (1998) as well as Durairaj, Ong, Nee & Tan (2002). These advantages include:

- Analysts do not need to draw arbitrary boundaries due to the fact that a comprehensive model of the economy is used.
- Analyses can be performed rapidly and inexpensively.
- Analyses are transparent due to the fact that only publicly available data and standard calculations are used.
- The sector model includes effects attributable to the influences of many indirect suppliers. These effects are often overlooked in the process models.

Online EIO LCA data is available at: http://www.eiolca.net

C 6: Design to Cost (DTC) Model

The DTC model is an attempt to combine cost modelling with Quality Function Deployment (QFD). The methodology can be applied in the design phase of products as it aims to assess the potential trade-offs between costs and performance of competing product alternatives. The application of the model is therefore limited to early stages of production system design (Durairaj, Ong, Nee & Tan, 2002). The DTC model consists of a procedure to select a system design, and has three main functions:

- Derivation of system performance
- Evaluation of system costs
- Presentation of results and decision-making.

Design to Cost differs from Design for Cost, since Design to Cost obtains a design satisfying the functional requirements for a given cost target while Design for Cost is the "*conscious use of engineering process technology to reduce life cycle cost*" (Asiedu & Gu, 1998).

C 7: Product Life Cycle Cost Analysis (PLCCA) Model

The aim of this methodology is to calculate the life cycle costs of capital goods like machines and it focus on single processes connected to a product's life cycle. Durairaj, Ong, Nee & Tan (2002) states that the model can achieve cost reduction in the different life cycle phases through *"a product conception directed towards the needs of the use phase"*. Atling (1993, as cited in Asiedu & Gu, 1998) identified the following costs in the different life cycle phases of a product (Table C.1):

	Company Cost	Users Cost	Society Cost
Design	• Market Recognition • Development		
Production	• Materials • Energy • Facilities • Wages, Salaries, etc		• Waste • Pollution • Health Damages
Usage	• Transportation • Storage • Waste • Breakage • Warranty Service	• Transportation • Storage • Energy • Materials • Maintenance	• Packaging • Waste • Pollution • Health Damages
Disposal/Recycling		• Disposal/Recycling Dues	• Waste • Disposal • Pollution • Health Damages

Table C.1: Product Life Cycle Stages and Costs

Source: Asiedu & Gu, 1998.

Asiedu and Gu (1998) proposes that various techniques must be used to calculate all cost elements in every phase, the bottom line is that the cost over the entire life-cycle must be calculated for the company, users and society.

C 8: Total Cost Assessment (TCA) Model

The American Institute of Chemical Engineers' (AIChE) Centre for Waste Reduction Technologies (CWRT) has conducted various research projects about the concept of Total Cost Assessment. These efforts have culminated in the publication of a TCA Methodology Manual in 1999 and a fully automated TCA tool called TCAce^{TM}. The CWRT markets TCA as an "Internal Managerial Decision Making Tool". Beaver (2000) regards total cost assessment as *"a dynamic and emerging concept that seeks to quantify all impacts and costs associated with a decision".*

The TCA Methodology distinguishes between five types of costs (see Table C.2).

Cost Type	Definition
Type 1: Direct costs for the manufacturing site	Direct costs of capital investment, labor, raw material and waste disposal. Includes both recurring and non-recurring costs as well as both capital and operations and management (O&M) costs.
Type 2: Potentially hidden corporate and manufacturing	Indirect costs not allocated to the product process. May include both recurring and non-recurring costs. Includes

site overhead costs	capital and O&M costs as well as outsourced services.
Type 3: Future and contingent liability costs	Liability costs include fines and penalties caused by non-compliance and future liabilities for forced clean-up, personal injury and property damage.
Type 4: Internal intangible costs	Costs paid by the company and includes difficult to measure cost entities such as worker wellness, worker morale, customer loyalty, corporate image, estimates of avoided costs, etc.
Type 5: External costs	Costs for which the company does not pay (see definition of externalities in Glossary).

Table C.2: Costs included in TCA Methodology

Source: AIChE CWRT, 1999.

The TCA Methodology consist of the following seven steps:

1. Project Definition & Scoping
2. Streamline the Analysis
3. Identify Potential Risks
4. Conduct Total Cost Inventory
5. Conduct Impact Assessment
6. Document Results
7. Feedback to the Company's Main Decision Loop

Gloria & Norris (2002) states that TCA is an aid to internal decision making due to the following properties (regarded by some as benefits) of the methodology:

- TCA captures direct and indirect costs
- TCA quantifies contingent and future liabilities
- TCA identifies intangible costs and costs of externalities and incorporate these costs in a semi-quantitative but transparent approach
- TCA is scalable and can therefore be applied to all sized of companies
- TCA is specific to location (RSA, US, Europe, etc)
- TCA is credible to internal stakeholders
- TCA allows the temporal nature of the costs to be considered
- TCA can be applied from process-specific to plant level

The CWRT's TCA Project team did undertake various case studies and pilot projects for integrating TCA into an existing corporate structure. The results were very favourable (Gloria & Norris, 2002).

C 9: Life Cycle Environment Cost Analysis (LCECA) Model

The LCECA Methodology focus on products but the ideas are more generic applicable. It aims to include eco-costs into the total costs of the products and defines eco-costs as all direct and indirect costs resulting from environmental impacts caused by the product over its entire life cycle (Kumaran, Ong, Tan & Nee, 2001). The methodology consists of nine steps and the methodological framework can be seen in Figure C.5.

The model introduces a new generic cost breakdown structure for eco-costs (see Figure C.6). The methodology then uses linear regression techniques to find the relationship between eco-costs and total costs.

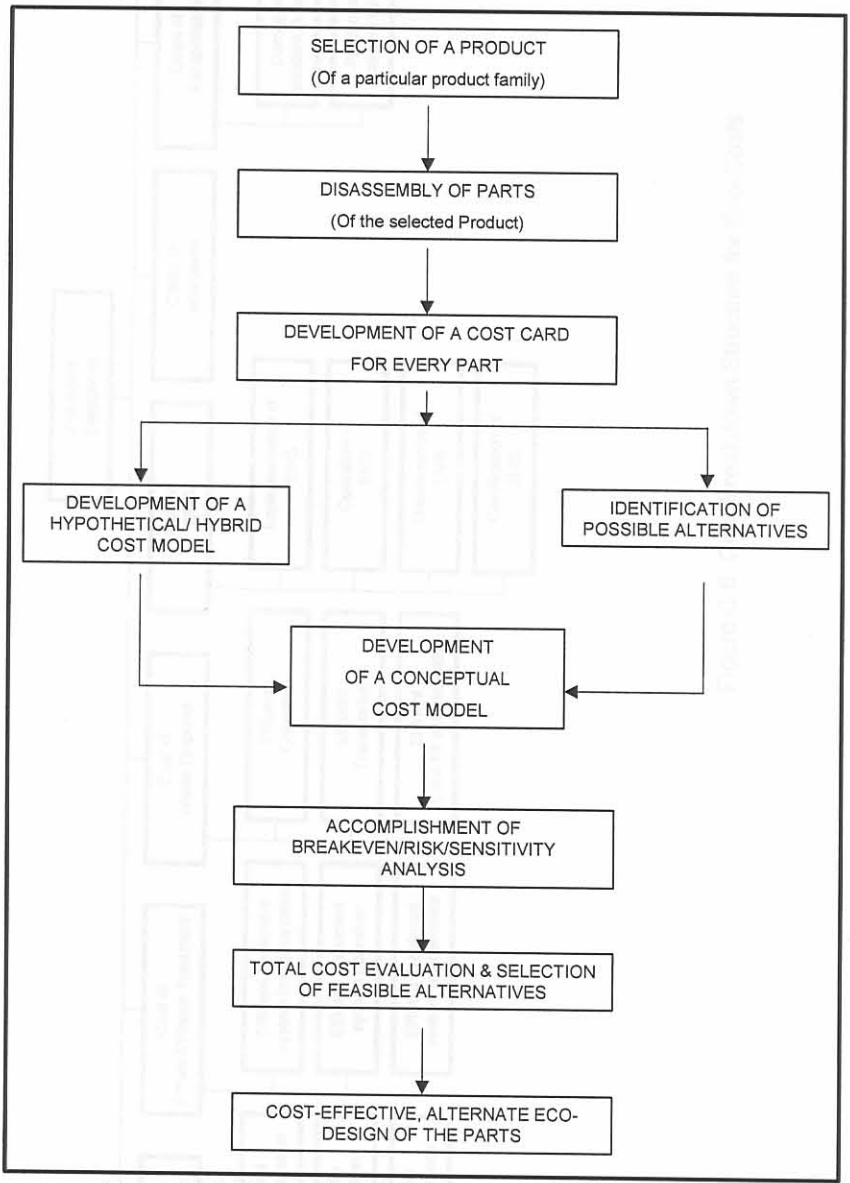


Figure C.5: The methodological framework for LCECA Model

Source: Kumaran, Ong, Tan & Nee, 2001

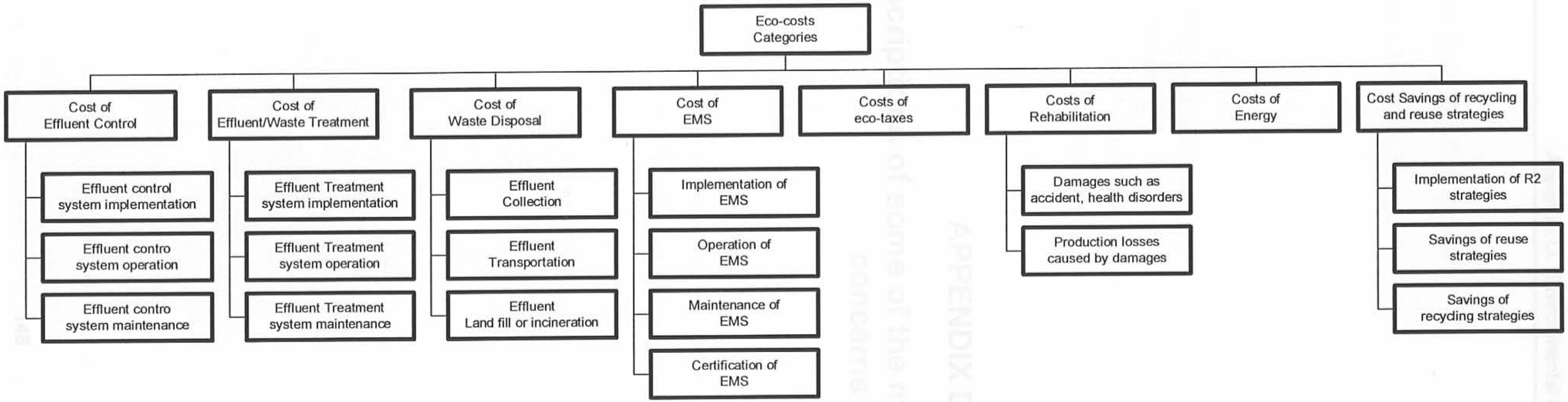


Figure C.6: Cost Breakdown Structure for Eco-Costs

Source: Kumaran, Ong, Tan & Nee, 2001

APPENDIX D:
Descriptions of some of the major environmental concerns

D.1 Global Scale Concerns

D.1.1 Global Climate Change

Climate can be defined as *"the patterns of common meteorological conditions (temperature, precipitation, winds, etc) over long time periods"* (Graedel & Allenby, 1995). According to the United States' Environmental Protection Agency (EPA) the global temperature has risen 0.45-0.6°C over the last century, precipitation has increased by about 1 percent over the world's continents and the sea level has risen with approximately 15-20 cm. Although climate has changed considerably over centuries or millennia through earth's history there is new and stronger evidence that most of the warming over the last 50 years is attributable to human activities (US EPA Global Warming Website).

"Energy from the sun drives the earth's weather and climate, and heats the earth's surface; in turn, the earth radiates energy back into space. Atmospheric greenhouse gases (water vapour, carbon dioxide, and other gases) trap some of the outgoing energy, retaining heat somewhat like the glass panels of a greenhouse. Without this natural "greenhouse effect," temperatures would be much lower than they are now, and life as known today would not be possible. However, problems may arise when the atmospheric concentration of greenhouse gases increases" (US EPA Global Warming Website). The greenhouse effect is shown in Figure D.1.

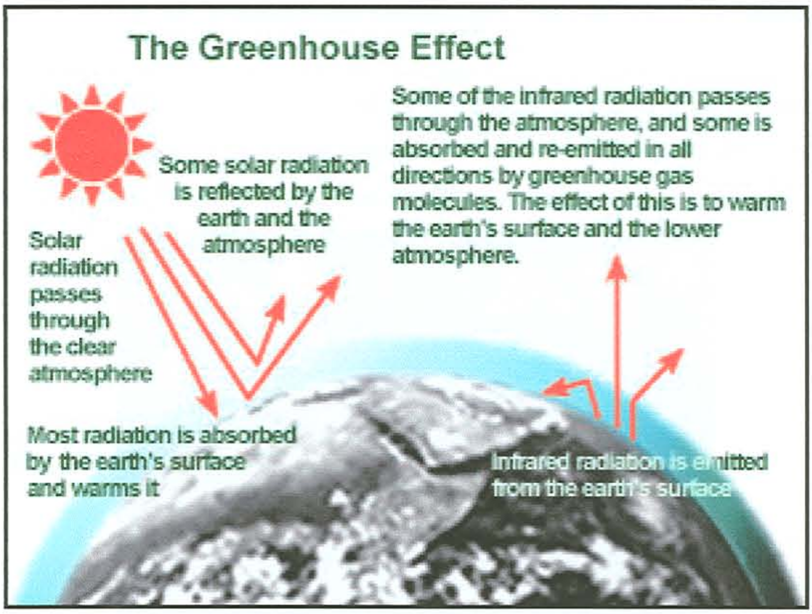


Figure D.1: Greenhouse Effect

Source: EPA Global Warming Website, http://www.epa.gov/globalwarming/climate/index.html

Certain greenhouse gases occur naturally in the atmosphere but the concentration thereof is increased by human activity, e.g. CO_2, whilst other greenhouse gases are the result of human activity e.g. chlorofluorocarbons (CFC). The concept of a Global Warming Potential (GWP) has been introduced to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to another gas (Guinée, 2001). Carbon dioxide (CO_2) was chosen as the reference gas to calculate a GWP.

D.1.2 Ozone Depletion

The ozone layer (found in the stratosphere) is of extreme importance for human health and ecosystem quality as it prevents a portion of the radiation from the sun to reach earth's surface by absorbing it. The importance of this also lies in the fact that ozone absorbs the harmful portion of ultraviolet light called UVB. The EPA believes that *"less protection from ultraviolet light will, over time, lead to higher skin cancer and cataract rates and crop damage"*.

A research group of the British Antarctic Survey (BAS) noticed a dramatic loss in ozone in the lower stratosphere over Antartica in the 1970's. Measurements taken in 1985 confirmed that the total amount of ozone in the stratosphere over Antartica has rapidly decreased (Cambridge University, 2002).

In the United Nations Environment Program's Scientific Assessment of Ozone Depletion (1994) it was confirmed "*that the observed middle-and high-latitude ozone losses are largely due to anthropogenic causes*"(as cited on Greenpeace Website). It is widely accepted that it is chlorine and bromine compounds in the atmosphere that causes ozone depletion.

Chlorofluorocarbon (CFC) was thought of as a miracle gas until it was realized that it is a ozone-depletion substance. The ozone depletion process in Figure 4.3 focuses on CFCs, but the basic concepts apply to all of the ozone-depleting substances.

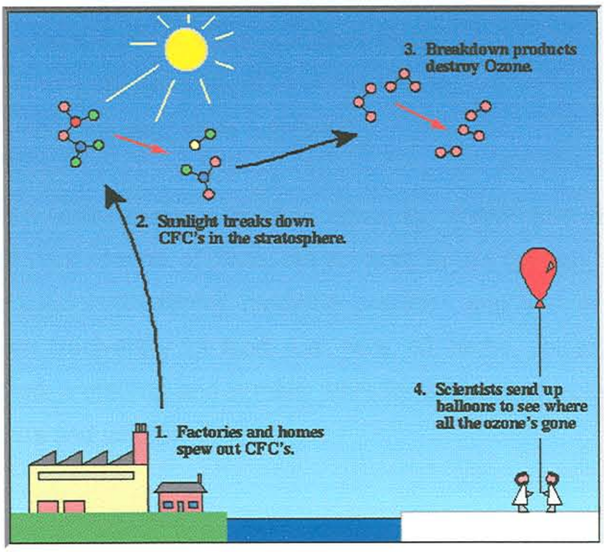


Figure D.2: Ozone Depletion Process

Source: http://www.atm.ch.cam.ac.uk/tour/part3.html

As for greenhouse gases an ozone depletion potential (ODP) has been introduced to compare ozone depletion substances, and CFC-11 is most commonly used as the reference gas to calculate equivalent factors (Guinée, 2001).

D.1.3 Reductions in Biodiversity

The World Resource Institute (WRI) define biological diversity or biodiversity as "*the variety of the world's organisms, including their genetic diversity and the assemblages they form*" while ENCARTA defines biodiversity as *"the range of organisms present in a given ecological community or system."*

Graedel & Allenby (1995) believe that there is general agreement among ecologists that the extinction of species of fauna and flora are rapidly increasing and that it could constitute a global extinction event. Figures for documented extinctions of species are most probably an underestimate for the following reasons:

- Species are generally not declared to be extinct until years after they have last been seen.
- The vast majority of species has not yet even been described, and many may disappear before they are even known to science (WRI)

According to the WRI 700 worldwide extinctions of vertebrates, invertebrates, and vascular plants have been recorded since 1600 and it is unknown how many species went extinct without anybody realising it. WWF believes that currently 34,000 plant species, or 12.5 per cent of the world's flora, are under threat of extinction. The WRI has identified 6 main mechanisms that causes a loss of biodiversity:

- Habitat loss and fragmentation
- Introduced species
- Over-exploitation of plant and animal species
- Pollution of soil, water, and atmosphere
- Global climate change
- Industrial agriculture and forestry

The reduction in biodiversity poses a threat to humanity. WWF has estimated that around 25,000 to 30,000 different species of plants are currently in use by man, while around 25,000 have or are being used in traditional medicine practices and that is only in the tropics. Humanity depends on biodiversity for food, fuel, fibre, oil, herbs, spices, medicines, building material, livestock feed, protection and in many ways for the aesthetic pleasure they can bring in their shapes, colours and smells.

D.2 Regional Scale Concerns

D.2.1 Surface Water Chemistry Changes

The effects of human activities can directly alter surface water chemistry e.g. the discharging of industrial residue streams into water or indirectly through atmospheric transportation and deposition of anthropogenic emissions. The result of the alteration in the chemistry of surface water causes highly publicized environmental problems such as:

- Acidification, whereby the concentration of free hydrogen ions increase in the ambient water resources.
- Euthropication, which is the process by which water becomes rich in dissolved nutrients, these circumstances then encourage the growth and decomposition of oxygen-depleting plant life that results in a lack of oxygen for other organisms living in the water.
- Pollution of water resource by toxic metals and organics

D.2.2 Soil Degradation

Soil degradation refers to the rate at which land is rendered unusable for agricultural activity. The land loss is due to soil erosion, poor water management, which leads to subsequent soil erosion and certain agricultural practices. The WRI estimates that an additional 5 million to 6 million hectares are lost to severe soil degradation annually. Soil degradation contributes in the decline in global food supply. Pierre Crosson (1994) (as cited on WRI website) estimated that soil degradation between 1945 and 1990 lowered world food production with 17 percent.

D.2.3 Precipitation Acidity

Precipitation acidity or acid rain as it is commonly known has been a topic of intense investigation in the 1980's. Precipitation acidity is caused by the presence of CO_2 and natural and anthropogenic nitrogen and sulphur species that increase the acidity of clouds and precipitation (Guinée,2001). The change in acidity effects water, land as well as species living in water and land.

D.2.4 Visibility

Graedel & Allenby (1995) defines visibility as *"the greatest distance over which one can see and identify familiar objects with the unaided eye"*. Visibility involves two factors:

- Degree to which light coming from the object is absorbed or scattered
- Visual threshold of perception

The first factor can however be influenced by anthropogenic activities. Graedel & Allenby (1995) state that the two principle causes of decreased visibility are:

- emission of small particles (0.2-0.7 μ) to the atmosphere
- emission of reactive gases that are subsequently converted to small particles

D.2.5 Herbicides and Pesticides

Herbicides and pesticides are an environmental concern mainly due to the fact that it is designed to be biological damaging. It is known that the chemicals in herbicides and pesticides influence and effects water, air as well as land resources. Graedel and Allenby (1995) believe that the level of concern is a function of: toxicity of product, longevity, method of application as well as intensity of application. Within Africa, the use of DDT for malaria purposes is one of the primary environmental concerns in this respect, and the application thereof is finely controlled (Department of Health Website).

D.3 Local Scale Concerns

D.3.1 Smog

The term 'smog' was first used during the 1950s to describe a mixture of smoke and fog experienced in London (Australian Environmental Protection Agency Website). Smog is of environmental concern as it influences visibility and can cause damage to vegetation and human health. It is possible to distinguish between "winter" and "summer" smog.

Summer smog is also known as photochemical ozone creation and refers to the production of ozone in the troposphere, i.e. at groundlevel. This is mainly due to the different nitrogen oxides being released into air. The pollutants in the air then undergo chemical reaction due to the sunlight and create harmful secondary pollutants such as ozone and peroxyacylnitrate (PAN). Photochemical smog is also often referred to as "brown-air smog".

Winter smog is also known as sulphurous smog, sometimes called gray-air smog. Particulates from factories and sulphur oxides are the primary cause of sulphurous smog. The Great London Smog experienced in 1952 is an example of winter smog.

D.3.2 Groundwater Pollution

The quality of groundwater has become an environmental concern lately, as high quality groundwater is essential to the health and welfare of a large fraction of the earth's population (Graedel & Allenby, 1995). Groundwater are polluted or contaminated by: sewage disposal, agricultural activities, solid-residue disposal in landfills, disposal of liquid residue, petroleum leakages, pesticides and other chemicals. The pollution of groundwater is starting to become a major environmental problem.

D.3.3 Toxics in Sludge

Sludge refers to a moist solid mass that is the product of treated wastewater. Sludge can contain undesirable anthropogenic pollutants and various disposal options have been investigated such as landfilling, land application as fertilizer and even ocean dumping (which is now illegal). The presence of toxics in sludge is therefor an environmental concern as the disposal thereof can lead to impacts on land, water and even air resources.

D.3.4 Oil Spills

Oil spills are usually major news events due to the photogenic properties of such an occurrence. Although experts regard it as a more moderate risk to the environment due to the fact that spoiled oil loses toxicity (Graedel & Allenby, 1995). It remains an environmental concern as it does have a local or even regional environmental impact.

D.3.5 Hazardous Waste Sites

Hazardous Waste sites are locations where toxic materials and waste are confined. These sites are of environmental concern as the emissions contained in the material still have the potential to cause significant harm. It is for that reason that active as well as inactive sites are monitored. Special attention must be given to older inactive sites, as often no liners or ineffective liners were used in these landfills and leachates to groundwater reserves could be problematic.

APPENDIX E:
Sustainable Development Indicators

E.1: United Nations: Sustainable Development Theme Indicator Framework

Theme	Sub-theme	Indicator
SOCIAL		
Equity	Poverty (3)	Percent of Population Living below Poverty Line
		Gini Index of Income Inequality
		Unemployment Rate
	Gender Equality (24)	Ratio of Average Female Wage to Male Wage
Health (6)	Nutritional Status	Nutritional Status of Children
	Mortality	Mortality Rate under 5 years old
		Life Expectancy at Birth
	Sanitation	Percent of Population with Adequate Sewage Disposal Facilities
	Drinking Water	Population with access to safe drinking water
	Healthcare Delivery	Percent of Population with access to primary health care facilities
		Immunization against infectious childhood diseases
		Contraceptive Prevalence Rate
Education (36)	Education Level	Children reaching Grade 5 of Primary Education
		Adult Secondary Education Achievement level
	Literacy	Adult Literacy Rate
Housing (7)	Living Conditions	Floor Area per person
Security	Crime (36.24)	Number of recorded crimes per 100.000 Population
Population (5)	Population Change	Population Growth Rate
		Population of Urban Formal and Informal Settlements
ENVIRONMENTAL		
Atmosphere (9)	Climate Change	Emissions of Greenhouse Gas
	Ozone Layer Depletion	Consumption of Ozone Depleting Substances
	Air Quality	Ambient Concentration of Air Pollutants in Urban Areas
	Agriculture (14)	Arable and Permanent Crop Land Area
		Use of Fertilizers

Land (10)		Use of Agricultural Pesticides
	Forests (11)	Forest Area as a percent of Land Area
		Wood Harvesting Intensity
	Desertification (12)	Land affected by desertification
	Urbanization (7)	Area of Urban Formal and Informal Settlements
Oceans, Sea and Coasts (17)	Coastal Zone	Algae Concentration in Coastal Waters
		Percent of Total Population Living in Coastal Areas
	Fisheries	Annual Catch by Major Species
Fresh Water (18)	Water Quantity	Annual Withdrawal of Ground and Surface Water as a percent of Total Available Water
	Water Quality	BOD in Water Bodies
		Concentration of Faecal Coliform in Freshwater
Biodiversity (15)	Ecosystem	Area of selected key ecosystems
		Protected area as a percentage of total area
	Species	Abundance of selected key species
ECONOMIC		
Economic Structure (2)	Economic Performance	GDP per Capita
		Investment Share in GDP
	Trade	Balance of Trade in Goods and Services
	Financial Status (33)	Debt to GNP Ratio
		Total ODA Given or Received as a Percent of GNP
Consumption and Production Patterns (4)	Material Consumption	Intensity of Material Use
	Energy Use	Annual Energy Consumption per Capita
		Share of Consumption of Renewable Energy Resources
		Intensity of Energy Use
	Waste Generation and Management (19-22)	Generation of Industrial and Municipal Solid Waste
		Generation of Hazardous Waste
		Generation of Radioactive Waste
		Waste Recycling and Reuse
	Transportation	Distance travel per capita by mode of transport
INSTITUTIONAL		

Institutional Framework (38.39)	Strategic Implementation of SD (8)	National Sustainable Development Strategy
	International Cooperation	Implementation of Ratified Global Agreements
Institutional Capacity (37)	Information Access (40)	Number of Internet subscribers per 1000 Inhabitants
	Communication Infrastructure (40)	Main Telephone lines per 1000 Inhabitants
	Science & Technology (35)	Expenditure on Research and Development as a percent of GDP
	Disaster Preparedness and Response	Economic and Human Loss due to Natural Disaster

*Numbers in brackets indicate relevant Agenda 21 chapters.

Table 2: Indicator Theme Framework

Source: UN: Indicators of Sustainable Development: Guidelines and Methodologies

E.2: South Africa: Environmental Indicators for National State of the Environment Reporting

Atmosphere & Climate	
Climate Change	• Greenhouse gas emissions • Energy Use • Size of the national net carbon sink • Malaria: morbidity and mortality • Mean annual temperature • Cost of carbon abatement • Cost of natural disaster relief • Energy intensity
Stratospheric Ozone	• Consumption of ozone depleting substances • UV-B trends • Stratospheric ozone level
Air Quality	• Ambient sulphur dioxide concentration • Ambient nitrogen dioxide concentration
Biodiversity and Natural Heritage	
Species diversity	• Threatened and extinct species per taxonomic group • Endemic species per taxonomic group • Alien (non-indigenous) species per taxonomic group • Population trends for selected species • Distribution and abundance of selected alien species
Habitat Change	• Extent of conserved areas • Extent of natural areas remaining • Disturbance regimes: fire frequency • Disturbance regimes: flood and drought
Resource Value	• Contribution to job creation: conservation areas • Contribution to job creation: eradication of alien species

	• Economic contribution of commercially utilised indigenous species • Economic contribution of commercially utilised freshwater species • Economic contribution of commercially utilised marine, coastal and estuarine species • Economic contribution of commercially utilised terrestrial species
Natural Heritage Resources	• Status of natural heritage resources • Investment into natural heritage resources • Visitors to natural heritage resources
Environmental Management	
Environmental Management	• Multi-lateral environmental agreements • Budgetary allocation to natural resource management • Budgetary allocation to environmental education • Budgetary allocation to environmental research • Inclusion of Integrated Environmental Management (IEM) into IDPs and SDIs • Conciliation Cases • Voluntary adoption of environmental management systems • Voluntary use of environmental accounting and reporting • Government capacity for environmental management • Environmental reporting by government departments
Human Well-Being	
Human Settlements	• Green space per settlement • Contaminated land per settlement • Housing density • Urban/rural population • Proportion of urban area in South Africa
Vulnerability	• GDP/capita • Life expectancy • Adult literacy rate • Employment rate • Population growth rate • HIV/AIDS incidence • Household energy use • Access to water • Access to sanitation
Land Use	
Land Use	• Land cover • Land productivity versus potential
Land Condition	• Desertification • Soil loss • Soil acidification • Soil salinisation • Land degradation • Persistent organic pollutants
Marine, Coastal and Estuarine Environments	
Resource Management	• Catches and Maximum Sustainable Yield per fishery sector • Distribution and abundance of resource species • Catch per unit effort per fishery sector

	• Commercial fishing rights supporting SMME development
Resource Quality	• Estuarine Health Index (State of South African Estuaries) • Pollutant lading entering the seas from land based sources • Blue Flag beaches • Concentrations of heavy metals in sediments or biological tissues • Oil pollution accidents along the coast • Land cover change in coastal zone • Population density change in the coastal zone
Waste Management	
Waste generation	• General waste produced per income group per year • General waste produced per capita per year • Hazardous waste produced per sector per year
Waste reduction	• Waste recycling • Value of waste recycled • General waste correctly disposed through landfill • Hazardous waste correctly disposed • Available landfill lifespan • Provincial expenditure on waste management • Provincial waste collection capacity
Inland Water	
Water Quantity	• Intensity of use of surface water resources • Intensity of use of ground water resources • Total surface water used per sector • Total ground water used per sector • Total surface water resources per capita • People dependent on ground water resources • Surface water affordability
Water Quality	• Surface water salinity • Ground water salinity • Surface water nutrients • Ground water nutrients • Surface water microbiology • Ground water microbiology • Surface water toxicity
Freshwater Ecosystem Integrity	• Riparian vegetation • Aquatic macro-invertebrate composition • Fish community health • Aquatic habitat integrity

Source: DEAT, 2002.

APPENDIX F:
Examples of Environmental Checklists

1. California Environmental Checklist (Retrieved from: http://ceres.ca.gov/topic/env_law/ceqa/guidelines/appendices.html)

2. Washington State: Department of Ecology (Retrieved from: http://www.ecy.wa.gov/programs/sea/sepa/forms.htm)

3. United States Department of Energy (Retrieved from: http://www.id.doe.gov/doeid/)

4. Environmental & Health Screening Checklist used in Total Cost Assessment (AIChE CWRT, 1999)

5. Generic Questionnaire Checklist for Addressing and/or Summarising the Cumulative Environmental Impacts of Projects (Canter & Kamath, 1995).

California Environmental Checklist

Environmental Checklist Form

1. Project title: ______________________________

2. Lead agency name and address:
____
____
____

3. Contact person and phone number: ______________________________

4. Project location: ______________________________

5. Project sponsor's name and address:
____
____
____

6. General plan designation: ______________ 7. Zoning: ______________

8. Description of project: (Describe the whole action involved, including but not limited to later phases of the project, and any secondary, support, or off-site features necessary for its Implementation. Attach additional sheets if necessary.)
____
____
____
____

9. Surrounding land uses and setting: Briefly describe the projectors surroundings:
____
____
____
____

10. Other public agencies whose approval is required (e.g., permits, financing approval, or Participation agreement.)
____
____
____
____

ENVIRONMENTAL FACTORS POTENTIALLY AFFECTED:
The environmental factors checked below would be potentially affected by this project, involving at least one impact that is a "Potentially Significant Impact" as indicated by the checklist on the following pages.

☐ Aesthetics	☐ Agriculture Resources	☐ Air Quality
☐ Biological Resources	☐ Cultural Resources	☐ Geology /Soils
☐ Hazards & Hazardous Materials	☐ Hydrology / Water Quality	☐ Land Use / Planning

☐ Mineral Resources ☐ Noise ☐ Population / Housing

☐ Public Services ☐ Recreation ☐ Transportation/ Traffic

☐ Utilities/Service Systems ☐ Mandatory Findings of Significance

DETERMINATION: (To be completed by the Lead Agency)

On the basis of this initial evaluation:

☐ I find that the proposed project COULD NOT have a significant effect on the environment, and a NEGATIVE DECLARATION will be prepared.

☐ I find that although the proposed project could have a significant effect on the environment, there will not be a significant effect in this case because revisions in the project have been made by or agreed to by the project proponent. A MITIGATED NEGATIVE DECLARATION will be prepared.

☐ I find that the proposed project MAY have a significant effect on the environment, and an ENVIRONMENTAL IMPACT REPORT is required.

☐ I find that the proposed project MAY have a "potentially significant impact" or "potentially significant unless mitigated" impact on the environment, but at least one effect 1) has been adequately analyzed in an earlier document pursuant to applicable legal standards, and 2) has been addressed by mitigation measures based on the earlier analysis as described on attached sheets. An ENVIRONMENTAL IMPACT REPORT is required, but it must analyze only the effects that remain to be addressed.

☐ I find that although the proposed project could have a significant effect on the environment, because all potentially significant effects (a) have been analyzed adequately in an earlier EIR or NEGATIVE DECLARATION pursuant to applicable standards, and (b) have been avoided or mitigated pursuant to that earlier EIR or NEGATIVE DECLARATION, including revisions or mitigation measures that are imposed upon the proposed project, nothing further is required.

______________________________ ______________________________
Signature Date

______________________________ ______________________________
Printed name for

EVALUATION OF ENVIRONMENTAL IMPACTS:

1) A brief explanation is required for all answers except "No Impact" answers that are adequately supported by the information sources a lead agency cites in the parentheses following each question. A "No Impact" answer is adequately supported if the referenced information sources show that the impact simply does not apply to projects like the one involved (e.g., the project falls

outside a fault rupture zone). A "No Impact" answer should be explained where it is based on project-specific factors as well as general standards (e.g., the project will not expose sensitive receptors to pollutants, based on a project-specific screening analysis).

2) All answers must take account of the whole action involved, including off-site as well as on-site, cumulative as well as project-level, indirect as well as direct, and construction as well as operational impacts.

3) Once the lead agency has determined that a particular physical impact may occur, then the checklist answers must indicate whether the impact is potentially significant, less than significant with mitigation, or less than significant. "Potentially Significant Impact" is appropriate if there is substantial evidence that an effect may be significant. If there are one or more "Potentially Significant Impact" entries when the determination is made, an EIR is required.

4) "Negative Declaration: Less Than Significant With Mitigation Incorporated" applies where the incorporation of mitigation measures has reduced an effect from "Potentially Significant Impact" to a "Less Than Significant Impact." The lead agency must describe the mitigation Measures, and briefly explain how they reduce the effect to a less than significant level (Mitigation measures from Section XVII; "Earlier Analyses" may be cross-referenced).

5) Earlier analyses may be used where, pursuant to the tiering, program EIR, or other CEQA Process, an effect has been adequately analyzed in an earlier EIR or negative declaration. Section 15063(c)(3)(D). In this case, a brief discussion should identify the following:

a) Earlier Analysis Used. Identify and state where they are available for review.
b) Impacts Adequately Addressed. Identify which effects from the above checklist were within the scope of and adequately analyzed in an earlier document pursuant to applicable legal standards, and state whether such effects were addressed by mitigation measures based on the earlier analysis.
c) Mitigation Measures. For effects that are "Less than Significant with Mitigation Measures Incorporated", describe the mitigation measures, which were incorporated or refined from the earlier document and the extent, to which they address site-specific conditions for the project.

6) Lead agencies are encouraged to incorporate into the checklist references to information sources for potential impacts (e.g., general plans, zoning ordinances). Reference to a previously prepared or outside document should, where appropriate, include a reference to the page or pages where the statement is substantiated.

7) Supporting Information Sources: A source list should be attached, and other sources used or Individuals contacted should be cited in the discussion.

8) This is only a suggested form, and lead agencies are free to use different formats; however, lead agencies should normally address the questions from this checklist that are relevant to a project's environmental effects in whatever format is selected.

9) The explanation of each issue should identify:

a) The significance criteria or threshold, if any, used to evaluate each question; and
b) The mitigation measure identified, if any, to reduce the impact to less than significance

SAMPLE QUESTION

Issues	Potentially Significant Impact	Less than Significant with Mitigation Incorporation	Less than significant impact	No Impact
I. AESTHETICS -- Would the project:				
a) Have a substantial adverse effect on a scenic vista?				
b) Substantially damage scenic resources, including, but not limited to, trees, rock outcroppings, and historic buildings within a state scenic highway?				
c) Substantially degrade the existing visual character or quality of the site and its surroundings?				
d) Create a new source of substantial light or glare, which would adversely affect day or nighttime views in the area?				
II. AGRICULTURE RESOURCES: In determining whether impacts to agricultural resources are significant environmental effects, lead agencies may refer to the California Agricultural Land Evaluation and Site Assessment Model (1997) prepared by the California Dept. of Conservation as an optional model to use in assessing impacts on agriculture and farmland. Would the project:				
a) Convert Prime Farmland, Unique Farmland, or Farmland of Statewide Importance (Farmland), as shown on the maps prepared pursuant to the Farmland Mapping and Monitoring Program of the California Resources Agency, to non-agricultural use?				
b) Conflict with existing zoning for agricultural use, or a Williamson Act contract?				
c) Involve other changes in the existing environment, which, due to their location or nature, could result in conversion of farmland, to non-agricultural use?				
III. AIR QUALITY -- Where available, the significance criteria established by the applicable air quality management or air pollution control district may be relied upon to make the following determinations. Would the project:				
a) Conflict with or obstruct implementation of the applicable air quality plan?				
b) Violate any air quality standard or contribute substantially to an existing or projected air quality violation?				
c) Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is non-attainment under an applicable federal or state ambient air quality standard (including releasing emissions, which exceed quantitative thresholds for ozone precursors)?				
d) Expose sensitive receptors to substantial pollutant concentrations?				
e) Create objectionable odors affecting a substantial number of people?				
IV. BIOLOGICAL RESOURCES -- Would the project:				
a) Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Game or U.S. Fish and Wildlife Service?				
b) **Have** a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, and regulations or by the California Department of Fish and Game or US Fish and Wildlife Service?				
c) Have a substantial adverse effect on federally protected wetlands as defined by Section 404 of the Clean Water Act (including, but not limited to, marsh, vernal pool, coastal, etc.) Through direct removal, filling, hydrological interruption, or other means?				
d) Interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors, or impede the use of native wildlife nursery sites?				
e) Conflict with any local policies or ordinances protecting				

biological resources, such as a tree preservation policy or ordinance?				
f) Conflict with the provisions of an adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other approved local, regional, or state habitat Conservation plan?				
V. CULTURAL RESOURCES -- Would the project:				
a) Cause a substantial adverse change in the significance of a historical resource as defined in ¤15064.5?				
b) Cause a substantial adverse change in the significance of an archaeological resource pursuant to ¤15064.5?				
c) Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature?				
d) Disturb any human remains, including those interred outside of formal cemeteries?				
VI. GEOLOGY AND SOILS -- Would the project:				
a) Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death Involving: i) Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault? Refer to Division of Mines and Geology Special Publication 42. ii) Strong seismic ground shaking? iii) Seismic-related ground failure, including liquefaction? iv) Landslides?				
b) Result in substantial soil erosion or the loss of topsoil?				
c) Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction or collapse?				
d) Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property?				
e) Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater?				
VII. HAZARDS AND HAZARDOUS MATERIALS -- Would the project:				
a) Create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials?				
b) Create a significant hazard to the public or the environment through reasonably foreseeable upset and accident conditions involving the release of hazardous materials into the environment?				
c) Emit hazardous emissions or handle hazardous or acutely hazardous materials, substances, or waste within One-quarter mile of an existing or proposed school?				
d) Be located on a site which is included on a list of hazardous materials sites compiled pursuant to Government Code Section 65962.5 and, as a result, would it create a significant hazard to the public or the environment?				
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project result in a safety hazard for people residing or working in the project area?				
f) For a project within the vicinity of a private airstrip, would the project result in a safety hazard for people residing or working in the project area?				
g) Impair implementation of or physically interfere with an adopted emergency response plan or emergency evacuation plan?				

h) Expose people or structures to a significant risk of loss, injury or death involving wild land fires, including where wildlands are adjacent to urbanized areas or where residences are intermixed with wildlands?				
VIII. HYDROLOGY AND WATER QUALITY -- Would the project:				
a) Violate any water quality standards or waste discharge requirements?				
b) Substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level (e.g., the production rate of pre-existing nearby wells would drop to a level which would not support existing land uses or planned uses for which permits have been granted)?				
c) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, in a manner, which would result in substantial erosion or siltation on- or off-site?				
d) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, or substantially increase the rate or amount of surface runoff in a manner, which would result in flooding on- or off-site?				
e) Create or contribute runoff water which would exceed the capacity of existing or planned stormwater drainage systems or provide substantial additional sources of polluted runoff?				
f) Otherwise substantially degrade water quality?				
g) Place housing within a 100-year flood hazard area as mapped on a federal Flood Hazard Boundary or Flood Insurance Rate Map or other flood hazard delineation map?				
h) Place within a 100-year flood hazard area structures, which would impede or redirect flood flows?				
I) Expose people or structures to a significant risk of loss, injury or death involving flooding, including flooding as a result of the failure of a levee or dam?				
j) Inundation by seiche, tsunami, or mudflow?				
IX. LAND USE AND PLANNING - Would the project:				
a) Physically divide an established community?				
b) Conflict with any applicable land use plan, policy, or regulation of an agency with jurisdiction over the project (including, but not limited to the general plan, specific plan, local coastal program, or zoning ordinance) adopted for the purpose of avoiding or mitigating an environmental effect?				
c) Conflict with any applicable habitat conservation plan or natural community conservation plan?				
X. MINERAL RESOURCES -- Would the project:				
a) Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state?				
b) Result in the loss of availability of a locally-important mineral resource recovery site delineated on a local General plan, specific plan or other land use plan?				
XI. NOISE -- Would the project result in:				
a) Exposure of persons to or generation of noise levels in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?				
b) Exposure of persons to or generation of excessive groundborne vibration or groundborne noise levels?				
c) A substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project?				
d) A substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project?				
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project expose people residing or working in the project area to excessive noise levels?				

f) For a project within the vicinity of a private airstrip, would the project expose people residing or working in the project area to excessive noise levels?				
XII. POPULATION AND HOUSING -- Would the project:				
a) Induce substantial population growth in an area, either directly (for example, by proposing new homes and businesses) or indirectly (for example, through extension of roads or other infrastructure)?				
b) Displace substantial numbers of existing housing, necessitating the construction of replacement housing elsewhere?				
c) Displace substantial numbers of people, necessitating the construction of replacement housing elsewhere?				
XIII. PUBLIC SERVICES				
a) Would the project result in substantial adverse physical impacts associated with the provision of new or physically altered governmental facilities, need for new or physically altered governmental facilities, the construction of which could cause significant environmental impacts, in order to maintain acceptable service ratios, response times or other performance objectives for any of the public services: • Fire protection? • Police protection? • Schools? • Parks? • Other public facilities?				
XIV. RECREATION --				
a) Would the project increase the use of existing neighborhood and regional parks or other recreational facilities such that substantial physical deterioration of the facility would occur or be accelerated?				
b) Does the project include recreational facilities or require the construction or expansion of recreational facilities which might have an adverse physical effect on the environment?				
XV. TRANSPORTATION/TRAFFIC -- Would the project:				
a) Cause an increase in traffic which is substantial in relation to the existing traffic load and capacity of the street system (i.e., result in a substantial increase in either the number of vehicle trips, the volume to capacity ratio on roads, or congestion at intersections)?				
b) Exceed, either individually or cumulatively, a level of service standard established by the county congestion management agency for designated roads or highways?				
c) Result in a change in air traffic patterns, including either an increase in traffic levels or a change in location that results in substantial safety risks?				
d) Substantially increase hazards due to a design feature (e.g., sharp curves or dangerous intersections) or incompatible uses (e.g., farm equipment)?				
e) Result in inadequate emergency access?				
f) Result in inadequate parking capacity?				
g) Conflict with adopted policies, plans, or programs supporting alternative transportation (e.g., bus turnouts, bicycle racks)?				
XVI. UTILITIES AND SERVICE SYSTEMS -- Would the project:				
a) Exceed wastewater treatment requirements of the applicable Regional Water Quality Control Board?				
b) Require or result in the construction of new water or wastewater treatment facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?				
c) Require or result in the construction of new storm water drainage facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?				

d) Have sufficient water supplies available to serve the project from existing entitlements and resources, or are new or expanded entitlements needed?				
e) Result in a determination by the wastewater treatment provider, which serves or may serve the project that it has adequate capacity to serve the project's projected demand in addition to the provider's existing commitments?				
f) Be served by a landfill with sufficient permitted capacity to accommodate the project's solid waste disposal needs?				
g) Comply with federal, state, and local statutes and regulations related to solid waste?				
XVII. MANDATORY FINDINGS OF SIGNIFICANCE --				
a) Does the project have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal or eliminate important examples of the major periods of California history or prehistory?				
b) Does the project have impacts that are individually limited, but cumulatively considerable? ("Cumulatively considerable" means that the incremental effects of a project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects)?				
c) Does the project have environmental effects which will cause substantial adverse effects on human beings, either directly or indirectly?				

Final Text - October 26, 1998

WAC 197-11-960 Environmental checklist.
ENVIRONMENTAL CHECKLIST

Purpose of checklist:
The State Environmental Policy Act (SEPA), chapter 43.21C RCW, requires all governmental agencies to consider the environmental impacts of a proposal before making decisions. An environmental impact statement (EIS) must be prepared for all proposals with probable significant adverse impacts on the quality of the environment. The purpose of this checklist is to provide information to help you and the agency identify impacts from your proposal (and to reduce or avoid impacts from the proposal, if it can be done) and to help the agency decide whether an EIS is required.

Instructions for applicants:
This environmental checklist asks you to describe some basic information about your proposal. Governmental agencies use this checklist to determine whether the environmental impacts of your proposal are significant, requiring preparation of an EIS. Answer the questions briefly, with the most precise information known, or give the best description you can. You must answer each question accurately and carefully, to the best of your knowledge. In most cases, you should be able to answer the questions from your own observations or project plans without the need to hire experts. If you really do not know the answer, or if a question does not apply to your proposal, write "do not know" or "does not apply." Complete answers to the questions now may avoid unnecessary delays later. Some questions ask about governmental regulations, such as zoning, shoreline, and landmark designations. Answer these questions if you can. If you have problems, the governmental agencies can assist you. The checklist questions apply to all parts of your proposal, even if you plan to do them over a period of time or on different parcels of land. Attach any additional information that will help describe your proposal or its environmental effects. The agency to which you submit this checklist may ask you to explain your answers or provide additional information reasonably related to determining if there may be significant adverse impact.

Use of checklist for nonproject proposals:
Complete this checklist for nonproject proposals, even though questions may be answered "does not apply." IN ADDITION, complete the SUPPLEMENTAL SHEET FOR NONPROJECT ACTIONS (part D). For nonproject actions, the references in the checklist to the words "project," "applicant," and "property or site" should be read as "proposal," "proposer," and "affected geographic area," respectively.

A. BACKGROUND

1. Name of proposed project, if applicable:

2. Name of applicant:

3. Address and phone number of applicant and contact person:

4. Date checklist prepared:
5. Agency requesting checklist:

6. Proposed timing or schedule (including phasing, if applicable):

7. Do you have any plans for future additions, expansion, or further activity related to or connected with this proposal? If yes, explain.

8. List any environmental information you know about that has been prepared, or will be prepared, directly related to this proposal.

9. Do you know whether applications are pending for governmental approvals of other proposals directly affecting the property covered by your proposal? If yes, explain.

10. List any government approvals or permits that will be needed for your proposal, if known.

11. Give brief, complete description of your proposal, including the proposed uses and the size of the project and site. There are several questions later in this checklist that ask you to describe certain aspects of your proposal. You do not need to repeat those answers on this page. (Lead agencies may modify this form to include additional specific information on project description.)

12. Location of the proposal. Give sufficient information for a person to understand the precise location of your proposed project, including a street address, if any, and section, township, and range, if known. If a proposal would occur over a range of area, provide

the range or boundaries of the site(s). Provide a legal description, site plan, vicinity map, and topographic map, if reasonably available. While you should submit any plans required by the agency, you are not required to duplicate maps or detailed plans submitted with any permit applications related to this checklist.

TO BE COMPLETED BY APPLICANT — EVALUATION FOR AGENCY USE ONLY

B. ENVIRONMENTAL ELEMENTS

1. Earth

a. General description of the site (circle one): Flat, rolling, hilly, steep slopes, mountainous, other . . . . . .

b. What is the steepest slope on the site (approximate percent slope)?

c. What general types of soils are found on the site (for example, clay, sand, gravel, peat, muck)? If you know the classification of agricultural soils, specify them and note any prime farmland.

d. Are there surface indications or history of unstable soils in the immediate vicinity? If so, describe.

e. Describe the purpose, type, and approximate quantities of any filling or grading proposed. Indicate source of fill.

f. Could erosion occur as a result of clearing, construction, or use? If so, generally describe.

g. About what percent of the site will be covered with impervious surfaces after project construction (for example, asphalt or buildings)?

h. Proposed measures to reduce or control erosion, or other impacts to the earth, if any:

2. Air

a. What types of emissions to the air would result from the proposal (i.e., dust, automobile, odors, industrial wood smoke) during construction and when the project is completed? If any, generally describe and give approximate quantities if known.

b. Are there any off-site sources of emissions or odor that may affect your proposal? If so, generally describe.

c. Proposed measures to reduce or control emissions or other impacts to air, if any:

TO BE COMPLETED BY APPLICANT — EVALUATION FOR AGENCY USE ONLY

3. Water

a. Surface:

1) Is there any surface water body on or in the immediate vicinity of the site (including year-round and seasonal streams, saltwater, lakes, ponds, wetlands)? If yes, describe type and provide names. If appropriate, state what stream or river it flows into.

2) Will the project require any work over, in, or adjacent to (within 200 feet) the described waters? If yes, please describe and attach available plans.

3) Estimate the amount of fill and dredge material that would be placed in or removed from surface water or wetlands and indicate the area of the site that would be affected. Indicate the source of fill material.

4) Will the proposal require surface water withdrawals or diversions? Give general description, purpose, and approximate quantities if known.

5) Does the proposal lie within a 100-year floodplain? If so, note location on the site plan.

6) Does the proposal involve any discharges of waste materials to surface waters? If so, describe the type of waste and anticipated volume of discharge.

b. Ground:

1) Will ground water be withdrawn, or will water be discharged to ground water? Give general description, purpose, and approximate quantities if known.

2) Describe waste material that will be discharged into the ground from septic tanks or other sources, if any (for example: Domestic sewage; industrial, containing the following chemicals. . . ; agricultural; etc.). Describe the general size of the system, the number of such systems, the number of houses to be served (if applicable), or the number of animals or humans the system(s) are expected to serve.

c. Water runoff (including stormwater):

1) Describe the source of runoff (including storm water) and method of collection and disposal, if any (include quantities, if known). Where will this water flow? Will this water flow into other waters? If so, describe.

2) Could waste materials enter ground or surface waters? If so, generally describe.

d. Proposed measures to reduce or control surface, ground, and runoff water impacts, if any:

TO BE COMPLETED BY APPLICANT

EVALUATION FOR AGENCY USE ONLY

4. Plants

a. Check or circle types of vegetation found on the site:

______deciduous tree: alder, maple, aspen, other
______evergreen tree: fir, cedar, pine, other
______shrubs
______grass
______pasture
______crop or grain
______wet soil plants: cattail, buttercup, bullrush, skunk cabbage, other
______water plants: water lily, eelgrass, milfoil, other
______other types of vegetation

b. What kind and amount of vegetation will be removed or altered?

c. List threatened or endangered species known to be on or near the site.

d. Proposed landscaping, use of native plants, or other measures to preserve or enhance vegetation on the site, if any:

5. Animals

a. Circle any birds and animals which have been observed on or near the site or are known to be on or near the site:

______birds: hawk, heron, eagle, songbirds, other:
______mammals: deer, bear, elk, beaver, other:
______fish: bass, salmon, trout, herring, shellfish, other:

b. List any threatened or endangered species known to be on or near the site.

c. Is the site part of a migration route? If so, explain.

d. Proposed measures to preserve or enhance wildlife, if any:

6. Energy and natural resources

a. What kinds of energy (electric, natural gas, oil, wood stove, solar) will be used to meet the completed project's energy needs? Describe whether it will be used for heating, manufacturing, etc.

b. Would your project affect the potential use of solar energy by adjacent properties? If so, generally describe.

c. What kinds of energy conservation features are included in the plans of this proposal? List other proposed measures to reduce or control energy impacts, if any:

TO BE COMPLETED BY APPLICANT

EVALUATION FOR AGENCY USE ONLY

7. Environmental health

a. Are there any environmental health hazards, including exposure to toxic chemicals, risk of fire and explosion, spill, or hazardous waste, that could occur as a result of this proposal? If so, describe.

1) Describe special emergency services that might be required.

2) Proposed measures to reduce or control environmental health hazards, if any:

b. Noise

1) What types of noise exist in the area which may affect your project (for example: traffic, equipment, operation, other)?

2) What types and levels of noise would be created by or associated with the project on a short-term or a long-term basis (for example: traffic, construction, operation, other)? Indicate what hours noise would come from the site.

3) Proposed measures to reduce or control noise impacts, if any:

8. Land and shoreline use

a. What is the current use of the site and adjacent properties?

b. Has the site been used for agriculture? If so, describe.

c. Describe any structures on the site.

d. Will any structures be demolished? If so, what?

e. What is the current zoning classification of the site?

f. What is the current comprehensive plan designation of the site?

g. If applicable, what is the current shoreline master program designation of the site?

h. Has any part of the site been classified as an "environmentally sensitive" area? If so, specify.

i. Approximately how many people would reside or work in the completed project?

TO BE COMPLETED BY APPLICANT

EVALUATION FOR AGENCY USE ONLY

j. Approximately how many people would the completed project displace?
k. Proposed measures to avoid or reduce displacement impacts, if any:

l. Proposed measures to ensure the proposal is compatible with existing and projected land uses and plans, if any:

9. Housing
a. Approximately how many units would be provided, if any? Indicate whether high, middle, or low-income housing.

b. Approximately how many units, if any, would be eliminated? Indicate whether high, middle, or low-income housing.

c. Proposed measures to reduce or control housing impacts, if any:

10. Aesthetics
a. What is the tallest height of any proposed structure(s), not including antennas; what is the principal exterior building material(s) proposed?

b. What views in the immediate vicinity would be altered or obstructed?

c. Proposed measures to reduce or control aesthetic impacts, if any:

11. Light and glare
a. What type of light or glare will the proposal produce? What time of day would it mainly occur?

b. Could light or glare from the finished project be a safety hazard or interfere with views?

c. What existing off-site sources of light or glare may affect your proposal?

d. Proposed measures to reduce or control light and glare impacts, if any:

12. Recreation
a. What designated and informal recreational opportunities are in the immediate vicinity?

b. Would the proposed project displace any existing recreational uses? If so, describe.

TO BE COMPLETED BY APPLICANT

EVALUATION FOR AGENCY USE ONLY

c. Proposed measures to reduce or control impacts on recreation, including recreation opportunities to be provided by the project or applicant, if any:

13. Historic and cultural preservation

a. Are there any places or objects listed on, or proposed for, national, state, or local preservation registers known to be on or next to the site? If so, generally describe.

b. Generally describe any landmarks or evidence of historic, archaeological, scientific, or cultural importance known to be on or next to the site.

c. Proposed measures to reduce or control impacts, if any:

14. Transportation

a. Identify public streets and highways serving the site, and describe proposed access to the existing street system. Show on site plans, if any.

b. Is site currently served by public transit? If not, what is the approximate distance to the nearest transit stop?

c. How many parking spaces would the completed project have? How many would the project eliminate?

d. Will the proposal require any new roads or streets, or improvements to existing roads or streets, not including driveways? If so, generally describe (indicate whether public or private).

e. Will the project use (or occur in the immediate vicinity of) water, rail, or air transportation? If so, generally describe.

f. How many vehicular trips per day would be generated by the completed project? If known, indicate when peak volumes would occur.

g. Proposed measures to reduce or control transportation impacts, if any:

TO BE COMPLETED BY APPLICANT

EVALUATION FOR AGENCY USE ONLY

15. Public services

a. Would the project result in an increased need for public services (for example: fire protection, police protection, health care, schools, other)? If so, generally describe.

b. Proposed measures to reduce or control direct impacts on public services, if any.

16. Utilities

a. Circle utilities currently available at the site: electricity, natural gas, water, refuse service, telephone, sanitary sewer, septic system, other.

b. Describe the utilities that are proposed for the project, the utility providing the service, and the general construction activities on the site or in the immediate vicinity which might be needed.

C. SIGNATURE

The above answers are true and complete to the best of my knowledge. I understand that the lead agency is relying on them to make its decision.

Signature: ....

Date Submitted: ....

TO BE COMPLETED BY APPLICANT

EVALUATION FOR AGENCY USE ONLY

D. SUPPLEMENTAL SHEET FOR NONPROJECT ACTIONS
(do not use this sheet for project actions)

Because these questions are very general, it may be helpful to read them in conjunction with the list of the elements of the environment.

When answering these questions, be aware of the extent the proposal, or the types of activities likely to result from the proposal, would affect the item at a greater intensity or at a faster rate than if the proposal were not implemented. Respond briefly and in general terms.

1. How would the proposal be likely to increase discharge to water; emissions to air; production, storage, or release of toxic or hazardous substances; or production of noise?

Proposed measures to avoid or reduce such increases are:

2. How would the proposal be likely to affect plants, animals, fish, or marine life?

Proposed measures to protect or conserve plants, animals, fish, or marine life are:

3. How would the proposal be likely to deplete energy or natural resources?

Proposed measures to protect or conserve energy and natural resources are:

4. How would the proposal be likely to use or affect environmentally sensitive areas or areas designated (or eligible or under study) for governmental protection; such as parks, wilderness, wild and scenic rivers, threatened or endangered species habitat, historic or cultural sites, wetlands, floodplains, or prime farmlands?

Proposed measures to protect such resources or to avoid or reduce impacts are:

TO BE COMPLETED BY APPLICANT

EVALUATION FOR AGENCY USE ONLY

5. How would the proposal be likely to affect land and shoreline use, including whether it would allow or encourage land or shoreline uses incompatible with existing plans?

Proposed measures to avoid or reduce shoreline and land use impacts are:

6. How would the proposal be likely to increase demands on transportation or public services and utilities?

Proposed measures to reduce or respond to such demand(s) are:

7. Identify, if possible, whether the proposal may conflict with local, state, or federal laws or requirements for the protection of the environment.

ID-EC98.1

APPLICANT ENVIRONMENTAL CHECKLIST

The following information must be provided to and approved by the Department of Energy (DOE) before a contractual document can be awarded. Complete and correct information expedites the review process.

SECTION A:

Project Title: ______________________________

Applicant Organization: ______________________________

Applicant Organization Contact (Usually the P.I.): ______________________________

Telephone Number: ______________________________

SECTION B: Attach a complete and concise description of the project or activity. Include purpose and need and enough information so that a verification of the impacts can be performed. This allows DOE to make the proper NEPA determination.

SECTION C: SOURCES OF IMPACTS: WOULD THE PROPOSAL INVOLVE OR GENERATE ANY OF THE FOLLOWING? (If yes, please provide brief explanation. For example, if yes is checked for question 15, indicate how much waste will be generated and the office or procedure in place to handle disposal.)

	YES	NO		YES	NO
1. Air Emissions			12. Petroleum Storage		
2. Asbestos			13. Solid Waste		
3. Work Force Adjustment			14. PCBs		
4. Excess Noise Levels			15. Hazardous Waste		
5. Utility Modification			16. Radioactive Waste		
6. Soil Disturbance			17. Mixed Waste		
7. Water Treatment			18. Radiation Exposure		
8. Water/Well Use			19. Liquid Effluent		
9. Water Course Modification			20. Sensitive Resources		
10. Pesticide Use			21. CERCLA/RCRA Site		
11. Chemical Use/Storage					

SECTION D: CATEGORY EVALUATION CRITERIA, WOULD THE ACTION:	YES	NO
1. Require cultural, historical, or biological clearances?		
2. Impact sensitive resources identified in Item 1 above. Describe the mitigation plan.		
3. Require or modify federal, state, or local permits, approvals, etc.?		
4. Create hazardous, radioactive, PCB, or mixed waste for which no disposal is available?		
5. Require siting, construction, or modification of a RCRA or TSCA regulated facility?		

SECTION E: CERTIFICATION To the best of the applicant' s knowledge at the time of signing, the responses given above are complete and accurate, and should new issues or concerns arise or changes occur anytime after award and during the course of performance, the applicant will alert DOE immediately.

______________________________ ______________________________
APPLICANT SIGNATURE & TITLE DATE

FOR DOE USE ONLY	
NEPA Doc Number:	**Solicitation #:**
NEPA CX Applied:	**Contract Specialist:**
Approved:	**Project Manager:**

	Yes/No
Eco-Efficiency 1. Materials use: a. Are materials planned for use in this project the most renewable, to the extent possible? b. Are recycled materials used, where possible, to reduce the use of newly-manufactured materials? c. Is the overall amount of all materials used reduced to the most economically and practical extent possible? 2. Material toxicity: given a choice, were the least toxic materials (both to the environment and human health exposure) selected? 3. Water use: a. Is the usage of water reduced to the lowest volume possible? b. Is the output water used from this project recycled? c. Is recycled water used to the extent possible? 4. Energy use: has the energy consumption per unit of output been reduced to the lowest extent possible? 5. End-of-life considerations: have end-of-product life considerations been considered? a. Recycle b. Reuse c. Recondition/refurbish d. Remanufacture e. Responsibly dispose (state method) f. Retrofit with upgrades	
Environmental 1. Will there be any increase in air emissions, any new source of air emissions or any increase in episodic emission potential? 2. Will there be any increase in materials discharged to the process or clean sewer systems? 3. Are there any plans to dispose of wastewater by underground injection? 4. Are there any or will there be any wastes generated, stored, treated, or disposed of at the project that that would be classified special? 5. Is there presently any soil or groundwater contamination at the project site? 6. Does the project increase the potential to contaminate soil or groundwater? 7. Will underground storage tanks be used for this project?	
Safety and Health Y/N 1. Will flammable, toxic, corrosive, reactive or otherwise hazardous substances be transported, stored, processed or produced at the project site? 2. Are extremes of pressure (500 psig) or temperature (400°C) present anywhere in the new facility? 3. Will this project use any new process technology? 4. Will this project adversely affect reliability of existing facility? 5. Are any process intermediates isolated that are not included on the governing chemical control law (TSCA in US) inventory listing for the location?	
Product Safety 1. Are any new products manufactured or will any existing products be directed toward a new market? 2. Will distribution schemes cause new or additional public exposures to this product? 3. Will this project introduce new contaminants, increase existing hazardous contaminant level or otherwise increase the hazardous nature of the products?	
Reviewer: .... Date:..........................	

Project:				
Locations:				
Environmental Checklists				
Environmental – General	**Yes**	**No**	**Other**	**Comments**
1. Does the geographic location of the project present any potential interstate or international air pollution liabilities?				
2. Does the geographic location of the project present any potential interstate or international water (surface or groundwater) pollution liabilities?				
3. Is process technology design derived from either proven commercial-scale facilities or six months or more of successful pilot scale operations?				
4. Is there a high degree of confidence that the predicted composition and quantities of air and water pollutants and residues generated from operation of the project have not emitted any chemical more toxic than those documented and have not understated any quantities by more than 50%?				
5. Are there any residuals from either environmental discharges or disposed wastes resulting from operation of the completed project believed to be a potential subject of future governmental rule-making that could cause future unfavorable economics or publicity for the project, location, or corporation?				
6. Will the design and operation of the project be consistent with the location's waste and release reduction programs?				
7. Has the design inventory of hazardous and toxic chemicals been minimized to the extent practical?				
8. Will the facility be staffed, or have readily available, personnel fully aware of the environmental consequences of operation problems and trained to implement timely and proper response actions?				
1. Have all significant air emissions (point, fugitive and secondary) been identified and described with respect to quantity, composition and their ultimate treatment? (Consider start-up/shutdown and abnormal operating conditions)				
2. Do proposed air emissions contain any material classified as hazardous under Federal, State or local regulations (pay special attention to Hazardous Air Pollutants [HAPs] identified under clean Air Act Amendments)				
3. Does the project design satisfy the design objectives for both routine (continuous & intermittent) emissions and episodic air emissions? (Pay special attention to known and suspected carcinogens and acutely toxic emissions)				
4. Will proposed air emissions require Prevention of Significant Deterioration (PSD) review and/or New Source Review?				
5. Do any proposed air emission sources require new air control systems or upgrading of existing systems?				
6. Are the air pollution control systems designed to meeting application governmental technological levels and corporate requirements?				
7. Are there any air pollution control systems that have not been reviewed to assure conformation with Federal, State or local regulations?				

Environmental – Surface/Groundwater Protection	Yes	No	Other	Comments
1. Have all significant water discharges been identified and described with respect to quantity, composition and their ultimate treatment and/or disposal? (Consider start-up/shutdown and abnormal operating conditions)				
2. Do proposed wastewater discharges contain any substances on EPA's priority pollutant list?				
3. Will wastewater discharges be restricted by water quality limits of the receiving stream or by the capacity of a Publicly-Owned Treatment Works (POTW)?				
4. Does the operation handle any compounds have EPA Reportable Quantities (RQ's)?				
5. Are adequate leak/spill prevention and detection measures provided?				
6. Will secondary containment be provided for all new and modified oil and chemical handling or storage areas?				
7. Are modifications to an existing or an entirely new Spill Prevention, Control and Countermeasures (SPCC) Plan required?				
8. Will underground storage tanks be used for this project?				
9. Are there any plans to dispose of wastewater by underground injection?				
10. Do any proposed wastewater discharges require new control systems or upgrading of existing systems?				
11. Are the water pollution control systems, underground storage tanks and injection wells designed to meet applicable governmental technological and corporate requirements?				
12. Are there any containment, storage, treatment or disposal design plans that have not been reviewed to assure conformance with Federal, State or local regulations?				
Environmental – Waste Management	**Yes**	**No**	**Other**	**Comments**
1. Have all significant special wastes been identified and described with respect to quantity, composition and their ultimate treatment and/or disposal? (Consider start-up/shutdown conditions and abnormal operating conditions)				
2. Have all special waste conservation/ minimization alternatives been reviewed and used where feasible?				
3. Are the off-site locations that are managing special wastes approved in accordance with corporate policy?				
4. Has land application of special wastes been minimized to the extent possible?				
5. Are any proposed wastes classified as hazardous under Federal, State or local regulations?				
6. Will the project necessitate the storage, treatment or disposal of hazardous waste, either on-site or off-site?				
7. Are the hazardous waste storage, treatment and disposal systems designed to meet applicable governmental technological levels and corporate requirements?				
8. Are there any storage, treatment or disposal design plans that have not been reviewed to assure conformance with Federal, State or local regulations?				
Environmental – Compliance/Permits	**Yes**	**No**	**Other**	**Comments**
1. If the project is associated with an existing facility, has the facility experienced any incidents of non-compliance with air,				

wastewater, storm water, solid/hazardous waste permits or regulations, or received any pollution-related citizen complaints in the past 12 months that may affect the project? Describe impact.				
2. Are there any Compliance Orders or other legal actions that may affect the project? Describe impact.				
3. Will the predicted air and water discharges from operation of the completed project comply with all applicable governmental rules? List significant applicable regulations?				
4. Will the planned storage, treatment and disposal of hazardous wastes comply with all applicable governmental rules? List significant applicable regulations?				
5. Have all required air, wastewater, storm water and solid/hazardous waste permits and permit modifications been identified? List new permits/modifications needed.				
6. Are there any other environmental permits needed or which require modification (example: underground storage tanks, Corps of Engineers, wetlands...)? List new permits/modifications needed.				
7. Are any delays in construction or operations start-up likely due to permitting or other regulatory requirements?				
Environmental – Site Condition	**Yes**	**No**	**Other**	**Comments**
1. Is background air quality monitoring data available for the past 12 months at the project site?				
2. If there are proposed wastewater or storm water discharges to surface water, is background water quality data available?				
3. Is the proposed project site to be located within ½ mile of any existing or potential surface or underground source of drinking water?				
4. Is there presently any known or suspected soil and/or groundwater contamination at the project site?				
5. Are there any active waste storage, treatment or disposal facilities located on the project site?				
6. Are there ongoing or past site investigations and/or remedial actions for present and/or past solid waste units that pose (d) a significant threat of release of hazardous constituents to the environment at the project site?				
7. Is there any material containing polychlorinated biphenyl (PCBs) located on the project site?				
8. Are underground tanks located on the project site?				
9. Does the project site contain US Coast Guard designated wetlands?				
Reviewer: .... Date:...........................				

Safety & Health				
Safety & Health - General	**Yes**	**No**	**Other**	**Comments**
1. Will toxic, flammable, corrosive or otherwise hazardous substances be transported, stored, processed or produced in facilities affected by this project?				
2. Will high noise levels (85 dBA and higher), radiation sources, heat stress, repetitive motion, or other new or unusual physical hazards be introduced by this project?				
3. Could any of the substances handled in facilities affected by this project cause an explosion if heated, contaminated, concentrated or otherwise mishandled?				
4. Is all necessary safety and health data known for each substance handled? (Include isolated intermediates)				
5. Do up-to-date Material Safety Data Sheets exist for each substance handled? (Include any stream or mixture handled or stored)				
6. Will this project introduce new chemicals that are highly reactive with other chemicals already handled at the location?				
7. Is there potential for mixing of incompatible chemicals in process, storage or waste disposal areas (in/outside boundaries) of this facility?				
8. Are operational safety standards required, and will they be prepared before startup?				
9. Are inventories of hazardous or toxic materials minimized?				
Safety & Health – Compliance	**Yes**	**No**	**Other**	**Comments**
1. Will any new safety or health programs be required to meet regulations?				
2. Have all Department of Transportation (or equivalent) requirements been identified for substances that will be shipped either to or from the plant location?				
3. Are there any proposed changes to safety and health regulations that could affect design or operation of project or facilities?				
4. Will the following be required to comply with safety and health regulations:				
a. Monitoring of employee exposure?				
b. Ventilation, noise suppression or other engineering controls?				
c. Special personal protective equipment?				
d. Special medical examinations or a medical surveillance program?				
e. Special operating or maintenance procedures?				
f. Regulated areas?				
5. Will employees need supplemental training beyond normal corporate or business programs to assure safe operation?				
6. Do any State or local regulations supersede Federal safety and health regulations?				
7. Are all chemicals that will be handled included in the governing chemical control law (TSCA in US) inventory or equivalent (including isolated intermediates)?				
8. Will this project involve installation or removal of asbestos or polychlorinated biphenyl (PCB) materials?				
9. Are new occupied buildings or expansions of existing				

occupied buildings planned?				
10. Will occupied buildings be affected by process changes that:				
a. Decrease the separation distance?				
b. Increase the hazard classification?				
c. Significantly increase the risk above current level (i.e., process complexity)?				
11. Will contractors be used for on-site work?				
Safety & Health – Public Impact	**Yes**	**No**	**Other**	**Comments**
1. Will emergency relief devices that protect facilities be affected by this project discharge directly to the atmosphere?				
2. Could releases from the emergency relief devices that discharge directly to the atmosphere have an adverse impact on the health or safety of the public?				
3. Could a process upset or other emergency situation (fire, explosion, spill, etc.) occur in the project facilities that could have an adverse impact on the public?				
4. In the event of the release of toxic chemicals from facilities affected by this project, would existing or planned monitoring, detection, and/or alarm systems be adequate?				
Safety & Health – Facility Design	**Yes**	**No**	**Other**	**Comments**
1. Will extremes of temperature or pressure (i.e., temperatures above 400°C or pressures above 500 psig) exist in facilities affected by this project?				
2. Will there be any new ignition sources associated with this project?				
3. Will recognized industry practices be followed in the layout of the facility?				
4. Will the pressure vessels, storage tanks, safety valves, piping, values and fittings that are part of the project facilities conform to applicable industry codes and standards and Federal, State and local laws and regulations?				
5. Will all normal project safety and health reviews be performed?				
6. Is there a need for a Process Hazard Analysis (PHA) of the facilities?				
7. Could the loss of any utility that supplies project facilities create a possible hazardous substance?				
8. Will flammable gas detectors be installed as part of this project?				
9. For facilities affected by this project, is any reaction sufficiently exothermic to result in a runaway reaction under any operating conditions that could occur?				
10. Does this project introduce a new process or incorporate process technology new to this location?				
11. Are process monitoring and control devices adequate to prevent upsets leading to hazardous operation or toxic releases?				
12. Would increased use of automation or advanced process control effectively reduce the risks of employee exposure?				
13. Will water spray protection be provided for processing, storage and distribution areas in accordance with corporate criteria?				
14. Are fire water supplies and distribution systems adequate to provide sufficient fire water to this facility?				

15. Could this project adversely impact on or be impacted by other facilities?				
16. Were there any areas considered for inherent safety that were rejected?				
17. Were there areas where inherent safety was incorporated? (If yes, where?)				
18. Have seismic zones been considered and appropriate design requirements used?				
19. Are considerations of ergonomic principles included in the facility and process design?				
Safety & Health – Emergency Response	**Yes**	**No**	**Other**	**Comments**
1. Will additional fire and emergency response equipment, personnel or procedures be required as a result of this project?				
2. Will any changes to the location's Community Emergency Response Plan (evacuation, etc.) be required as a result of this project?				
Safety & Health – ERMS Compliance	**Yes**	**No**	**Other**	**Comments**
1. Will this project change the ERMS Hazard Ranking Model (HRM) data?				
2. Has a consequence or other type analysis been conducted to evaluate potential for off-site fatality events?				
3. Have there been prior Risk Reviews done for this facility?				
4. Is a Risk Review required for this project (e.g., does off-site fatality potential exist?				
5. Have all scenarios identified by a Risk Review or Third Tier Study been mitigated as required by ERMS?				
Reviewer: .... **Date:**...........................				

E& H Screening Checklist				
Product Safety – General	**Yes**	**No**	**Other**	**Comments**
1. Will any of the products from this facility be marketed as a consumer product?				
2. Will any of the products be used as an intermediate by this corporation or others to formulate a product that will be marketed as a consumer product?				
3. Are any of the products intended for use in the manufacture of food, drugs or their packaging materials?				
4. Are any of the products classified by the Food and Drug Administration as medical devices?				
5. Are any of the products subject to regulation under:				
a. Federal Insecticide, Fungicide, Rodenticide Act (FIFRA)				
b. Toxic Substances Control Act (TSCA)				
c. Consumer Product Safety Commission				
d. Federal Food, Drug and Cosmetic Act				
6. Are any of the product classified as toxic, explosive, flammable or otherwise hazardous?				
7. Can any product harm persons or property in normal use or any potential misuse?				
8. Does the product, or any component in the product, appear on any listing of chemicals requiring customer, employee or public notification?				

Product Safety – Design	Yes	No	Other	Comments
1. Has the product undergone a product safety risk analysis to evaluate downstream exposure/health risk potential?				
2. Are any Premanufacture Notifications necessary for any of the products or intermediates?				
3. Does any product require certification or testing by Federal, State or local governmental agencies?				
4. Does any product require testing or approval by a nationally recognized testing agency?				
5. Will this project introduce new contaminants, increase existing hazardous contaminant level, or otherwise increase the hazardous nature of the product?				
6. Is this a new or modified product, or a product directed toward a new market?				
Product Safety – Distribution	**Yes**	**No**	**Other**	**Comments**
1. Will distribution cause new or additional public exposure to this product?				
2. Have all regulatory requirements for shipping the products been identified?				
3. Has all labeling and Material Safety Data Sheet data been obtained for all products?				
4. Will any special handling, storage or shipping equipment or procedures be required for any of the product?				
Product Safety – Image	**Yes**	**No**	**Other**	**Comments**
1. Is there any history of product liability with any of these products or similar products?				
2. Could any of the products be viewed by the public or regulatory agencies as presenting an unacceptable risk to health, safety or the environment?				
3. Will communication with any regulatory agency be required regarding the safety of any of the products?				
Reviewer:	**Date:............................**			

Canter & Kamath's Generic Questionnaire Checklist for Addressing and/or Summarizing the Cumulative Environmental Impacts of Projects

Environmental Category	Will the project result in.... Yes/Maybe/No Comments	Will the cumulative impacts of the project result in.... Yes/Maybe/No Comments
Physical Environmental Indicators • Fractures on geologic strata? • Landslides and landsubsidence? • Seismic activity? • Compaction and settling? • Deposition (sedimentation, precipitation)? • Erosion of soils due to increased wind, floods, removal of vegetation? • Impact to unique physical features (due to destruction, modification or covering)? • Impact to land classified as prime or unique farmland? • Change existing topography (ground contours, shorelines, river banks)? • Extensive use of existing mineral resources (mining, oil and gas)? • Disposal of construction debris? • Excessive fields and radiation (magnetic fields, electromagnetic radiation)? • Changes in hydrology (water table, gradient, infiltration)?		
Air/Climatology • Impact on air quality due to gases, particulates and fugitive dusts? • Air pollutant emissions which will exceed federal or state standards or cause deterioration of ambient air quality? • Objectionable odors? • Changes in climate due to alteration in humidity, air movement or temperature? • Emissions of hazardous air pollutants (VOCs, SOGs and other toxic regulated under the Clean Air Act)? • Acid rain?		
Water • Changes in the quality and quantity of surface water? • Discharge of wastewater to potable drinking		

water systems? • Alter flows due to construction? • Increase tendency to flooding? • Salinate water bodies? • Unsightly appearance of water bodies? • Eutrophication ? • Increase in temperature and turbidity due to impoundment? • Destruction of streams? • Considerable effects on conventional water quality parameters (that is, DO, fecal coliforms, pH, BODs, NO_3, PO_4, temperature deviation, turbidity, total solids)? • Alter the rate or direction of ground water flow? • Alter the quantity and quality of ground water? • Introduce pollutants to ground water due to land application of waste? • Contamination of public water supplies? • Impact to recharge area or recharge rate? • Make ground water vulnerable to contamination (due to wells, boreholes, cracks, etc)? • Impact on or construction in wetland or inland floodplain? • Thawing snow, ice and permafrost? • Impact to wellhead protection zone? • Impact on fisheries?		
Solid Waste • Generation of significant solid waste? • Impact existing landfill capacity?		
Noise • Increase existing noise levels? • Expose people or wildlife to excessive noise? • Vibrations?		
Hazardous Waste • Generation, transport, storage or disposal of regulated hazardous waste?		
Biological environment flora • Change to the diversity or productivity of vegetation (namely trees, shrubs, grass, crop, microflora and aquatic plants)? • Impact to riparian habitat? • Impact to rare or endangered plant species? • Introduce new plant species into area or		

create a barrier to the normal replenishment of existing species? • Reduce acreage or create damage to any agricultural crop? • Impact forests?		
Fauna • Reduce the habitat or numbers of unique, rare or endangered species of birds or animals? • Affect to land animals, benthic organisms, insects and microfauna? • Attraction, entrapment or impingement of animal life? • Impact to existing fish, wildlife habitat, and nesting areas? • Introduction of new species of animals into an area or create a barrier to the migration of movement of animals or fish? • Cause emigration resulting in human-wildlife interaction problems? • Affect to food chain?		
Socioeconomic environment landuse • Substantial altering existing or proposed land use of an area? • Impacts to wilderness qualities and open-space qualities? • Impact to destruction of wetlands? • Impact to Special Management Areas (SMAs)?		
Recreation • Impact to hunting, fishing, boating, swimming, camping and hiking, picnicking and holiday resorts?		
Aesthetics • Impact to scenic views and vistas? • Impact to landscape design? • Impact to unique physical features? • Impact to parklands and reserves? • Impact on monuments? • Presence of misfits (out of place)?		
Archaeological sites • Impact to or destruction of historical, archaeological, cultural and paleontological sites or objects?		
Health and safety • Health hazards or potential health hazards? • Exposure of people to potential health		

hazards? • Risk of accidents due to explosion, release of oil, radioactive materials, toxic substances, etc.?		
Cultural patterns • Change existing cultural patterns (or life style)?		
Local services Need for new or altered services in any of the following areas: • Health care? • Police? • Fire protection? • Education? • Churches? • Child care? • Other services?		
Public utilities Need for a new or alterations to the following utilities: • Electricity? • Natural gas? • Potable water? • Wastewater treatment and disposal? • Stormwater control? • Solid waste collection and disposal? • Communication system? • Transmission pipelines? • Other utilities?		
Population • Alteration of location or distribution of human population in the area? • Change to demographic characteristics in the area? • Change to housing and households?		
Economic • Adverse effect on local or regional economy? • Changes in per capita income? • Changes in the standard of living> • Employment?		
Transportation • Change to existing rail, road, waterway and/or air traffic? • Increase in movement? • Increase in accident and traffic hazards? • Affect to transportation network? • Construction of new roads?		

• Change in existing patterns of movement of men and materials?		
Natural resources • Deplete natural resources? • Destruction of natural resources?		
Energy • Substantial use of fuel or energy? • Increase in demand for existing sources of energy?		
Note: Due consideration has to be given to the time and space scales. The project may have short-term or long-term impacts, and the geographical extent of the impacts may be either the vicinity of the project or considerable distances away.		

Source: Canter & Kamath, 1995.

APPENDIX G:

Scoring Guidelines for Environmental Evaluation Matrix Tool

Construction (Gate 1)

C1,1
Life Stage: Construction: Supply Processes
Environmental Factor: Water

In order to determine the rating answer the following question:

	Yes	No
Will the supply processes have an impact on water quantity and/or water quality?	5	1

If the supply processes do have an environmental impact on water resources, the matrix element is 5. As an example, one of the following conditions may be applicable for the evaluated system:

- The extraction of raw material creates residues with high water pollution potential (see Water Resource Table for information) to the ambient environment.
- The packaging of raw material that enters the construction site contains toxic or hazardous substances that might leak from it if improper disposal occurs.
- Acids are required during the ore extraction of virgin materials.

C1,2
Life Stage: Construction: Supply Processes
Environmental Factor: Air

In order to determine the rating answer the following question:

	Yes	No
Will the supply processes have an impact on regional air quality and/or global conditions?	5	1

If the supply processes do have an environmental impact on air resources, the matrix element is 5. As an example, one of the following conditions may be applicable for the evaluated system:

- The materials used cause substantial emissions of toxic, smog-producing or greenhouse gases into the environment and suitable alternatives that do not do so are available.
- Resources (raw material, consumables etc) are manufactured or extracted by processes generating residues with air pollution potentials.

C1,3
Life Stage: Construction: Supply Processes
Environmental Factor: Land

In order to determine the rating answer the following question:

	Yes	No
Will the supply processes have an impact on land quality and/or land quantity?	5	1

If the supply processes do have an environmental impact on land resources, the matrix element is 5. As an example, one of the following conditions may be applicable for the evaluated system:

- The extraction of raw material creates substantial toxic solid and/or liquid residues.
- Large amounts of the raw material required for the construction phase is restricted, toxic and/or radioactive.
- Acids are required during the ore extraction of virgin materials.

C1,4
Life Stage: Construction: Supply Processes
Environmental Factor: Mined Resources

In order to determine the rating answer the following question:

	Yes	No
Will the supply processes have an impact on mineral and/or energy resources?	5	1

If the supply processes do have an environmental impact on Mined Resources, the matrix element is 5. As an example, one of the following conditions may be applicable for the evaluated system:

- A scarce material is used where a reasonable alternative is available
- One or more of the principal materials used during the construction process requires energy-intensive extraction.
- Large quantities of scarce consumables are used in the construction process
- All incoming packaging is from virgin sources and consists of three or more type of materials

C2,1
Life Stage: Construction: Site Selection & Development
Environmental Factor: Water

In order to determine the rating answer the following question:

	Yes	No
Will the site selection and development have an impact on water quantity and/or water quality?	5	1

If the site selection and development does have an environmental impact on water resources, the matrix element is 5. As an example, the following condition may be applicable for the evaluated system:

- The site is developed with any disturbance of river flows and/or groundwater sources.
- Toxic residues result from the development and are not recycled but discharged into the water system.

C2,2
Life Stage: Construction: Site Selection & Development
Environmental Factor: Air

In order to determine the rating answer the following question:

	Yes	No
Will the site selection and development have an impact on regional air quality and/or global conditions?	5	0

If the site selection and development does have an environmental impact on air resources, the matrix element is 5. As an example, the following condition may be applicable for the evaluated system:

- Toxic residues (gaseous and/or solid) are generated during site development and no recycling is practiced.

C2,3
Life Stage: Construction: Site Selection & Development
Environmental Factor: Land

In order to determine the rating answer the following question:

	Yes	No
Will the site selection and development have an impact on land quality and/or land quantity?	5	1

If the site selection and development does have an environmental impact on land resources, the matrix element is 5. As an example, the following condition may be applicable for the evaluated system:

- The site is developed with massive disturbance or any destruction of natural areas.
- Toxic residues or large quantities of solid residues are generated during site development and no recycling is practiced.

C2,4
Life Stage: Construction: Site Selection & Development
Environmental Factor: Mined Resources

In order to determine the rating answer the following question:

	Yes	No
Will the site selection and development have an impact on mineral and/or energy resources?	5	1

If the site selection and development does have an environmental impact on Mined Resources, the matrix element is 5. As an example, the following condition may be applicable for the evaluated system:

- A complete new energy infrastructure is installed during site development.
- Energy use for construction is high and less energy-intensive alternatives are available.

Operation (Gate 1)

O1,1
Life Stage: Operation: Supply Processes
Environmental Factor: Water

In order to determine the rating answer the following question:

	Yes	No
Will the supply processes have an impact on water quantity and/or water quality?	5	1

If the supply processes do have an environmental impact on water resources, the matrix element is 5. As an example, one of the following conditions may be applicable for the evaluated system:

- The extraction of raw material creates residues with high water pollution potential (see Water Resource Table for information) to the ambient environment.
- The packaging of raw material that enters the plant contains toxic or hazardous substances that might leak from it if improper disposal occurs.
- Acids are required during the ore extraction of virgin materials.

O1,2
Life Stage: Operation: Supply Processes
Environmental Factor: Air

In order to determine the rating answer the following question:

	Yes	No
Will the supply processes have an impact on regional air quality and/or global conditions?	5	1

If the supply processes do have an environmental impact on air resources, the matrix element is 5. As an example, one of the following conditions may be applicable for the evaluated system:

- The materials used cause substantial emissions of toxic, smog-producing or greenhouse gases into the environment and suitable alternatives that do not do so are available.
- Resources (raw material, consumables etc) are manufactured or extracted by processes generating residues with air pollution potentials.

O1,3
Life Stage: Operation: Supply Processes
Environmental Factor: Land

In order to determine the rating answer the following question:

	Yes	No
Will the supply processes have an impact on land quality and/or land quantity?	5	1

If the supply processes do have an environmental impact on land resources, the matrix element is 5. As an example, one of the following conditions may be applicable for the evaluated system:

- The extraction of raw material creates substantial toxic solid and/or liquid residues.
- Large amounts of the raw material required for the operation phase is restricted, toxic and/or radioactive.
- Acids are required during the ore extraction of virgin materials.

O1,4
Life Stage: Operation: Supply Processes
Environmental Factor: Mined Resources

In order to determine the rating answer the following question:

	Yes	No
Will the supply processes have an impact on mineral and/or energy resources?	5	1

If the supply processes do have an environmental impact on Mined Resources, the matrix element is 5. As an example, one of the following conditions may be applicable for the evaluated system:

- A scarce material is used where a reasonable alternative is available
- One or more of the principal materials used during the operational process requires energy-intensive extraction.
- Large quantities of scarce consumables are used in the primary and/or complementary process
- All incoming or outgoing packaging is from virgin sources and consists of three or more type of materials

O2,1
Life Stage: Operation: Primary Process
Environmental Factor: Water
In order to determine the rating answer the following question:

	Yes	No
Will the primary process have an impact on water quantity and/or water quality?	5	1

If the primary process does have an environmental impact on water resources, the matrix element is 5. As an example, the following condition may be applicable for the evaluated system:

- Toxic residues (liquid/gaseous/solid) result from the primary process and are not recycled or reused but discharged into the water system.

O2,2
Life Stage: Operation: Primary Process
Environmental Factor: Air
In order to determine the rating answer the following question:

	Yes	No
Will the primary process have an impact on regional air quality and/or global conditions?	5	1

If the primary process does have an environmental impact on air resources, the matrix element is 5. As an example, the following condition may be applicable for the evaluated system:

- Toxic gaseous and/or solid residues result from the primary process and are not recycled or reused but discharged into the ecosystem.

O2,3
Life Stage: Operation: Primary Process
Environmental Factor: Land
In order to determine the rating answer the following question:

	Yes	No
Will the primary process have an impact on land quality and/or land quantity?	5	1

If the primary process does have an environmental impact on land resources, the matrix element is 5. As an example, the following condition may be applicable for the evaluated system:

- Toxic or radioactive of solid and/or liquid residues result from the primary process.

O2,4
Life Stage: Operation: Primary Process
Environmental Factor: Mined Resources
In order to determine the rating answer the following question:

	Yes	No
Will the primary process have an impact on mineral and/or energy resources?	5	1

If the primary process does have an environmental impact on Mined Resources, the matrix element is 5. As an example, the following condition may be applicable for the evaluated system:

- Energy use in the primary process is very high

O3,1
Life Stage: Operation: Complementary Processes
Environmental Factor: Water
In order to determine the rating answer the following question:

	Yes	No
Will the complementary processes have an impact on water quantity and/or water quality?	5	1

If the complementary processes do have an environmental impact on water resources, the matrix element is 5. As an example, the following condition may be applicable for the evaluated system:

- Toxic residues (liquid/gaseous/solid) result from the complementary processes and are not recycled or reused but discharged into the water system.

O3,2
Life Stage: Operation: Complementary Processes
Environmental Factor: Air
In order to determine the rating answer the following question:

	Yes	No
Will the complementary processes have an impact on regional air quality and/or global conditions?	5	1

If the complementary processes do have an environmental impact on air resources, the matrix element is 5. As an example, the following condition may be applicable for the evaluated system:

- Toxic gaseous and/or solid residues result from the complementary processes and are not recycled or reused but discharged into the ecosystem.

O3,3
Life Stage: Operation: Complementary Processes
Environmental Factor: Land
In order to determine the rating answer the following question:

	Yes	No
Will the complementary processes have an impact on land quality and/or land quantity?	5	1

If the complementary processes do have an environmental impact on land resources, the matrix element is 5. As an example, the following condition may be applicable for the evaluated system:

- Toxic or radioactive of solid and/or liquid residues result from the complementary processes.

O3,4
Life Stage: Operation: Complementary Processes
Environmental Factor: Mined Resources
In order to determine the rating answer the following question:

	Yes	No
Will the complementary processes have an impact on mineral and/or energy resources?	5	1

If the complementary processes do have an environmental impact on Mined Resources, the matrix element is 5. As an example, the following condition may be applicable for the evaluated system:

- Energy use in the complementary processes is very high

O4,1
Life Stage: Operation: Products
Environmental Factor: Water
In order to determine the rating answer the following question:

	Yes	No
Will the products have an impact on water quantity and/or water quality?	5	1

If the products do have an environmental impact on water resources, the matrix element is 5. As an example, the following condition may be applicable for the evaluated system:

- Product generates a significant quantity of hazardous/toxic residues that have an impact on water during use or disposal.

O4,2
Life Stage: Operation: Products
Environmental Factor: Air
In order to determine the rating answer the following question:

	Yes	No
Will the products have an impact on regional air quality and/or global conditions?	5	1

If the products do have an environmental impact on air resources, the matrix element is 5. As an example, the following condition may be applicable for the evaluated system:

- Product generates a significant quantity of hazardous/toxic residues that have an impact on air during use or disposal.

O4,3
Life Stage: Operation: Products
Environmental Factor: Land

In order to determine the rating answer the following question:

	Yes	No
Will the products have an impact on land quality and/or land quantity?	5	1

If the products do have an environmental impact on land resources, the matrix element is 5. As an example, one of the following conditions may be applicable for the evaluated system:

- Product generates a significant quantity of hazardous/toxic residues during use.
- Product contains significant quantities of mercury, asbestos or cadmium that are not clearly identified and easily removable.

O4,4
Life Stage: Operation: Products
Environmental Factor: Mined Resources

In order to determine the rating answer the following question:

	Yes	No
Will the products have an impact on mineral and/or energy resources?	5	1

If the products do have an environmental impact on Mined Resources, the matrix element is 5. As an example, one of the following conditions may be applicable for the evaluated system:

- Product use and/or maintenance are energy intensive.
- Consumables used during product use or maintenance contains significant quantities of materials in restricted supply or toxic/hazardous substances.
- Recycling/Disposal of this product is relatively energy intensive due to its weight, construction and/or complexity.

Decommissioning (Gate 1)

D1,1
Life Stage: Decommissioning: Supply Processes
Environmental Factor: Water

In order to determine the rating answer the following question:

	Yes	No
Will the supply processes have an impact on water quantity and/or water quality?	5	1

If the supply processes do have an environmental impact on water resources, the matrix element is 5. As an example, one of the following conditions may be applicable for the evaluated system:

- The packaging contains toxic or hazardous substances that might leak from it if improper disposal occurs.
- The extraction of raw material creates residues with high water pollution potential (see Water Resource Table for information) to the ambient environment.

D1,2
Life Stage: Decommissioning: Supply Processes
Environmental Factor: Air

In order to determine the rating answer the following question:

	Yes	No
Will the supply processes have an impact on regional air quality and/or global conditions?	5	1

If the supply processes do have an environmental impact on air resources, the matrix element is 5. As an example, one of the following conditions may be applicable for the evaluated system:

- The materials used cause substantial emissions of toxic, smog-producing or greenhouse gases into the environment and suitable alternatives that do not do so are available.
- Resources (raw material, consumables etc) are manufactured or extracted by processes generating residues with air pollution potentials.

D1,3
Life Stage: Decommissioning: Supply Processes
Environmental Factor: Land

In order to determine the rating answer the following question:

	Yes	No
Will the supply processes have an impact on land quality and/or land quantity?	5	1

If the supply processes do have an environmental impact on land resources, the matrix element is 5. As an example, one of the following conditions may be applicable for the evaluated system:

- The extraction of raw material creates substantial toxic solid and/or liquid residues.
- Large amounts of the raw material required for the construction phase is restricted, toxic and/or radioactive.
- Acids are required during the ore extraction of virgin materials.

D1,4
Life Stage: Decommissioning: Supply Processes
Environmental Factor: Mined Resources

In order to determine the rating answer the following question:

	Yes	No
Will the supply processes have an impact on mineral and/or energy resources?	5	1

If the supply processes do have an environmental impact on Mined Resources, the matrix element is 5. As an example, one of the following conditions may be applicable for the evaluated system:

- A scarce material is used where a reasonable alternative is available
- One or more of the principal materials used during the construction process requires energy-intensive extraction.
- Large quantities of scarce consumables are used in the construction process

- All incoming packaging is from virgin sources and consists of three or more type of materials

D2,1
Life Stage: Decommissioning: Process Implementation
Environmental Factor: Water

In order to determine the rating answer the following question:

	Yes	No
Will the process implementation have an impact on water quantity and/or water quality?	5	1

If the process implementation does have an environmental impact on water resources, the matrix element is 5. As an example, the following condition may be applicable for the evaluated system:

- Process equipment contains primarily unrecyclable materials with high water pollution potential.
- Large amounts residues with high water pollution potential will be produced by facility closure.

D2,2
Life Stage: Decommissioning: Process Implementation
Environmental Factor: Air

In order to determine the rating answer the following question:

	Yes	No
Will the process implementation have an impact on regional air quality and/or global conditions?	5	1

If the process implementation does have an environmental impact on air resources, the matrix element is 5. As an example, the following condition may be applicable for the evaluated system:

- Process equipment contains or produces primarily unrecyclable gaseous material that is dissipated to the atmosphere at the end of its life.
- Large amounts residues with high air pollution potential will be produced by facility closure.

D2,3
Life Stage: Decommissioning: Process Implementation
Environmental Factor: Land

In order to determine the rating answer the following question:

	Yes	No
Will the process implementation have an impact on land quality and/or land quantity?	5	1

If the process implementation does have an environmental impact on land resources, the matrix element is 5. As an example, the following condition may be applicable for the evaluated system:

- Large amounts of solid residues that cannot be recycled will be produced by facility closure

- Site structure must be completely demolished with major impacts on natural areas or existing ecosystems.
- Process equipment contains primarily unrecyclable materials with a land impact potential

D2,4
Life Stage: Decommissioning: Process Implementation
Environmental Factor: Mined Resources

In order to determine the rating answer the following question:

	Yes	No
Will the site process implementation have an impact on mineral and/or energy resources?	5	1

If the process implementation does have an environmental impact on Mined Resources, the matrix element is 5. As an example, the following condition may be applicable for the evaluated system:

- Recycling/Disposal of this process facility is relatively energy intensive due to its weight, construction and/or complexity

Construction (GATE 2)

C1,1
Life Stage: Construction: Supply Processes
Environmental Factor: Water

If the supply processes do have a significant environmental impact on water resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Does the process use materials or energy whose extraction, purification or conversion involves the generation of residues with end effects on water resources (water pollution potential)? (See Water Resource Table attached for potential causes of water pollution)	2	0
Will the transport of material to the facility result in significant residues with the potential to pollute ambient water?	1	0
Is water used to extract, clean or transform supplied components or materials?	1	0
Do the construction processes require supplied water?	1	0

C1,2
Life Stage: Construction: Supply Processes
Environmental Factor: Air

If the supply processes do have a significant environmental impact on air, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Does the process use materials or energy whose extraction, purification or conversion involves the generation of residues with air pollution potential? (See Air Resource Table attached for potential causes of air pollution)	2	0
Will the transport of material to the facility result in significant residues with the potential to pollute air?	1	0
Are any proposed materials ozone-depleting substances or global-warming substances?	1	0
Is any proposed material or energy source a substance with an air pollution potential (e.g. mercury)?	1	0

C1,3
Life Stage: Construction: Supply Processes
Environmental Factor: Land

If the supply processes do have a significant environmental impact on land resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Does the process use materials or energy whose extraction or purification or conversion involves the generation of residues with land impact potential? (See Land Resource Table attached for potential causes of land impacts)	2	0
Will the transport of material to the facility result in significant residues with the potential to have an impact on land?	1	0

Are any proposed materials toxic and/or radioactive in nature?	1	0
Have raw material and part suppliers been contacted to encourage them to minimize the amounts and types of packaging material that enters the facility?	1	0

C1,4

Life Stage: Construction: Supply Processes
Environmental Factor: Mined Resources

If the supply processes do have a significant environmental impact on Mined Resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Are any proposed materials or energy sources in restricted supply or are they likely to become over the process's life cycle?	3	0
Have raw material and part suppliers been contacted to encourage them to minimize the amounts and types of packaging material that enters the facility?	0	2

C2,1

Life Stage: Construction: Site Selection & Development
Environmental Factor: Water

If the site selection and development do have a significant environmental impact on water resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Is the construction process designed to avoid the use of water?	0	1
Is the construction process designed to minimize the use of materials and energy whose extraction, purification or conversion involves the generation of residues with water pollution potential and have alternatives been investigated?	0	1
Is the site such that it can be made operational with only minimal production of residues with high water pollution potential (see Water Resource Table)?	0	1
Is necessary development activity, if any, planned that will cause a disturbances of riverflows?	1	0
Do the residues from the construction process have water pollution potential?	1	0

C2,2

Life Stage: Construction: Site Selection & Development
Environmental Factor: Air

If the site selection and development do have a significant environmental impact on air resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Are the site selection and development designed to avoid the use of materials and energy with air pollution potential? (see the Air Resource Table for potential causes of air pollution	0	1
Are the construction process designed to avoid or minimize the generation of residues with air pollution potential? (see Air Resource Table)	0	1

Do the residues from the construction processes have air pollution potential?	2	0
Is the site such that it can be made operational with only minimal production of residues with high air pollution potential (see Air Resource Table)?	0	1

C2,3

Life Stage: Construction: Site Selection & Development
Environmental Factor: Land

If the site selection and development do have a significant environmental impact on land resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Are the site selection and development designed to avoid the use of materials and energy with land impact potential? (see the Land Resource Table for potential causes of land impacts)	0	1
Are the site selection and development designed to minimize the generation of residues with land impact potential? (See Land Resource Table attached	0	1
Do the residues from the construction processes have the potential to impact land resources?	1	0
Is necessary development activity, if any, planned to avoid disruption of existing biological communities?	0	0.5
Can all areas that are disturbed during site development be carefully restored?	0	0.5
Is the biota of the site compatible with all planned facility emissions, including possible exceedances?	0	1

C2,4

Life Stage: Construction: Site Selection & Development
Environmental Factor: Mined Resources

If the site selection and development do have a significant environmental impact on Mined Resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Are the construction process designed to minimize the use of energy-intensive process steps, especially process steps that require non-renewable energy sources, and to utilize otherwise wasted energy?	0	1
Are the construction process designed in such a way as to minimize the use of any non-renewable mineral resources?	0	2
Is energy-intensive product transportation avoided or minimized?	0	1
Are arrangements made to take back product packaging for reuse or recycling?	0	1

Operation (GATE 2)

O1,1

Life Stage: Operation: Supply Processes
Environmental Factor: Water

If the supply processes do have a significant environmental impact on water resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Does the process use materials or energy whose extraction, purification or conversion involves the generation of residues with end effects on water resources (water pollution potential)? (See Water Resource Table attached for potential causes of water pollution)	2	0
Will the transport of material to the facility result in significant residues with the potential to pollute ambient water?	1	0
Is water used to extract, clean or transform supplied components or materials?	1	0
Do the primary and complementary processes require supplied water?	1	0

O1,2

Life Stage: Operation: Supply Processes

Environmental Factor: Air

If the supply processes do have a significant environmental impact on air, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Does the process use materials or energy whose extraction, purification or conversion involves the generation of residues with air pollution potential? (See Air Resource Table attached for potential causes of air pollution)	2	0
Will the transport of material to the facility result in significant residues with the potential to pollute air?	1	0
Are any proposed materials ozone-depleting substances or global-warming substances?	1	0
Is any proposed material or energy source a substance with an air pollution potential (e.g. mercury)?	1	0

O1,3

Life Stage: Operation: Supply Processes

Environmental Factor: Land

If the supply processes do have a significant environmental impact on land resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Does the process use materials or energy whose extraction or purification or conversion involves the generation of residues with land impact potential? (See Land Resource Table attached for potential causes of land impacts)	2	0
Will the transport of material to the facility result in significant residues with the potential to have an impact on land?	1	0
Are any proposed materials toxic and/or radioactive in nature?	1	0
Have raw material and part suppliers been contacted to encourage them to minimize the amounts and types of packaging material that enters the facility?	0	1

O1,4
Life Stage: Operation: Supply Processes
Environmental Factor: Mined Resources

If the supply processes do have a significant environmental impact on Mined Resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Are any proposed materials or energy sources in restricted supply or are they likely to become over the process's life cycle?	3	0
Are recyclable material used in the transport and retail packaging?	0	2

O2,1
Life Stage: Operation: Primary Process
Environmental Factor: Water

If the primary processes do have a significant environmental impact on water resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Is the primary process designed to avoid the use of water?	0	2
Is the primary process designed to avoid or minimize the generation of residues with an end effect on water resources (water pollution potential)? (see Water Resource Table for potential causes of water pollution)	0	1
Is the process designed to minimize the use of materials and energy whose extraction, purification or conversion involves the generation of residues with water pollution potential and have alternatives been investigated?	0	1
Is the use of material whose transport to the facility will result in significant residues with the potential to pollute ambient water avoided or minimized ?	0	1

O2,2
Life Stage: Operation: Primary Process
Environmental Factor: Air

If the primary processes do have a significant environmental impact on air resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Is the primary process designed to avoid the use of materials with air pollution potential?	0	1
Is the primary process designed to avoid or minimize the generation of residues with air pollution potential? (see Air Resource Table for potential causes of air pollution)	0	2
Is the process designed to minimize the use of materials whose extraction, purification or conversion involves the generation of residues with air pollution potential? (see Air Resource Table)	0	1
Is the use of material whose transport to the facility will result in significant residues with the potential to pollute air avoided or minimized?	0	1

O2,3
Life Stage: Operation: Primary Process
Environmental Factor: Land

If the primary processes do have a significant environmental impact on land resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Is the primary process designed to avoid the use of materials with land impact potential?	0	1
Is the process designed to minimize the use of materials whose extraction, purification or conversion involves the generation of residues with land impact potential? (See Land Resource Table attached for potential causes of land impacts)	0	2
Is the use of material whose transport to the facility will result in significant residues with the potential to have an impact on land avoided or minimized? (See Land Resource Table attached)	0	1
Is the primary process designed to minimize the generation of residues with land impact potential? (See Land Resource Table attached)	0	1

O2,4
Life Stage: Operation: Primary Process
Environmental Factor: Mined Resources

If the primary processes do have a significant environmental impact on Mined Resources, the matrix element is 5. In order to determine the rating complete the checklist below:

	Yes	No
Is the primary process designed to utilize recycled materials or components where possible?	0	1
Does the primary process use co-generation, heat exchange, and other techniques to utilize otherwise wasted energy?	0	2
Is the primary process designed in such a way as to minimize the use of energy intensive process steps and methods that depends on non-renewable mineral resources?	0	2

O3,1
Life Stage: Operation: Complementary Processes
Environmental Factor: Water

If the complementary processes do have a significant environmental impact on water resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Have the potential sales of residues with an end effect on water resources been considered?	0	1
Are the complementary processes designed to avoid the use of water?	0	0.5
Is the process designed to minimize the use of materials and energy whose extraction, purification or conversion involves the generation of residues with water pollution potential and have alternatives been investigated?	0	0.5
Are the complementary processes designed to avoid or minimize the generation of water pollutants? (see Water Resource Table for potential causes of water pollution)	0	1

Have maximum precautions been taken to prevent hazardous liquid spills during product storage and transportation?	0	1
Do the residues from the primary and complementary processes have water pollution potential?	1	0

O3,2
Life Stage: Operation: Complementary Processes
Environmental Factor: Air

If the complementary processes do have a significant environmental impact on air resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Have the potential sales of residues with an end effect on air resources been considered?	0	1
Are the complementary processes designed to avoid the use of materials and energy with air pollution potential? (see the Air Resource Table for potential causes of air pollution)	0	1
Are the complementary processes designed to avoid or minimize the generation of residues with air pollution potential? (see Air Resource Table)	0	1
Do the residues from the primary and complementary processes have air pollution potential?	1	0
Are product distribution plans designed to minimize residues, with air pollution potential, from transport vehicles?	0	1

O3,3
Life Stage: Operation: Complementary Processes
Environmental Factor: Land

If the complementary processes do have a significant environmental impact on land resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Have the potential sales of residues with an end effect on land resources been considered?	0	1
Are the complementary processes designed to avoid the use of materials and energy with land impact potential? (see the Land Resource Table for potential causes of land impacts)	0	1
Are the complementary processes designed to minimize the generation of residues with land impact potential? (See Land Resource Table attached	0	1
Do the residues from the primary and complementary processes have the potential to impact land resources?	1	0
Do any proposed materials or residues have potential disposal problems, i.e. a Type I or II hazardous rating?	1	0

O3,4
Life Stage: Operation: Complementary Processes
Environmental Factor: Mined Resources

If the complementary processes do have a significant environmental impact on Mined Resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Are the complementary processes designed to minimize the use of energy-intensive process steps, especially process steps that require non-renewable energy sources, and to utilize otherwise wasted energy?	0	1
Are the complementary processes designed in such a way as to minimize the use of any non-renewable mineral resources?	0	2
Is energy-intensive product transportation avoided or minimized?	0	1
Are arrangements made to take back product packaging for reuse or recycling?	0	1

O4,1

Life Stage: Operation: Products

Environmental Factor: Water

If the products do have a significant environmental impact on water resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Does the use and disposal of this product avoid the release of residues with end effects on water resources?	0	2
Does the **design** of the product minimize the releases of residues with end effects on water resources during the use and disposal phase of the product's life cycle?	0	1
Does the design of the product minimize the storage, transport and distribution requirements with consequent residues with end effects on water resources?	0	2

O4,2

Life Stage: Operation: Products

Environmental Factor: Air

If the products do have a significant environmental impact on air resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Does the use and disposal of this product avoid the release of residues with air pollution potential?	0	2
Does the **design** of the product minimize the releases of residues with air pollution potential during the use and disposal phase of the product's life cycle?	0	1
Does the design of the product minimize the storage, transport and distribution requirements with consequent residues with air pollution potential?	0	2

O4,3

Life Stage: Operation: Products

Environmental Factor: Land

If the products do have a significant environmental impact on air resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Does the use and disposal of this product avoid the release of residues with land impact potential? (see the Land Resource Table for	0	2

potential causes of land impacts)		
Does the **design** of the product minimize the releases of residues with land impact potential during the use and disposal phase of the product's life cycle?	0	1
Does the **design** of the product minimize the storage, transport and distribution requirements with consequent residues with land impact potential?	0	2

O4,4
Life Stage: Operation: Products
Environmental Factor: Mined Resources

If the products do have a significant environmental impact on Mined Resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Do the product use and disposal phases of products rely on non-renewable mineral resources i.e. input for waste treatment?	1	0
Is the product design to minimize energy use during the product use and disposal phase?	0	1
Is the product design to minimize consumable materials necessary in the product use and disposal phases?	0	1
Is the product design to minimize the use of packaging materials?	0	2

Decommissioning (GATE 2)

D1,1
Life Stage: Decommissioning: Supply Processes
Environmental Factor: Water

If the supply processes do have a significant environmental impact on water resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Does the process use materials or energy whose extraction, purification or conversion involves the generation of residues with end effects on water resources (water pollution potential)? (See Water Resource Table attached for potential causes of water pollution)	2	0
Will the transport of material to the facility result in significant residues with the potential to pollute ambient water?	1	0
Is water used to extract, clean or transform supplied components or materials?	1	0
Do the decommissioning processes require supplied water?	1	0

D1,2
Life Stage: Decommissioning: Supply Processes
Environmental Factor: Air

If the supply processes do have a significant environmental impact on air, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Does the process use materials or energy whose extraction, purification or conversion involves the generation of residues with air pollution potential? (See Air Resource Table attached for potential	2	0

causes of air pollution)		
Will the transport of material to the facility result in significant residues with the potential to pollute air?	1	0
Are any proposed materials ozone-depleting substances or global-warming substances?	1	0
Is any proposed material or energy source a substance with an air pollution potential (e.g. mercury)?	1	0

D1,3
Life Stage: Decommissioning: Supply Processes
Environmental Factor: Land

If the supply processes do have a significant environmental impact on land resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Does the process use materials or energy whose extraction or purification or conversion involves the generation of residues with land impact potential? (See Land Resource Table attached for potential causes of land impacts)	2	0
Will the transport of material to the facility result in significant residues with the potential to have an impact on land?	1	0
Are any proposed materials toxic and/or radioactive in nature?	1	0
Have raw material and part suppliers been contacted to encourage them to minimize the amounts and types of packaging material that enters the facility?	1	0

D1,4
Life Stage: Decommissioning: Supply Processes
Environmental Factor: Mined Resources

If the supply processes do have a significant environmental impact on Mined Resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Are any proposed materials or energy sources in restricted supply or are they likely to become over the process's life cycle?	2	0
Is the decommissioning process designed to utilize recycled materials or components where possible?	0	1.5
Is the decommissioning process designed in such a way as to minimize the use of any non-renewable mineral resources?	0	1.5

D2,1
Life Stage: Decommissioning: Process Implementation
Environmental Factor: Water

If the process implementation does have a significant environmental impact on water resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Is the decommissioning process designed to avoid the use of water?	0	2
Is the decommissioning process designed to minimize the use of materials and energy whose extraction, purification or conversion	0	1

involves the generation of residues with water pollution potential and have alternatives been investigated?		
Is the decommissioning process designed as such that the site can be repaired with minimal production of residues with high water pollution potential (see Water Resource Table)?	0	1
Do the residues from the decommissioning process have water pollution potential?	1	0

D2,2

Life Stage: Decommissioning: Process Implementation
Environmental Factor: Air

If the process implementation does have a significant environmental impact on air resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Is the decommissioning process designed to avoid the use of materials and energy with air pollution potential? (see the Air Resource Table for potential causes of air pollution	0	1
Is the decommissioning process designed to avoid or minimize the generation of residues with air pollution potential? (see Air Resource Table)	0	1
Do the residues from the decommissioning processes have air pollution potential?	2	0
Is the decommissioning process designed as such that the site can be repaired with minimal production of residues with high air pollution potential (see Air Resource Table)?	0	1

D2,3

Life Stage: Decommissioning: Process Implementation
Environmental Factor: Land

If the process implementation does have a significant environmental impact on land resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Is the decommissioning process designed to avoid the use of materials and energy with land impact potential? (see the Land Resource Table for potential causes of land impacts)	0	1
Is the decommissioning process designed to minimize the generation of residues with land impact potential? (See Land Resource Table attached	0	1
Do the residues from the decommissioning processes have the potential to impact land resources?	1	0
Is necessary development activity, if any, planned to undo any disruption of existing biological communities?	0	1
Can all areas that are disturbed during decommissioning be carefully restored?	0	1

D2,4
Life Stage: Decommissioning: Process Implementation
Environmental Factor: Mined Resources

If the process implementation does have a significant environmental impact on Mined Resources, the matrix element is 5. In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Yes	No
Is the decommissioning process designed to minimize the use of energy-intensive process steps, especially process steps that require non-renewable energy sources, and to utilize otherwise wasted energy?	0	1
Is the decommissioning process designed in such a way as to minimize the use of any non-renewable mineral resources?	0	2
Is energy-intensive material or residue transportation avoided or minimized?	0	2

GATE 3

If any of the life cycle phases do have a significant environmental impact on a resource, the matrix element is 25. In order to determine the rating complete the checklist below. The final value for each question can be read from the following risk table.

		Intensity of occurrence		
		High	Medium	Low
Probability of occurrence	High	5	4	2
	Medium	4	3	1
	Low	2	1	1

CONSTRUCTION

C1,1
Life Stage: Construction: Supply Processes
Environmental Factor: Water

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Generation of residues with water pollution potential during the extraction, purification or conversion of material and energy (See Water Resource Table attached for potential causes of water pollution)	H M L	H M L	2 x Risk Factor
Generation of residues with water pollution potential during transport of material to facility.	H M L	H M L	Risk Factor
Water requirements for extraction, cleaning or transformation of supplied components or materials.	H M L	H M L	Risk Factor
Water Requirements of the construction processes	H M L	H M L	Risk Factor

C1,2
Life Stage: Construction: Supply Processes
Environmental Factor: Air

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Generation of residues with air pollution potential during the extraction, purification or conversion of material and energy (See Air Resource Table attached for potential causes of air pollution)	H M L	H M L	2 x Risk Factor

Generation of residues with air pollution potential during transport of material to facility.	H M L	H M L	Risk Factor
Material requirements for ozone-depleting substances or global-warming substances	H M L	H M L	Risk Factor
Material requirements for material or energy source that is a substance with air pollution potential (e.g. mercury)	H M L	H M L	Risk Factor

C1,3

Life Stage: Construction: Supply Processes

Environmental Factor: Land

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Generation of residues with land impact potential during the extraction, purification or conversion of material and energy (See Land Resource Table attached for potential causes of land impacts)	H M L	H M L	2 x Risk Factor
Generation of residues with land impact potential during transport of material to facility.	H M L	H M L	Risk Factor
Requirements for toxic and/or radioactive materials	H M L	H M L	Risk Factor
Amounts and types of packaging material that enters the facility	H M L	H M L	Risk Factor

C1,4

Life Stage: Construction: Supply Processes

Environmental Factor: Mined Resources

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Materials or energy sources in restricted supply or are likely to become over the process's life cycle.	H M L	H M L	3 x Risk Factor
Impact of proposed packaging material of components and materials	H M L	H M L	2 x Risk Factor

C2,1
Life Stage: Construction: Site Selection & Development
Environmental Factor: Water
In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Effect of planned (designed) releases during the construction process on ambient water resources. (see Water Resource Table for potential causes of water pollution)	H M L	H M L	3 x Risk Factor
Effect of unplanned releases during the construction process on ambient water resources. (see Water Resource Table for potential causes of water pollution)	H M L	H M L	2 x Risk Factor

C2,2
Life Stage: Construction: Site Selection & Development
Environmental Factor: Air
In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Effect of planned (designed) releases during the construction process on air resources. (see Air Resource Table for potential causes of air pollution)	H M L	H M L	3 x Risk Factor
Effect of unplanned releases during the construction process on air resources. (see Air Resource Table for potential causes of air pollution)	H M L	H M L	2 x Risk Factor

C2,3
Life Stage: Construction: Site Selection & Development
Environmental Factor: Land
In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Effect of planned (designed) releases during the construction process on land. (see Land Resource Table for potential causes of land impacts)	H M L	H M L	3 x Risk Factor
Effect of unplanned releases during the construction process on land. (see Land Resource Table for potential causes of land impacts)	H M L	H M L	2 x Risk Factor

C2,4
Life Stage: Construction: Site Selection & Development
Environmental Factor: Mined Resources
In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Effect of planned (designed) releases during the construction process on mined resources. (see Mined Resource Table for potential causes of impacts)	H M L	H M L	3 x Risk Factor
Effect of unplanned releases during the construction process on mined resources. (see Mined Resource Table for potential causes of impacts)	H M L	H M L	2 x Risk Factor

OPERATION

O1,1
Life Stage: Operation: Supply Processes
Environmental Factor: Water
In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Generation of residues with water pollution potential during the extraction, purification or conversion of material and energy (See Water Resource Table attached for potential causes of water pollution)	H M L	H M L	2 x Risk Factor
Generation of residues with water pollution potential during transport of material to facility.	H M L	H M L	Risk Factor
Water requirements for extraction, cleaning or transformation of supplied components or materials.	H M L	H M L	Risk Factor
Water Requirements of the primary and complementary processes	H M L	H M L	Risk Factor

O1,2
Life Stage: Operation: Supply Processes
Environmental Factor: Air
In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Generation of residues with air pollution potential during the extraction, purification or conversion of material and energy (See Air Resource Table attached for potential causes of air pollution)	H M L	H M L	2 x Risk Factor
Generation of residues with air pollution potential during transport of material to facility.	H M L	H M L	Risk Factor
Material requirements for ozone-depleting substances or global-warming substances	H M L	H M L	Risk Factor

Material requirements for material or energy source that is a substance with air pollution potential (e.g. mercury)	H M L	H M L	Risk Factor

O1,3
Life Stage: Operation: Supply Processes
Environmental Factor: Land

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Generation of residues with land impact potential during the extraction, purification or conversion of material and energy (See Land Resource Table attached for potential causes of land impacts)	H M L	H M L	2 x Risk Factor
Generation of residues with land impact potential during transport of material to facility.	H M L	H M L	Risk Factor
Requirements for toxic and/or radioactive materials	H M L	H M L	Risk Factor
Amounts and types of packaging material that enters the facility	H M L	H M L	Risk Factor

O1,4
Life Stage: Operation: Supply Processes
Environmental Factor: Mined Resources

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Materials or energy sources in restricted supply or are likely to become over the process's life cycle.	H M L	H M L	3 x Risk Factor
Impact of proposed packaging material of products	H M L	H M L	2 x Risk Factor

O2,1
Life Stage: Operation: Primary Process
Environmental Factor: Water

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Effect of planned (designed) releases during the primary process on ambient water resources. (see	H M L	H M L	3 x Risk

Water Resource Table for potential causes of water pollution)			Factor
Effect of unplanned releases during the primary process on ambient water resources. (see Water Resource Table for potential causes of water pollution)	H M L	H M L	2 x Risk Factor

O2,2
Life Stage: Operation: Primary Process
Environmental Factor: Air

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Effect of planned (designed) releases during the primary process on air resources. (see Air Resource Table for potential causes of air pollution)	H M L	H M L	3 x Risk Factor
Effect of unplanned releases during the primary process on air resources. (see Air Resource Table for potential causes of air pollution)	H M L	H M L	2 x Risk Factor

O2,3
Life Stage: Operation: Primary Process
Environmental Factor: Land

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Effect of planned (designed) releases during the primary process on land. (see Land Resource Table for potential causes of land impacts)	H M L	H M L	3 x Risk Factor
Effect of unplanned releases during the primary process on land. (see Land Resource Table for potential causes of land impacts)	H M L	H M L	2 x Risk Factor

O2,4
Life Stage: Operation: Primary Process
Environmental Factor: Mined Resources

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Effect of planned (designed) releases during the primary process on mined resources. (see Mined Resource Table for potential causes of impacts)	H M L	H M L	3 x Risk Factor
Effect of unplanned releases during the primary process on mined resources. (see Mined Resource Table for potential causes of impacts)	H M L	H M L	2 x Risk Factor

Note: Complementary Processes include storage and transport of product from facility to clients

O3,1
Life Stage: Operation: Complementary Processes
Environmental Factor: Water

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Effect of planned (designed) releases during the complementary processes on ambient water resources. (see Water Resource Table for potential causes of water pollution)	H M L	H M L	3 x Risk Factor
Effect of unplanned releases during the complementary processes on ambient water resources. (see Water Resource Table for potential causes of water pollution)	H M L	H M L	2 x Risk Factor

O3,2
Life Stage: Operation: Complementary Processes
Environmental Factor: Air

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Effect of planned (designed) releases during the complementary processes on air resources. (see Air Resource Table for potential causes of air pollution)	H M L	H M L	3 x Risk Factor
Effect of unplanned releases during the complementary processes on air resources. (see Air Resource Table for potential causes of air pollution)	H M L	H M L	2 x Risk Factor

O3,3
Life Stage: Operation: Complementary Processes
Environmental Factor: Land

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Effect of planned (designed) releases during the complementary processes on land. (see Land Resource Table for potential causes of land impacts)	H M L	H M L	3 x Risk Factor
Effect of unplanned releases during the complementary processes on land. (see Land Resource Table for potential causes of land impacts)	H M L	H M L	2 x Risk Factor

O3,4
Life Stage: Operation: Complementary Processes
Environmental Factor: Mined Resources

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Effect of planned (designed) releases during the complementary processes on mined resources. (see Mined Resource Table for potential causes of impacts)	H M L	H M L	3 x Risk Factor
Effect of unplanned releases during the complementary processes on mined resources. (see Mined Resource Table for potential causes of impacts)	H M L	H M L	2 x Risk Factor

O4,1
Life Stage: Operation: Products
Environmental Factor: Water

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Effect of planned (designed) releases during the product use and phase out phases on ambient water resources. (see Water Resource Table for potential causes of water pollution)	H M L	H M L	3 x Risk Factor
Effect of unplanned releases during the product use and phase out phases on ambient water resources. (see Water Resource Table for potential causes of water pollution)	H M L	H M L	2 x Risk Factor

O4,2
Life Stage: Operation: Products
Environmental Factor: Air

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Effect of planned (designed) releases during the product use and phase out phases on air resources. (see Air Resource Table for potential causes of air pollution)	H M L	H M L	3 x Risk Factor
Effect of unplanned releases during the product use and phase out phases on air resources. (see Air Resource Table for potential causes of air pollution)	H M L	H M L	2 x Risk Factor

O4,3
Life Stage: Operation: Products
Environmental Factor: Land

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Effect of planned (designed) releases during the product use and phase out phases on land. (see Land Resource Table for potential causes of land impacts)	H M L	H M L	3 x Risk Factor
Effect of unplanned releases during the product use and phase out phases on land. (see Land Resource Table for potential causes of land impacts)	H M L	H M L	2 x Risk Factor

O4,4
Life Stage: Operation: Products
Environmental Factor: Mined Resources

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Effect of planned (designed) releases during the product use and phase out phases on mined resources. (see Mined Resource Table for potential causes of impacts)	H M L	H M L	3 x Risk Factor
Effect of unplanned releases during the product use and phase out phases on mined resources. (see Mined Resource Table for potential causes of impacts)	H M L	H M L	2 x Risk Factor

DECOMMISSIONING

D1,1
Life Stage: Decommissioning: Supply Processes
Environmental Factor: Water

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Generation of residues with water pollution potential during the extraction, purification or conversion of material and energy (See Water Resource Table attached for potential causes of water pollution)	H M L	H M L	2 x Risk Factor
Generation of residues with water pollution potential during transport of material to facility.	H M L	H M L	Risk Factor
Water requirements for extraction, cleaning or transformation of supplied components or materials.	H M L	H M L	Risk Factor
Water Requirements of the decommissioning processes	H M L	H M L	Risk Factor

D1,2
Life Stage: Decommissioning: Supply Processes
Environmental Factor: Air

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Generation of residues with air pollution potential during the extraction, purification or conversion of material and energy (See Air Resource Table attached for potential causes of air pollution)	H M L	H M L	2 x Risk Factor
Generation of residues with air pollution potential during transport of material to facility.	H M L	H M L	Risk Factor
Material requirements for ozone-depleting substances or global-warming substances	H M L	H M L	Risk Factor
Material requirements for material or energy source that is a substance with air pollution potential (e.g. mercury)	H M L	H M L	Risk Factor

D1,3
Life Stage: Decommissioning: Supply Processes
Environmental Factor: Land

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Generation of residues with land impact potential during the extraction, purification or conversion of material and energy (See Land Resource Table attached for potential causes of land impacts)	H M L	H M L	2 x Risk Factor
Generation of residues with land impact potential during transport of material to facility.	H M L	H M L	Risk Factor
Requirements for toxic and/or radioactive materials	H M L	H M L	Risk Factor
Amounts and types of packaging material that enters the facility	H M L	H M L	Risk Factor

D1,4
Life Stage: Decommissioning: Supply Processes
Environmental Factor: Mined Resources

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Materials or energy sources in restricted supply or are	H M L	H M L	3 x

likely to become over the process's life cycle.			Risk Factor
Impact of proposed packaging material of components and materials	H M L	H M L	2 x Risk Factor

D2,1

Life Stage: Decommissioning: Process Implementation

Environmental Factor: Water

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Effect of planned (designed) releases during the decommissioning process on ambient water resources. (see Water Resource Table for potential causes of water pollution)	H M L	H M L	3 x Risk Factor
Effect of unplanned releases during the decommissioning process on ambient water resources. (see Water Resource Table for potential causes of water pollution)	H M L	H M L	2 x Risk Factor

D2,2

Life Stage: Decommissioning: Process Implementation

Environmental Factor: Air

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Effect of planned (designed) releases during the decommissioning process on air resources. (see Air Resource Table for potential causes of air pollution)	H M L	H M L	3 x Risk Factor
Effect of unplanned releases during the decommissioning process on air resources. (see Air Resource Table for potential causes of air pollution)	H M L	H M L	2 x Risk Factor

D2,3

Life Stage: Decommissioning: Process Implementation

Environmental Factor: Land

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Effect of planned (designed) releases during the decommissioning process on land. (see Land Resource Table for potential causes of land impacts)	H M L	H M L	3 x Risk Factor

Effect of unplanned releases during the decommissioning process on land. (see Land Resource Table for potential causes of land impacts)	H M L	H M L	2 x Risk Factor

D2,4

Life Stage: Decommissioning: Process Implementation
Environmental Factor: Mined Resources

In order to determine the rating complete the checklist below and add the subsequent indicated values:

	Intensity of occurrence	Probability of occurrence	Score
Effect of planned (designed) releases during the decommissioning process on mined resources. (see Mined Resource Table for potential causes of impacts)	H M L	H M L	3 x Risk Factor
Effect of unplanned releases during the decommissioning process on mined resources. (see Mined Resource Table for potential causes of impacts)	H M L	H M L	2 x Risk Factor

APPENDIX H:

Questionnaire to evaluate scoring guidelines

The following questionnaire has been used for purposes of evaluating the scoring guidelines:

Questionnaire: Evaluating Environmental Matrix Evaluation Tool
1. Did completing the scoring guideline questions prompt you to think of or consider aspects not previously taken into account? If so, what are these aspects?
2. Do you think the scoring guidelines address all relevant aspects? If not, what aspects should also be considered?
3. Comment on the following aspects of the scoring guideline questions: • Clarity • Level of difficulty • Availability of information to answer questions
4. Did you need to contact other project members to provide information? If so, what type of information?
5. How long did it take you to complete the scoring guideline questions per gate: • Gate 1: • Gate 2: • Gate 3:
6. Would you have done anything differently if the environmental matrix evaluation tool were available and used during the actual project?

7. General impression of the environmental matrix tool and its applicability for projects

APPENDIX I:
Economic Valuation Methods

I.1 Generally Applicable Techniques

The techniques, which are viewed as generally applicable to all projects, all rely on market prices to determine the economic values of environmental impacts.

I.1.1 Techniques in which market price are used

These are based on classical cost-benefit analysis methodologies. The reasoning is that impacts on environmental quality or quantity are reflected in changes in the productivity of the systems involved, and that these changes can be used to determine an economic value for the original impact (Dixon, Scura, Carpenter & Sherman, 1994). Examples of the use of the techniques can be found in Dixon, Scura, Carpenter & Sherman (1994).

a) Changes in Productivity

This technique value the physical changes in production caused by the environmental effect or project by using the market prices of input and output materials. It is based on neoclassical welfare economics. Dixon, Scura, Carpenter & Sherman (1994) identified three steps that must be taken in order to use the technique:

- Both on site and off site changes in productivity due to the environmental impact must be identified.
- The effects on productivity both of proceeding with the project (that causes the environmental impact) and of not going ahead should be discussed.
- Assumptions have to be made about:
    - Time over which changes in productivity must be measured.
    - The "correct" prices to use.
    - Future changes expected in relative prices.

A damage function can then be established, that can be used to determine monetary values.

b) Cost of Illness

This approach is often used for valuing the cost of pollution-related morbidity (sickness). The approach is also based on a damage function, which relates level of pollution to the degree of health effects. It therefore requires information on the damage function as well as information on how the project's environmental impacts will affect the levels of pollution. Typical costs associated with an increase in morbidity such as medical costs, e.g. hospital fees, and loss of earnings resulting from morbidity and any other related out-of-pocket expenses are used to determine an economic value for the environmental impact (The World Bank: Environment Department, 1998).

The cost-of-illness approach ignores an individual's preference for health versus sickness and the associated willingness-to-pay for health (Dixon, Scura, Carpenter & Sherman, 1994). Dixon, Scura, Carpenter & Sherman (1994) provide the following guidelines to identify projects with environmental impacts for which the cost-of-illness approach may be useful:

- A direct cause-and-effect relationship can be established and the etiology of the disease is clearly identifiable.
- The illness is not life threatening and has no chronic effects.
- An accurate estimate of economic value of earnings and medical care is available.

If this approach is extended to estimate the costs associated with pollution-related mortality, it is known as the human-capital approach (The World Bank: Environment Department, 1998).

c) Opportunity Cost

Opportunity cost refers to *"the value of these lost economic opportunities due to environmental protection"* (The World Bank: Environment Department, 1998). It therefore measures the cost of preservation and it does not measure the benefits gained from preserving.

It is a very powerful technique because although it follows a cost-side approach, it is actually used to evaluate the benefits of preservation, which cannot always be valued, by estimating the additional cost to use alternatives. The technique is often used to value unique natural resources and is relatively quick and straightforward (Dixon, Scura, Carpenter & Sherman, 1994). The approach also forms the basis of compensation payments by government (Garrod & Willis, 1999).

I.1.2 Techniques in which market prices of actual or potential expenditures are used

These techniques rely on market prices and are cost-side approaches i.e. the techniques do not attempt to assign monetary value to the benefits of environmental impact but look at the cost to mitigate, minimize or prevent it.

a) Cost-effectiveness Analysis

Cost-effectiveness analysis is a technique widely used by engineers and economists to evaluate the cost of mitigation. Dixon, Scura, Carpenter & Sherman (1994) set the following guidelines for applying this technique:

- Set a target for the effect of the environmental impact e.g. a certain ambient air quality or level of exposure. The target can be set after examining targets in both developed and developing countries as well as targets recommended by organisations such as the World Health Organisation.

- Evaluate the seriousness of the environmental impacts, which is to be controlled.
- Apply the cost-effectiveness analysis technique to all alternatives available to control the impact.
- Evaluate the effect of the most cost-effective method of control on the financial and economic return from the project.
- Determine whether compromises exist which will minimize environmental damage while still allowing the project to continue.

b) Preventive Expenditures

The technique relies on subjective valuations of the expenditures people will be willing to pay in an attempt to avert damage from pollution, to establish the minimum cost of these environmental problems. It thus views the expenditures on mitigation of environmental damage as a surrogate demand for environmental protection (Dixon, Scura, Carpenter & Sherman, 1994).

The technique gives a minimum estimate of the cost of environmental problems because actual willingness-to-pay is constrained by the ability to pay. The following assumptions are implicit in this kind of analysis:

- Accurate data on the costs of mitigating expenditures are available
- No secondary benefits are associated with the expenditures (Dixon, Scura, Carpenter & Sherman, 1994).

c) Replacement Costs

The technique is often used to estimate the cost of pollution. It does not rely on subjective valuations but uses true costs of damage that can occur (The World Bank: Environment Department, 1998). The technique gives an estimate of the upper limit of the costs of environmental damage but does not measure the benefits of environmental protection.

Dixon, Scura, Carpenter & Sherman (1994) identified the following assumptions implicit in this kind of analysis:

- The magnitude of damage is measurable.
- The replacement costs are calculable.
- No secondary benefits are associated with the expenditures.

d) Relocation Costs

The relocation costs approach is similar to the replacement costs approach, it only uses estimated costs of a forced relocation of a natural or physical asset due to environmental damage (The World Bank: Environment Department, 1998).

e) Shadow Projects

A shadow project is a special type of application of the replacement-cost technique. If an environmental impact diminishes environmental services, which are difficult to value, the costs thereof can be approximated by examining the costs of a hypothetical, supplementary project, which will provide substitutes.

Shadow-project costs are then included in the project economic valuation. The following assumptions are implicit in this kind of analysis:

- Endangered resource is scarce and highly valued.
- A human-built alternative will provide the same quantity and quality of goods and services as does the natural environment.
- Original level of goods and services is desirable and should therefore be maintained.
- Costs of shadow project do not exceed the value of the lost productive service of the natural environment (Dixon, Scura, Carpenter & Sherman, 1994).

I.2 Selectively Applicable Techniques

I.2.1 Techniques in which surrogate market prices are used

Market prices are not available for all aspects of the environment e.g. clean air and unobstructed views. Surrogate-market techniques use actual market prices to value an unmarketed quality of the environment with some limitations (Dixon, Scura, Carpenter & Sherman, 1994).

a) Travel Cost

Renowned resource economist Harold Hotteling observed that behaviour can be used to derive a demand curve as well as to estimate a value for an unpriced environmental good by treating increasing travel costs as a surrogate for variable admission prices. The technique thus assumes that changes in total travel cost are equivalent to changes in admission fees and that the total benefit visitors obtain can be calculated from this demand curve (The World Bank: Environment Department, 1998).

Travel cost is mostly used to value the cost of recreation and has been used numerous times to estimate individual's willingness to pay for national parks. The technique is however site-specific and has limited use in the project environment.

I.2.2 Contingent Valuation

It is not always possible to value the environmental effects and impacts of a project by using market-oriented techniques or surrogate-market techniques due to the fact that these markets do not exists or are not well-developed. In such cases a viable alternative is contingent valuation methods also known as hypothetical valuation.

These techniques involve the direct questioning of consumers to determine how they would react to certain situations. The concepts of "willingness to pay" and "willingness to accept" are utilized in these techniques. Contingent valuation techniques tend to rely on public surveys as a method to determine the consumers' reaction. Examples of contingent valuation methods include:

- Bidding Games
- Take-it-or-leave-it experiments
- Trade-off games
- Costless choice
- Delphi technique (Dixon, Scura, Carpenter & Sherman, 1994).

Contingent valuation techniques can in principle be used to value any environmental impact (The World Bank: Environment Department, 1998). These techniques are nevertheless limited by the fact that it only simulates conditions of the real world and does not analyse actual behaviour.

I.3 Potentially Applicable Techniques

I.3.1 Hedonic Value Techniques

Hedonic value techniques are based on an alternative to neoclassical consumer theory (Dixon, Scura, Carpenter & Sherman, 1994) and are used to *"examine the contribution of different attributes e.g. to prices for housing and to wage levels, including the contribution of environmental quality"* (The World Bank: Environment Department, 1998). The technique thus estimates the implicit contribution of various attributes, which together makes up the sale price or wage. Two types of hedonic value techniques are often used:

- Property and other land-value approaches that can be used to determine the value of environmental quality.
- Wage Differential that is based on the theory that workers have to be paid a premium to undertake jobs that are inherently risky.

I.3.2 Macro Economic Variables and Models

These types of techniques are used to assign a monetary value to the widespread environmental impacts resulting from macroeconomic policy decisions. Three techniques that are often used:

- Linear Programming
- Natural Resource Accounting
- Macroeconomic and economy-wide policies

APPENDIX J:
Multi Criteria Decision Analysis Techniques

J.1 Structured Approach to Decision-Making

Keeney (1992) stated that decision analysis provides decision makers with a structured approach to decision making. This systematic approach to decision making can be divided into two stages, namely problem structuring and problem analysis (Petrie, Basson, Stewart, Notten and Alexander, 2001).

The aim of the first stage, problem structuring, is to:

- Identify stakeholders
- Identify and obtain agreement about:
  - exactly what decision needs to be made
  - all possible objectives that must be satisfied by the decision outcome
  - available alternatives

The outcome of the first stage is often "*an objectives hierarchy, which shows criteria that can be used to evaluate alternatives*" (Petrie, Basson, Stewart, Notten and Alexander, 2001). The problem analysis stage is focused on evaluating the alternatives and determining to what extent each different alternative satisfy the agreed upon decision objectives.

J.2 Multi Criteria Decision Analysis

Decision-making involves trade-offs, usually within a context of uncertainty. Decision-makers usually have more than one objective against which they would like to compare the different alternatives. The introduction of multiple objectives resulted in the development of a new form of decision analysis, namely: Multi Criteria Decision Analysis.

The advantages of multi criteria decision analysis are that each decision criteria receives due consideration without necessarily converting it to a common scale such as a monetary value (Petrie, Basson, Stewart, Notten and Alexander, 2001). These techniques can assist in incorporating environmental criteria, which is often difficult to express in monetary values, into decision-making. A number of multi criteria decision analysis techniques are, e.g.:

- Goal Programming
- Preemptive Optimisation
- Weighted Sums
- Analytic Hierarchy Process

J.3 Analytic Hierarchy Process (AHP)

Thomas Saaty developed the Analytic Hierarchy Process. The procedure starts by breaking down the decision problem into a hierarchy of interrelated decision elements or objectives, e.g. sustainability that can be broken down into three decision elements, objectives or attributes, namely: economic, environmental and social. The number of levels in the hierarchy will depend on the complexity of the problem. Weights are determined for each one of these decision objectives, which must add up to 1. The alternatives are weighted against each other for each objective in order to determine a score for each alternative for each objective. There are many user friendly software products available that an be used for weighting and scoring purposes (Pöyhönen & Hämäläinen, 2001) and example is Web-HIPRE Multi Criteria Decision Analysis software, which is available online at http://www.hipre.hut.fi/WebHipre/.

J.3.1 Weighting Methods

Weights for the different objectives can be determined in numerous ways. Two techniques are discussed in more detail: Direct Weighting and Pair-wise Comparison.

a) Direct Weighting

The decision-makers must assign a direct weight to each attribute, usually the decision-maker is asked to divide 100 points between the various attributes. Decision-makers can also be asked to mention the level of uncertainty when assigning these weights. Advantages of this approach according to Heuberger & Brent (2002) are:

- Straight forwardness of approach.
- No computer or software package is needed.
- Trade-off between attributes become more visible.

b) Pair-Wise Comparison

Decision-makers are asked to compare two attributes at a time and to answer the question *"Which one of these two attributes is more important and how much more important?"*. The following numerical scale is used to express importance:

Numerical Value	Verbal Terms
1	Equally important
3	Moderately more important
5	Strongly more important
7	Very strongly/Demonstrably more important
9	Extremely/Absolutely more important
2,4,6,8	Intermediate Values

Table J.1: Values for Pair-wise Comparison

Source: Winston, 1994

Each attribute is weighted against all other attributes separately and decision-makers must indicate their level of uncertainty. Results are put into a matrix, from which the relative weight of each attribute is calculated (Heuberger & Brent, 2002). Software programs are often used for this purpose. Figure J.1 shows an example of a matrix that can be used to evaluate environmental attributes.

AHP	← Criterion A more important									Criterion B more important →									
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9		Level of uncertainty in decision
Criterion A	extremely more important		very strongly more important		strongly more important		slightly more important		equally important		slightly more important		strongly more important		very strongly more important		extremely more important	Criterion B	1= certain 3= strongly uncertain 5= extremely uncertain
Air Quality																		Water Quality	
Air Quality																		Minersl / Energy Resources	
Air Quality																		Land Resource	
Water Quality																		Land Resource	
Water Quality																		Minersl / Energy Resources	
Land Resource																		Minersl / Energy Resources	

Figure J.1: Example of pair-wise comparison matrix

Source: Heuberger & Brent, 2002.

J.3.2. Scores for alternatives

Scores for alternatives can be determined in numerous ways. Pair-wise comparison can also be used to determine scores for each alternative for each objective. Heuberger & Brent (2002) proposes a different scoring method that is discussed in Chapter 7. Scores can also be directly assigned or ranking can be used. Consistency should be checked.