# CHAPTER 2

# Literature survey

## 2.1 BACKGROUND

Environmental management can be defined as the process of allocating natural 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 to the environment (Barrow, 1997). However, earth's ecosystems cannot sustain current levels of economic activity and material consumption, therefore effective sustainability initiatives are required as basis of corporate environmental management frameworks to relieve pressure on ecological and social integrity (Wackernagel and Rees, 1996).

Environmental cost accounting is an innovative sustainability initiative (The World Bank Group, 2003). Coupled to the various standarised procedures and practices for effective environmental management, for example, ISO 14000 and Integrated Environmental Management Systems (IEMS), it defines the environmental management frameworks that exist at present that can assist companies in managing, measuring and improving the environmental aspects of their operations (Tibor, 1996) and within which industries must operate today (Grace *et al.,* 1999).

Recognition of environmental costs through environmental accounting systems reveals cost effective opportunities to prevent pollution and eliminate wastes, and encourages business decisions that are financially beneficial to the environment (UNDP, 2002).

## 2.2 ENVIRONMENTAL ACCOUNTING

Steele and Powell (s.a.) define environmental accounting as the identification, allocation and analysis of material streams and their related money flows by using environmental accounting systems to provide insight in environmental impacts and associated financial issues.

Companies utilise environmental accounting systems to include environmental costs into corporate decision making (ICF, 1996). Compared with conventional financial accounting, which typically includes environmental health and safety (EHS) costs as direct labour, direct material and overheads, environmental accounting improves the management of environmental costs and communication of risks by incorporating standard environmental accounting practices (Little, 2000).

Mainly three different types of environmental accounting practices are recognised at present (Figure 2.1), all with the same overarching goal of increasing the amount of relevant financial information available to decision makers. These are (EPA, 1995):

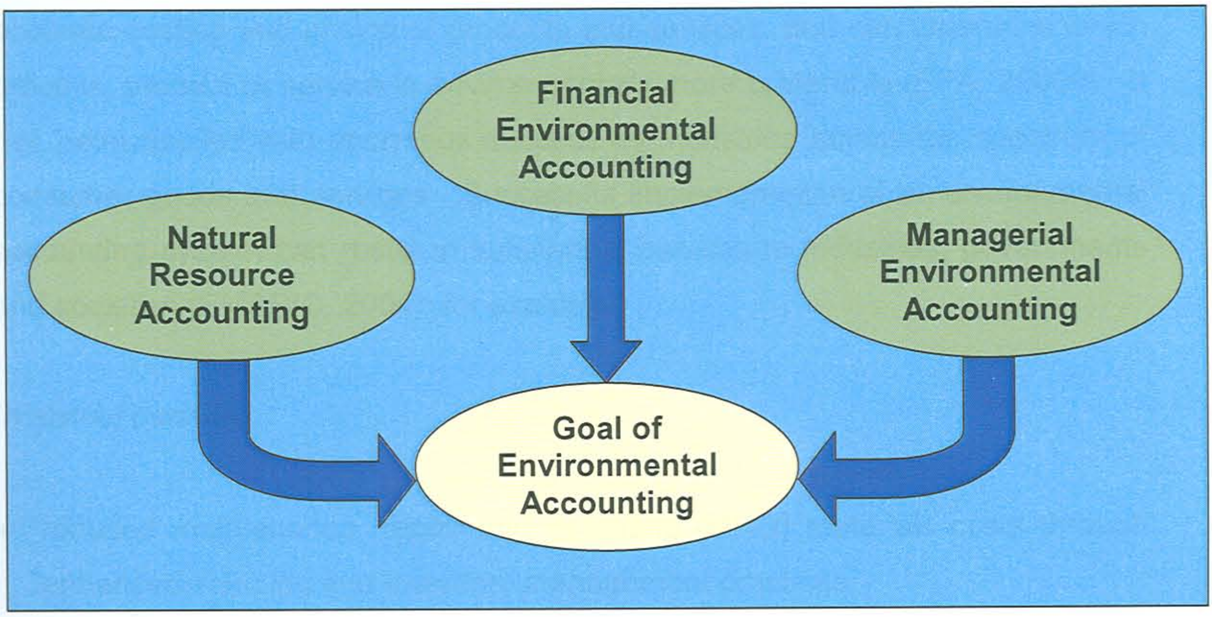


**Figure 2.1** Types of Environmental Accounting Practices.

- *Natural Resource Accounting*: A macro-economic measure, expressed in consumption of a nation's natural resources, both renewable and non-renewable, in physical or monetary units.
- *Financial Environmental Accounting*: Company focused and refers to the estimation and public reporting of environmental liabilities. Generally accepted accounting principles form the basis of reporting in this context.

- *Managerial Environmental Accounting*: Uses data of environmental costs and performance in business decisions and operations. This type of accounting is also company specific and internally focused.

Based on the relevant environmental accounting practice, various types of environmental accounting systems can be used to account for environmental costs, depending on the scope of costs considered in the system (Veefkind, 2003). The scope of costs refers to the different environmental costs included in a system (Section 2.3).

### 2.2.1 Advantages gained through environmental accounting

Environmental accounting can enhance corporate advantage, promote more accurate costing and pricing of products and services, and can determine which process, product or service is environmentally more preferable (EPA, 2000a). It has been applied with enormous success by industries across the spectrum of consumer goods and services. Successful implementation of an environmental accounting system can result in substantial benefits to industries, governments and societies (EMARIC, 2004), for example:

*Industrial benefits*

- reduced maintenance, repair and operating (MRO) materials costs through enhanced sourcing and inventory management practices,
- decreased costs associated with scrap and material losses,
- lowered training, material handling and other extra expenses associated with hazardous materials,
- increased revenues by converting wastes to by-products,
- reduced use of hazardous materials through more timely and accurate materials tracking and reporting systems,
- decreased use and waste of solvents, paints and other chemicals through chemical service partnerships, and
- recovered valuable materials and assets through efficient product take back programmes.

*Governmental benefits* (EMARIC, 2004)

- the more that industry is able to justify environmental programmes on the basis of financial self-interest, the lower the financial, political and other burdens of environmental protection on government,
- implementation of environmental accounting by industry should strengthen the effectiveness of existing government policies/regulations by revealing to companies the true environmental costs and benefits resulting from those policies/regulations,
- government can use environmental accounting data to estimate and report financial and environmental performance metrics for government stakeholders, such as regulated industries or industry partners in voluntary programmes,
- environmental accounting data can be used to inform government programme/policy design,
- government can use environmental accounting data to develop metrics for reporting the financial and environmental benefits of voluntary partnership programmes with industry, innovative approaches to environmental protection, and other government programmes and policies, and
- environmental accounting data can be used for regional or national-level accounting purposes.

*Societal benefits* (EMARIC, 2004)

- more efficient and cost-effective use of natural resources, including energy and water,
- cost-effective reduction of pollutant emissions,
- reduced external costs related to industry pollution, such as the costs of environmental monitoring, control and remediation as well as public health costs,
- provision of improved information for improved public policy decision-making, and
- provision of industrial environmental performance information that can be used in the broader context of evaluations of environmental performance and conditions in economies and geographic regions.

The following examples illustrate the benefits obtained by industries that have incorporated environmental accounting as part of their environmental management framework (EPA, 2000a):

- General Motors reduced its disposal costs by $12 million by establishing a reusable container programme with its suppliers,
- Commonwealth Edison, a major electric utility company, realised $25 million in financial benefits through more effective resource utilisation,
- Andersen Corporation implemented several programmes that reduced waste at its source and had internal rates of return (IRR) exceeding 50% (EPA, 2000b), and
- Public Service Electric and Gas Company saved more than $2 million in 1997 by streamlining its inventory process.

In addition, government organisations can implement environmental accounting themselves, with the following benefits:

- Environmental accounting data can be used for environmental and other decisions within government operations, for example, purchasing, capital budgeting and government facility environmental management systems.
- Environmental accounting data can be used to estimate and report financial and environmental performance metrics for government operations.

Environmental accounting can therefore be used not only to determine the financial impact of environmental activities, but also to find less costly alternatives by either changing process or product designs, or developing an exit strategy to eliminate environmentally costly products (Goodstein, 2002).

### 2.2.2 Problems experienced with environmental accounting

Environmental accounting is not performed without inherent problems. This can be illustrated by a survey conducted by the Tellus Institute that focused on the use of environmental accounting for internal decision making regarding environmental investments.

The survey concluded that conventional financial project analyses often put environmental investments at a disadvantage. This is due to the following (Veefkind, 2003):

- incorrect allocation of costs and revenues,
- incomplete inventory of costs and revenues, and
- short time horisons of the analyses.

For example, companies typically tend to lump environmental costs, with the exception of water and energy costs, into the category of overhead costs; while others allocate environmental costs to individual processes using surcharges. These surcharges normally have no direct relation with the environmental related costs of the material stream, production volume and materials use. When improper allocation occurs, managers receive distorted signals regarding the true costs and benefits of retaining or changing processes and products. Like incomplete cost inventories, misallocation of environmental costs prevents effective performance monitoring, product pricing and other activities essential to maintaining a competitive enterprise (White *et al.*, 1995).

Also, companies generally recognise, for example, direct waste disposal costs but tend to forget about related costs such as that for handling and storing hazardous waste. None of the respondents to the Tellus survey recognised less tangible costs like future liability costs and health costs or less tangible benefits like an improved company image. Table 2.1 portrays the survey results of costs normally considered in financial analyses by percentage of respondents (White *et al.*, 1995).

The costs presented in Table 2.1 do not include all cost items that should be considered, nor are the listed costs pre-defined as environmental. At present, there is no single standardised list of environmental costs to which all firms adheres, nor is there likely to be one in the foreseeable future. Devoting substantial energy to defining what is and is not an environmental cost diverts attention from the fundamental challenge: enlarging the cost inventory to ensure that all costs, environmental and non-environmental, are properly accounted for in the capital budgeting process (Ditz, Ranganathan and Banks, 1995).

**Table 2.1** Environmental costs normally considered in financial analyses.

| Cost item | % |
|---|---|
| On-site air/wastewater/hazardous waste testing/monitoring | 79 |
| Energy costs | 78 |
| On-site wastewater pre-treatment/treatment/disposal | 77 |
| Licensing/permitting | 76 |
| Water costs | 74 |
| Production efficiency/yield | 74 |
| On-site hazardous waste pre-treatment/treatment/disposal | 71 |
| On-site hazardous waste handling (storage, labeling) | 70 |
| On-site air emission controls | 69 |
| Employee safety/health compensation claims | 69 |
| Off-site hazardous waste transport | 62 |
| Manifesting for off-site hazardous waste transport | 59 |
| Staff training for environmental compliance | 59 |
| Future regulatory compliance costs | 59 |
| Environmental penalties/fines | 57 |
| Insurance costs | 55 |
| Corporate image effects | 55 |
| Personal injury claims | 54 |
| Reporting to government agencies | 53 |
| Frequency of plant shutdown | 51 |
| Off-site wastewater/hazardous waste pre-treatment/treatment | 50 |
| Property damage | 50 |
| Environmental staff labour time | 41 |
| Air pollutant emission credits ($SO_x$, $NO_x$) | 40 |
| Marketable by-products | 36 |
| Natural resource damage | 31 |
| Legal staff labor time | 28 |
| Sales of environmentally friendly/green products | 25 |

Finally, most companies use short time horisons when completing the relevant analyses (up to ten years); resulting in incompatible economic and ecological scales.

Certain environmental costs will have an impact over a much larger period, for example, the cost of environmental damage due to the effects of global climate change, which may only occur over a few decades (Holub *et al.*, 1999).

## 2.3 ENVIRONMENTAL COSTS

The main component to consider for environmental accounting is that of environmental costs. The EPA (1996) defines environmental costs as those costs that have a direct financial impact on a company (internal costs), and costs to individuals, society and the environment for which the company is not accountable (external costs). The type of costs included in the environmental accounting system determines the scope of the system (see Figure 2.2). EPA (1995) advises businesses to address at least all internal environmental costs in their environmental accounting systems and to correctly allocate these costs. Companies are also encouraged to move beyond consideration of internal costs to incorporate external costs, at least qualitatively, into their business decisions (EPA, 1995).

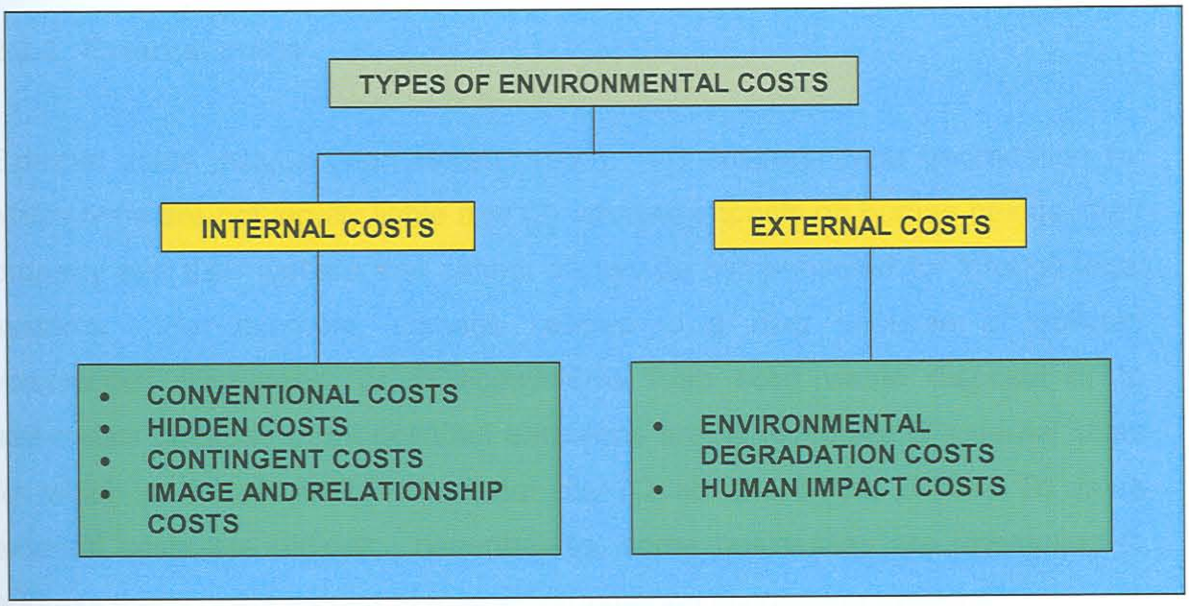


**Figure 2.2** Types of environmental costs.

### 2.3.1 Internal costs

Internal costs may include conventional costs, potentially hidden costs, contingent costs and image or relationship costs (EPA, 1995).

- *Conventional costs* include costs of capital equipment, raw materials and supplies.
- *Hidden costs* refer to the results of assigning environmental costs to overhead pools or overlooking future and contingent costs (see Section 2.4).
- *Contingent costs* refer to environmental costs that are not certain to occur in the future but depend on uncertain future events, for example, the costs involved in remediating future spills.
- *Image and relationship costs* are less tangible costs because they are incurred to affect subjective perceptions of management, customers, employees, communities, and regulators. This category can include the costs of annual environmental reports and community relations activities and costs expended voluntarily for environmental activities such as tree planting. The costs themselves are not intangible, but the direct benefits that result from relationship or corporate image expenses often are.

### 2.3.2 External costs

External costs include (Van Horen, 1996): (1) environmental degradation for which firms are not legally liable and (2) adverse impacts on human beings, their property and their welfare that cannot always be compensated for through legal systems. For example, damage caused to a river because of polluted wastewater discharges, or to ecosystems from solid waste disposal or to asthmatics because of air pollutant emissions are all examples of external costs for which an industry often does not pay (Quah and Boon, 2003). To value external costs are difficult; nevertheless, some businesses are attempting to address these costs as part of their environmental accounting systems.

A precise method or model of accounting for external costs has not been defined up to this instance (Carter *et al.*, 2001). However, many techniques have been suggested to assist in the evaluation of external costs. These techniques include (Bishop *et al.*, 1979):

- contingent valuation,
- travel cost approach,
- conjoint analysis,
- hedonic pricing,
- direct costs,
- property approach, and
- averting behaviour technique

### *2.3.2.1 Contingent valuation*

Changes in non-market values, associated with an alternative, are measured using information that stakeholders provide about their preferences or are derived implicitly from market data. The contingent valuation (CV) technique questions people about their willingness to pay (WTP) for hypothetical or actual policies that affect the allocation of resources. This approach is commonly used to estimate the value of changes in the condition of the natural environment where willingness to pay is used to gauge the potential economic benefits (that is, changes in stakeholder values) related to resource management decisions.

For example, the CV technique is used to determine, by means of surveys, how much residents would be willing to pay for recreational services supplied by, say for instance, a healthy wetland system. Surveyed information is then used to estimate the potential recreational opportunity cost of filling the wetland or, conversely, the benefit of preserving the wetland.

Contingent valuation researchers have identified at least four sources of possible error in their survey estimates that include free riding, strategic bias, hypothetical bias and embedding bias (Goodstein, 2002):

- Free riding exists when people are asked to pay for a public good. One individual might accept not to pay for preservation of a natural resource, in hopes that the cost would be borne by another member of society. In this case, the individual has an incentive to understate his true WTP to contingent valuation researchers.

- Strategic bias arises if people really do not have to pay their stated WTP for a resource in question. Under these circumstances, WTP estimates can be inflated, being a good strategy if respondents to the survey thought that larger WTP values in the survey results would lead to higher likelihood of protection of the resource.
- Hypothetical bias may lead respondents to provide hypothetical answers to the survey questions (poorly thought out or even meaningless).
- Embedding bias reveals the most serious problem with CV surveys. Answers will be strongly affected by the amount of information provided about the issues at stake. This is particularly evident when valuation questions are 'embedded' in a broader context.

#### 2.3.2.2 *Travel cost*

The travel cost (TC) approach is a popular hedonic technique that estimates the value or price of environmental amenities based on the cost of traveling to recreational areas. This approach is useful because travel expenditures give an idea of the minimum cost that people are willing to pay for access to environmental amenities (Hayden, 1989).

Several significant assumptions are made in defining these costs - first, it must be determined what are substitutable sites or activities. Second, a decision has to be made on an appropriate value of time to travel to the site. Third, decisions have to be made on how to allocate the value of a site between its ambience and its various other activities.

There are a number of data requirement problems related to this approach. Cummings, Brookshire and Schulze, 1986, conclude that the problems in specification and data collection with the TC approach "result in the dispelling of what was once regarded as the TC method's greatest potential strength: appealing to the notion that visitor values must equal or exceed travel costs".

#### *2.3.2.3 Conjoint analysis*

Conjoint analysis is used to determine the relative value that people place on the attributes of a product or experience. This information is used to estimate the value of policies that change the distribution and/or availability of attributes (Goodstein, 2002).

#### *2.3.2.4 Hedonic pricing*

Hedonic pricing is used to determine the portion of property value that is attributed to its proximity to natural amenities (Pearson, 2000). For example, properties close to natural amenities have greater value compared to properties close to mine-tailing dams.

#### *2.3.2.5 Direct cost*

Direct costs include numerous non-monetary and non-market systems. Direct costs mean "off-the-shelf" or "real-world" prices and costs of buying goods and services to accomplish a project. It is most consistent with the price or cost we pay or expect to pay. Direct costs reflect the consequences of (Hayden, 1989):

- subsidies and taxes,
- collective bargaining,
- monopoly rents,
- government regulations,
- social customs,
- rent and price controls,
- labour laws, and
- court decisions etc.

These are usually the costs that must be paid to acquire resources. The costs are quite consistent with the cost measure for restoration due to natural resource damage, as well as for determining use value (Seller *et al.*, 1985).

#### 2.3.2.6 *Property approach*

The literature on property approach is broad, varied in attempt, and diverse in purpose. The property concern with regard to ecosystem does not constitute a clear-cut technique for doing system evaluations or natural resource valuations or restoration assessments. The focus is on how to arrange and establish property institutions with regard to the use and abuse of the natural environment.

If the internalisation of external costs through the assignment of property rights is the answer to externality problems, then the creation of markets for resources that were not previously traded in markets follows. The problem of externalities is not market failure but rather the lack of a market. In cases where externalities affect resources that are not privately owned, markets should be created according to this approach. Thus, through the demand and supply mechanisms of a market, value can be determined. This approach will result in the following (Quiggin, 1988):

- individuals can rationally calculate all costs associated with externalities,
- individuals can calculate costs in monetary terms,
- the problems of transaction costs in the (potential) market can be overcome,
- property rights will develop when the costs associated with externality-producing behaviour exceeds the benefits,
- all resources can be privately owned, and
- society has no interest in protecting resources beyond what private interests wish to protect them.

#### 2.3.2.7 *Averting behaviour technique*

The averting behaviour technique assesses expenditure incurred after a change in environmental quality has occurred. The common goal of this technique is to express the value of changes in stakeholder wellbeing in monetary terms, so the differences may be directly compared. It is important, however, that information on all potential changes in stakeholder value is carried to the final step of the cost assessment process, even if some of the changes in value cannot be quantified (Steele and Powell, s.a.).

Given the diverse nature of the techniques available to value external costs, it is more important to specify the approach used to value these costs than to develop a standalone technique. Once all corporate environmental and social impacts are valued, the costs need to be allocated to the specific activity that causes the costs. Cost allocation is the cornerstone to successful corporate environmental accounting.

## 2.4 COST ALLOCATION

Conventional management accounting systems most often attribute environmental costs to general overhead accounts with the consequence that product and production managers have no incentive to reduce environmental costs and executives are often unaware of the extent of these costs. By identifying, assessing and correctly allocating environmental costs, environmental accounting allows management to identify opportunities for cost savings (UN, 2001). Environmental costs should be allocated directly to the relevant cost drivers, that is, to the activity that causes the costs. For example, the costs of handling and treating a toxic waste brought about by the production of, say product X, should directly and exclusively be allocated to product X.

Understanding cost drivers and allocating costs accordingly is the conceptual cornerstone of activity-based costing (ABC). Activity-based costing improves internal cost calculation by allocating costs typically found in overhead accounts to the polluting activities and products. The strength of activity-based costing is that it enhances the understanding of the business processes associated with each product (UN, 2001). The activity-based costs of each product are calculated by adding the appropriate share of joint fixed and the joint variable costs to the direct costs of production.

A simple example illustrates the concept (EPA, 1995). Figure 2.3 depicts a conventional accounting system that assigns environmental and certain other costs to overheads. Such overhead costs are generally allocated to products A and B in proportion to their consumption of labour and materials. Suppose product B is solely responsible for toxic waste management costs and product A creates no toxic waste costs.

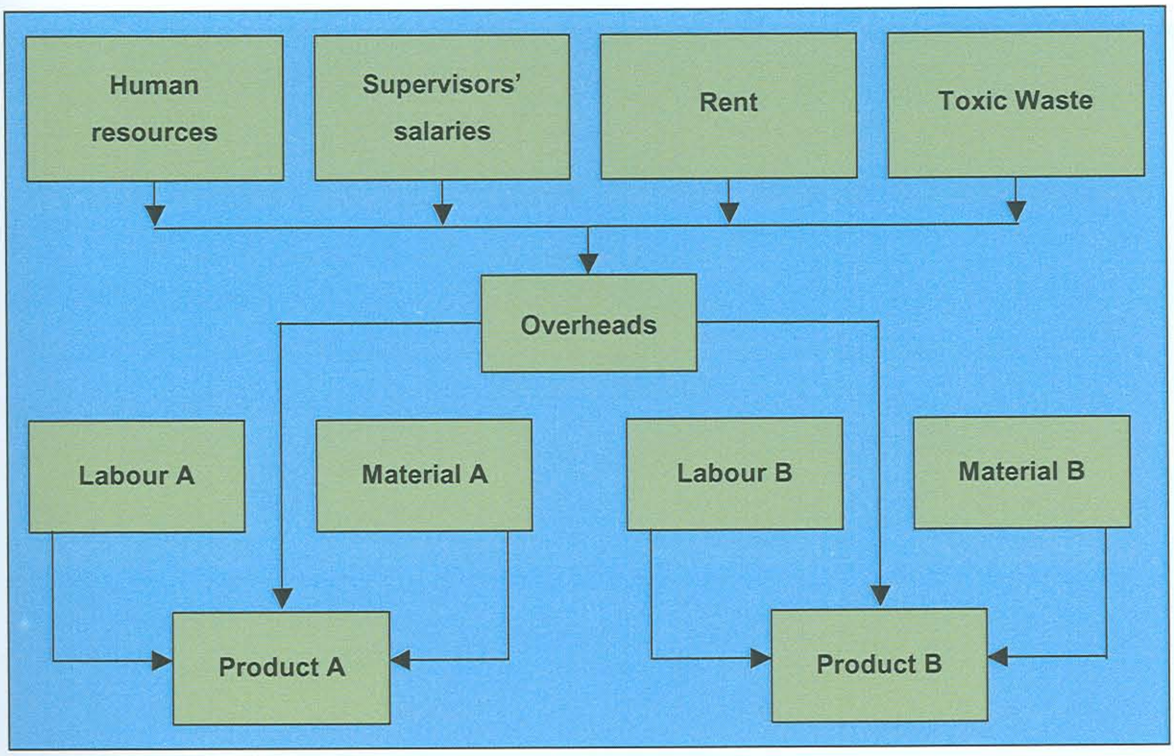


**Figure 2.3** Conventional cost accounting system.

A misallocation occurs because the toxic waste management cost is lumped together in an overhead cost pool that is misallocated to both products A and B, even though none of the toxic waste management cost results from the production of product A. The effect is to distort the actual costs of producing product A and product B. Figure 2.4 illustrates an environmental accounting system that correctly attributes the environmental costs of product B only to product B.

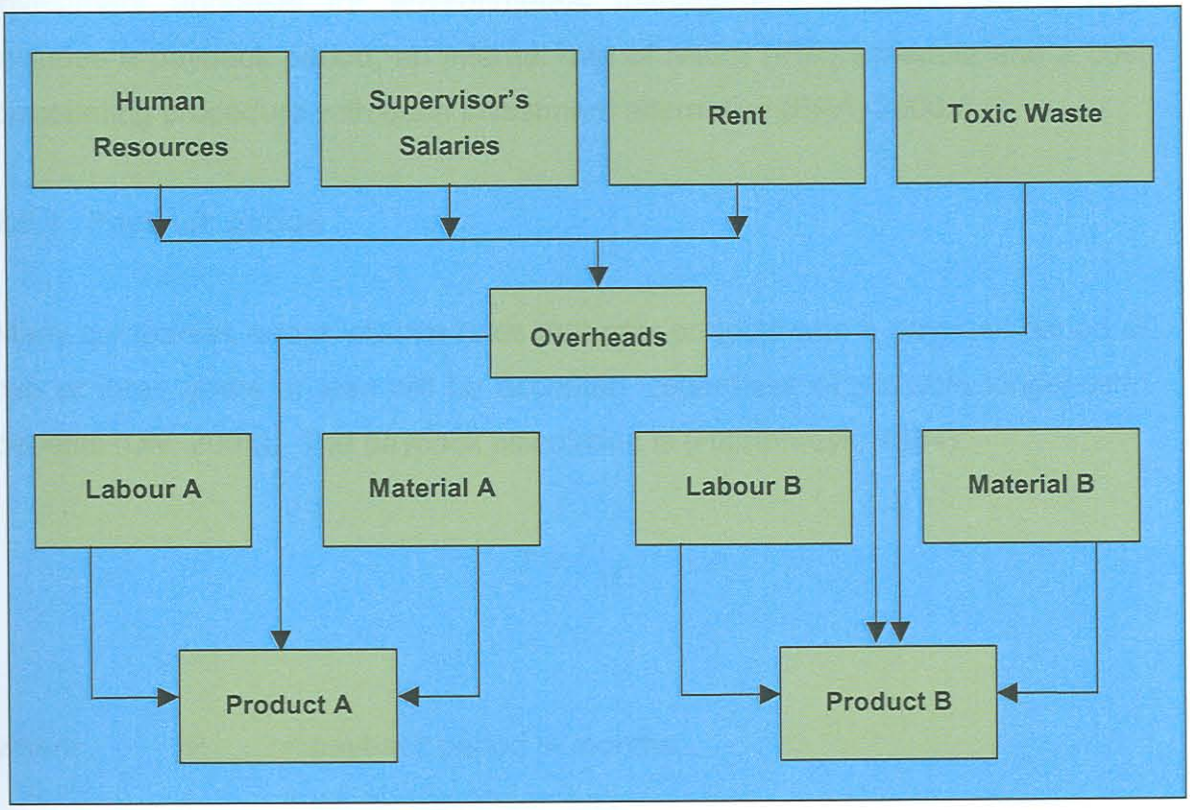


**Figure 2.4** Revised environmental accounting system.

## 2.5 CAPITAL BUDGETING FOR ENVIRONMENTAL PROJECTS

Once all corporate environmental and social costs are allocated, capital budgeting can be performed. Capital budgeting is part of the environmental accounting process for determining financial returns on future environmental management investments to compare different investment alternatives by means of investment appraisal. Investment appraisal determines the cost savings of an investment with regard to its goals. The economic indicators for investment appraisal in capital budgeting analysis include (UN, 2001):

- initial investment costs,
- operating costs and earnings,
- profit,
- payback period,
- return on investment (rate of return), and
- cost discounting.

Investment appraisal for environmental management projects usually only includes a payback period, an internal rate of return (IRR) schedule and a cost discounting procedure with each investment alternative (EPA, 2000a).

### 2.5.1 Payback period

Many companies adopt internal rules that only projects with a payback period of two or three years or less will be accepted, regardless of possible longer-term benefits (UN, 2001). The payback calculation is (Humphreys, 1984):

$$P = I/M$$

where P = payback period in months,
I = initial investment, and
M = monthly saving.

### 2.5.2 Return on investment

Return on investment (IRR) is the interest rate at which the net present value (NPV) of an investment is zero. It takes into consideration the amount and timing of the costs, savings and revenues of the investment (UN, 2001). A money-saving project will have a high IRR; the higher the IRR, the better the project. The NPV calculation is shown below (Pearson, 2000):

$$NPV = 0 = C_0 + \sum C_i/(1+IRR)^i$$

where NPV = net present value,
$C_0$ = initial investment,
$C_i$ = monthly savings, and
i = number of months.

### 2.5.3 Cost discounting

Cost discounting is a procedure of expressing future costs or revenues in terms of its present value. Expected future monetary inflows and outflows are discounted to the time of the investment using an internal discount rate or annuity. Theoretically, the discount rate is a question of (Schmidt, 2003):

- the companies demands for profitability as well as the companies interest rates,
- the assumed consumer's specific interest and inflation rate, and
- the discounting assumptions for those financially responsible for end-of-life operations.

The high risks, difficult monetarisation and high uncertainty of many future environmental costs, as well as the potential cost savings of using cleaner technologies, have made estimation of future earnings and expenses difficult during cost discounting procedures. Estimation of these future earnings and expenses can be supported by a process of sound project appraisal (UN, 2001).

## 2.6 PROJECT APPRAISAL

Any project is constantly reviewed throughout its life cycle in terms of economic feasibility, environmental compatibility and technical justification (UN, 2001). Project appraisal is the critical determinant of an industry's competitiveness and its commitment to environmental management. The purpose of this initiative is primarily to reduce both costs and waste, to determine project alternatives and to determine project values (EPA, 2000a).

Although many companies are striving to improve their logistics and materials management processes at present, important environmental burdens are usually not addressed appropriately (EPA, 2000a). Project appraisal for environmental accounting systems is based on the output of product or project life cycle assessments by coupling a monetary value to identified environmental and social impacts.

Proper project appraisal, considering all stages over the whole life cycle of a project provides industries with the advantage to incorporate and address environmental attributes already during the early stages of a project.

Life cycle assessment (LCA) for project appraisal is a technique for assessing the potential environmental and social aspects associated with a product or project by compiling an inventory of relevant inputs and outputs, evaluating the potential impacts associated with these inputs and outputs, and interpreting the results of the inventory and impact phases in relation to the objective of the study (Senthil *et al.*, 2002b). Life cycle assessment is a cradle to grave approach, beginning with the use of raw materials from the earth to create the product and ending at the point where all materials are returned (disposed) to earth. The LCA framework is depicted in Figure 2.5 (Little, 2000).

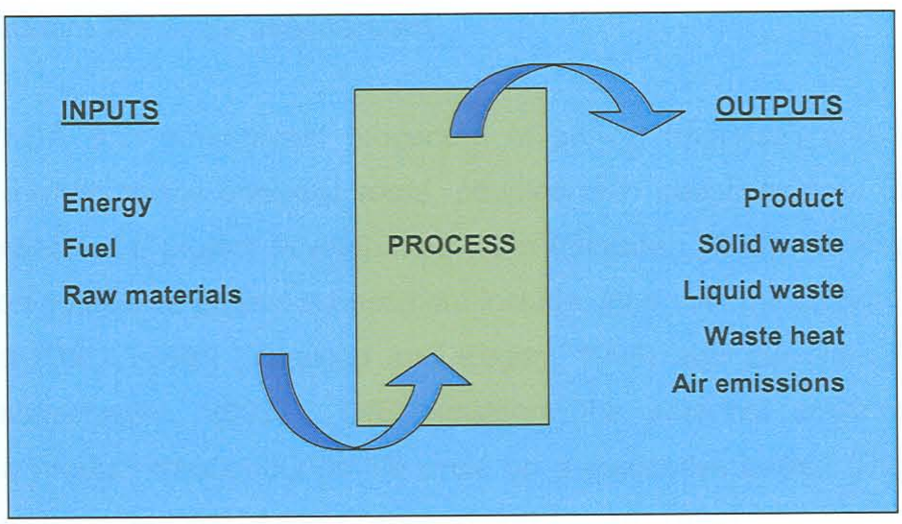


**Figure 2.5** LCA framework.

Life cycle assessment evaluates all stages of a product's life from the perspective that they are interdependent, meaning that one operation leads to the next, in producing either quantitative or qualitative outputs (Senthil *et al.*, 2002a).

### 2.6.1 Quantitative life cycle assessment

Quantitative life cycle assessment entails coupling a quantitative value to environmental impacts associated with a project by (Little, 2000):

- compiling an inventory of relevant energy and material inputs and environmental releases,
- evaluating the potential environmental and social impacts associated with identified inputs and releases, and
- interpreting the results to make informed decisions.

Including all impacts throughout the project life cycle, quantitative life cycle assessment provides a comprehensive view of the environmental aspects of the project and a more accurate picture of the true environmental trade-offs in product and process selection (EPA, 2001).

### 2.6.2 Qualitative life cycle assessment

Qualitative LCA is a streamlined procedure of project appraisal, and usually follows an environmental checklist route, coupled with questionnaires used to survey members of a project development team (Graedel, 1998). Examples of work done on qualitative project assessment include, *inter alia*, the Design for the Environment (DfE) Toolkit (Yarwood and Eagan, 1998) and the Gate Review method (Labuschagne, 2002). DfE considers the potential environmental impacts of a product throughout its life cycle on a qualitative basis. There are three unique characteristics of DfE (Yarwood and Eagan, 1998):

- the entire life cycle of a product is considered,
- point of application is early in the product development process, and
- decisions are made using a set of values consistent with industrial ecology and integrative systems thinking.

DfE is an integral part of the product development process along with other design considerations, such as product economics, customer requirements, manufacturability and required product functionality (Yarwood and Eagan, 1998).

The Gate Review method determines a project's continuability through a procedure of asking certain feasibility questions relating to the environmental and social concerns of the project, at typical objective stages or gates throughout the project's development (Labuschagne, 2002). In order to answer these questions, a project must be evaluated against certain criteria at the different gates. All aspects of the project are addressed in parallel and gate criteria are often repeated in consecutive gates. This ensures that important issues and impacts are addressed throughout the project life cycle (Buttrick, 2000). The main stages usually considered in gate reviews are presented in Figure 2.6 (Labuschagne, 2002).

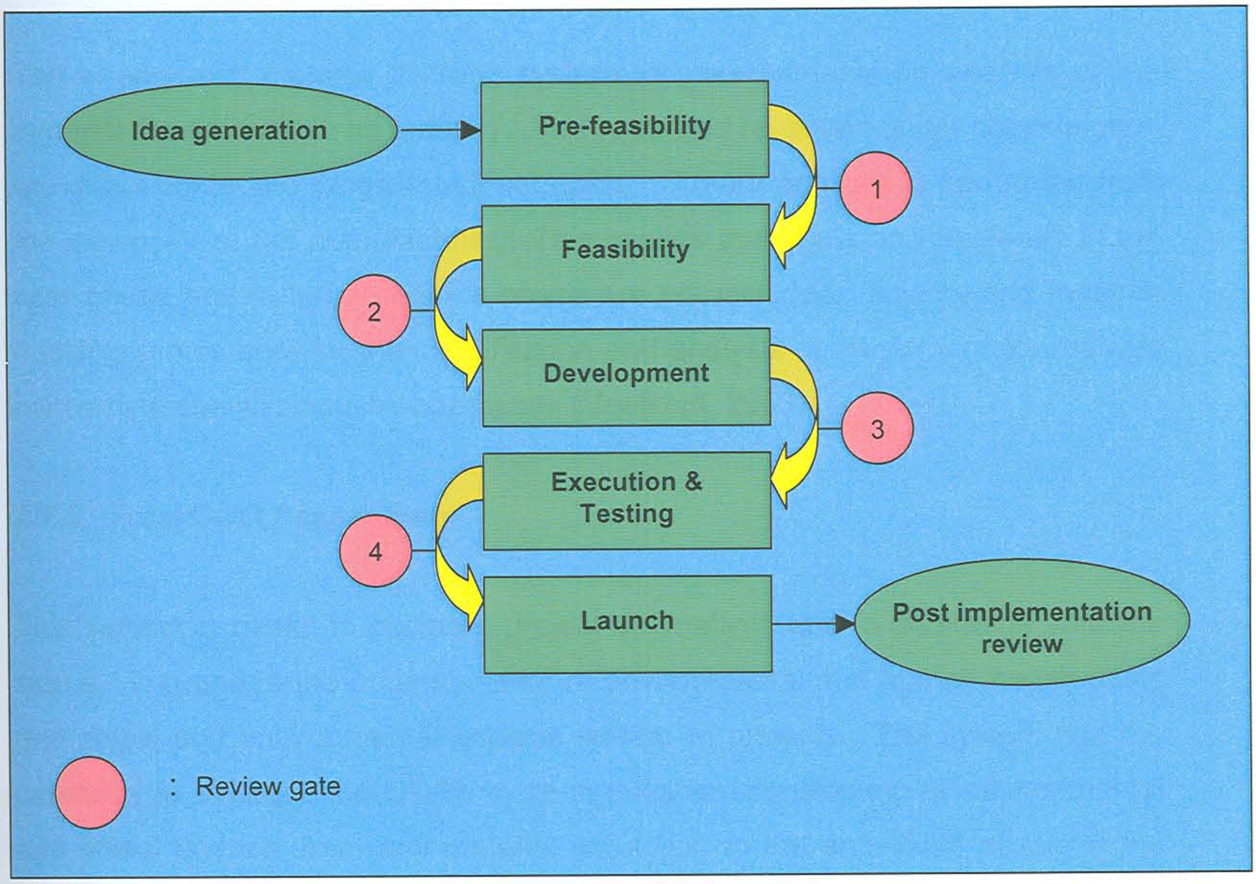


**Figure 2.6** Project life cycle with gate reviews.

## 2.7 ENVIRONMENTAL ACCOUNTING SYSTEMS

Several systems have been developed for incorporating environmental costs and capital budgeting procedures into managerial decision making, based on product or project life cycle assessments. These include (Veefkind, 2003):

- Energy and Material Tracking (EMT),
- Total Cost Assessment (TCA),
- Life Cycle Costing (LCC), and
- Full Cost Assessment (FCA).

### 2.7.1 Energy and Material Tracking

The energy and material tracking system focuses primarily on analysis of the material streams within an industry. The costs and revenues under consideration are direct costs and tangible indirect costs. Stream analysis is performed from the viewpoint of the manufacturer. This implies that costs and revenues in the user phase and in the end-of-life phase are not included. Energy and material tracking serves best for the identification and analysis of investment alternatives concerning specific industry operations (Veefkind, 2003).

### 2.7.2 Total Cost Assessment

This system is useful to compare project alternatives and to determine baseline status. It supports the understanding of environmental and human health costs and social and environmental impacts related to projects. The system has the capability to evaluate the full life cycle in question, considering all environmental and social aspects from raw material extraction to the end-of-life phase of the product or process. Total cost assessment (TCA) is not designed to replace existing capital project and product development cost estimating practices, but rather to enhance these costing exercises by focusing attention on the potentially hidden environmental, human health and external costs (Little, 2000).

The TCA methodology is based on a life cycle approach and is designed for internal managerial decision making. When a corporation must decide between alternative projects, all potential environmental and human health costs should be fully considered. This methodology provides the framework for that decision process, as well as the framework for estimating baseline costs that have a much broader and potentially longer timeframe. Potential user groups of this system include (Little, 2000):

- product or process engineers in the design stage of new products and processes,
- engineers in the assessment of environmental projects, and
- business managers and analysts in developing product and business strategies.

The TCA methodology consists of six steps of analysis with a final step being a feedback loop providing input into the company's main decision process (Little, 2000). The purpose of the first three steps is to clearly define what aspects of the project or alternatives are important enough to carry forward and to fully evaluate. Once the first three steps have been completed, the financial inventory is developed for each project or alternative. The steps are as follows:

- *Goal and scope definition*: clearly identifies and defines the project and purpose of the total cost assessment.
- *Streamlining the analysis*: refines the first step by connecting the objectives and other elements of the decision at hand to sustainability metrics and impact categories and provides for the incorporation of life cycle information.
- *Identification of risks*: evaluates the relative importance of the impact categories and the current feasibility of expressing the costs for each attribute of an alternative or project.
- *Conducting the financial inventory*: with the focus on acquiring company specific environmental costs.
- *Impact assessment*: revision of costs to determine the largest cost contributors for each category and to assess how that information may be best incorporated into the overall decision making process.

- *Feedback to company's main decision loop*: feedback to the main decision making process within the company, recognising that the total cost assessment is only one element or input to an overall decision making process that includes many types of information.

The total costs assessment system does not advise a method of valuing internal intangible and external costs. As these costs are subjective, an objective framework to evaluate and determine cost factors involved in the development of these costs is important. Another weakness of applying the system is the availability of data for some materials and processes as input into the system. Divergence in inventory data is inevitable due to many factors, including (Little, 2000):

- the differences in unit operations among alternative systems,
- the overall quality of the data (for example, completeness and representativeness), and
- the complexity of environmental and social processes.

### 2.7.3 Life Cycle Costing

Life cycle costing (LCC) entails a number of economic assessment models, all of which considers the money flows that are related to the existence of a project or product (Dhillon, 1989). Life cycle costing has a cradle to grave approach based on the output of a quantitative life cycle assessment with all costs and revenues being accounted for on equal percentages (Kirk and Dell'Isola, 1995). This valuable information is used to account for the full impacts of decisions, especially those that occur outside of the site that are directly influenced by the selection of a product or process (Yarwood and Eagan, 1998).

Life cycle assessment (LCA) data are often directly applied to existing life cycle costing models. The focus of LCA models is on environmental objectives, whereas LCC models focus on cost structures and economical implications of a product, process or system (Labuschagne, 2002). The differences between LCA and costing models are summarised in Table 2.2 (Norris, 2001). Important life cycle costing characteristics include (Fabrycky and Blanchard, 1991):

- costs and revenues being allocated to individual products instead of lumping them into an overhead costs category,
- large time horisons are applicable, and
- economic equivalent financial indicators determine benefits of investments.

**Table 2.2** Differences between LCA and LCC models.

| Features | LCA | Costing models |
|---|---|---|
| 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 casually 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 impacting decision maker. |
| Units for tracking flows | Primarily mass and energy; occasionally volume or other physical units. | Monetary units (for example, $, R). |
| 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 value of costs and benefits. A specific time horison scope is adopted and any cost or benefits that occurs outside that scope is ignored. |

Although the objectives of different LCC models vary from each other, the goal is the same - intending to reduce the total cost of a product, project or asset. Life cycle costing models available in the world market include (Senthil *et al.*, 2002a):

1 The LCC model of Dahlen and Bolmsjo.
2 The LCC model of Woodward.
3 The Activity Based Costing model.
4 The LCC model of Fabrycky and Blanchard.
5 The Economic Input-output LCA model.
6 The Design to Cost model.
7 The Product Life Cycle Cost Analysis model.
8 The Life Cycle Environment Cost Analysis model.

#### 2.7.3.1 *The LCC model of Dahlen and Bolmsjo*

Dahlen and Bolmsjo's LCC model is also referred to as 'Life cycle cost analysis of the labour factor' (Labuschagne, 2002). It widens the field of application for LCC by focusing on the cost of an employee over the entire employment cycle, that is from recruitment to retirement (Dahlen and Bolmsjo, 1996). The model carries out an analysis of investments done when raising the production factor of labour (Senthil *et al.*, 2002a).

Dahlen and Bolmsjo (1996) distinguished between three types of labour cost categories, with their classification, in a cost of labour breakdown structure. These are presented in Table 2.3. The benefit of the model is that it assists with industrial decision making through the inclusion of labour related costs in the LCC methodology. It qualifies and assists the verification process related to the following labour related decisions (Labuschagne, 2002):

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

Cost drivers for labour related costs could be labour hours, the number of employees, absenteeism or the number of work injuries. This leads to a wider allocation basis where labour costs are directly related to activities that cause the costs.

The weakness of the model relates to the costs being grouped according to the original cause of the costs. Only thereafter can all the costs be allocated to the cost unit on a proper allocation basis (Senthil *et al.*, 2002a).

**Table 2.3** Cost of labour breakdown structure.

| Cost of labour | | |
|---|---|---|
| **Employment costs** | **Operation costs** | **Work environment costs** |
| Recruitment costs | Wages | Absence costs |
| Interviews | Employee salary | - Quality related costs |
| Information | Payroll taxes | Rejects |
| Advertisements | Overhead | Reworks |
| Administration | Manufacturing overhead | - Productivity loss |
| Additional production costs | Factory overhead | Overtime |
| Learning curve | | Over staffing |
| Controls | | Stand-ins |
| Rework | | - Administration |
| Education costs | | Foreman |
| Instructors | | Planner |
| External education | | Central admin. |
| | | Sickness benefits |
| | | Sick pay |
| | | Payroll taxes |
| | | Vacation benefit |
| | | Rehabilitation costs |
| | | Equipment |
| | | Training |
| | | Investigations |
| | | Disability pension costs |

#### 2.7.3.2 *The LCC model of Woodward*

This model emerged from the objective of essentially planning and monitoring assets throughout their entire life cycle from the development or procurement stage through to disposal of waste (Senthil *et al.*, 2002a). The 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 (Labuschagne, 2002).

The model is concerned with optimising the value of money in the ownership of physical assets by taking into consideration all the cost factors relating to assets during their operational life (Senthil *et al.*, 2002a). Optimising the trade-off between these cost factors will give the minimum life cycle cost of the asset (Woodward, 1997). The LCC model of Woodward (1997) comprises eight steps of analysis:

1. Establishment of operation profiles to qualify the periods when the equipment will operate.
2. Establishment of utilisation factors to establish how the equipment will operate within the periods determined above.
3. Identification of cost elements.
4. Determination of critical cost parameters that may include energy use rate, mean time between failures, mean time to repair and the time period for scheduled maintenance.
5. Calculation of costs at current prices.
6. Escalation of costs at assumed inflation rates.
7. Discounting costs to present values.
8. Summing of discounted costs to establish a net present value.

The model has its strength in estimation of costs of assets, based on the whole life cycle of assets before making a choice to purchase a specific asset from a list of alternative assets. This encourages a long-term outlook of a company's investment decision making process. The model aims at establishing investment options to be more effectively evaluated considering the impact of all costs, rather than only initial capital costs, assisting in the effective management of completed projects and facilitating the choice between competing alternatives.

The success of this model depends on accurate, relevant and timely information. The restriction of this model lies in the optimisation of the value of money in asset ownership. It aims to optimise the total cost of asset ownership by identifying and quantifying all significant net expenditures that may arise during the ownership of an asset (Woodward, 1997).

#### 2.7.3.3 *The Activity Based Costing model*

The activity based costing model can be applied to determine the life cycle cost of a product or project and has the best potential for effective cost assessment in the context of life cycle design (Senthil *et al.,* 2002a). This model is generic and can be applied whenever the activities are described in detail. The model has the capability of dealing with uncertainty and applies Monte Carlo simulation for such purposes (Labuschagne, 2002). The model consists of six steps (Bras and Emblemsvag (1996), as cited by Senthil *et al.,* 2002a):

- Creation of an activity hierarchy and network that will ensure that all activities in the part of the life cycle are considered.
- Identification and ordering of all the necessary cost drivers and consumption intensities.
- Identification of relationships between cost drivers and design changes.
- Determination and minimisation of the cost of the consumption activities, that use an optimisation algorithm where the design parameters serve as the source variable and the total cost as the response variable.
- Evaluating the solution.
- Iteration.

When dealing with environmental issues, uncertainty must be included due to the predominant lack of hard data. The inclusion of Monte Carlo simulation in conjunction with the above mentioned steps provide the capability to identify the project and product design aspects and uncertainty that contribute most to the costs (Society of Management Accountants of Canada, 1996). The activity based costing model for the assessment of external environmental and social impacts and costs, however, still needs more rigour in its development and functionality before it can be applied as a standalone decision making tool (Labuschagne, 2002).

#### 2.7.3.4 *The LCC model of Fabrycky and Blanchard*

Fabrycky and Blanchard (1991) presented an LCC model that addresses detailed cost analysis of all the costs concerned with the entire life cycle of any product. The excellence of the model lies in its detailed cost breakdown structure. The methodology of the model is presented in Figure 2.7.

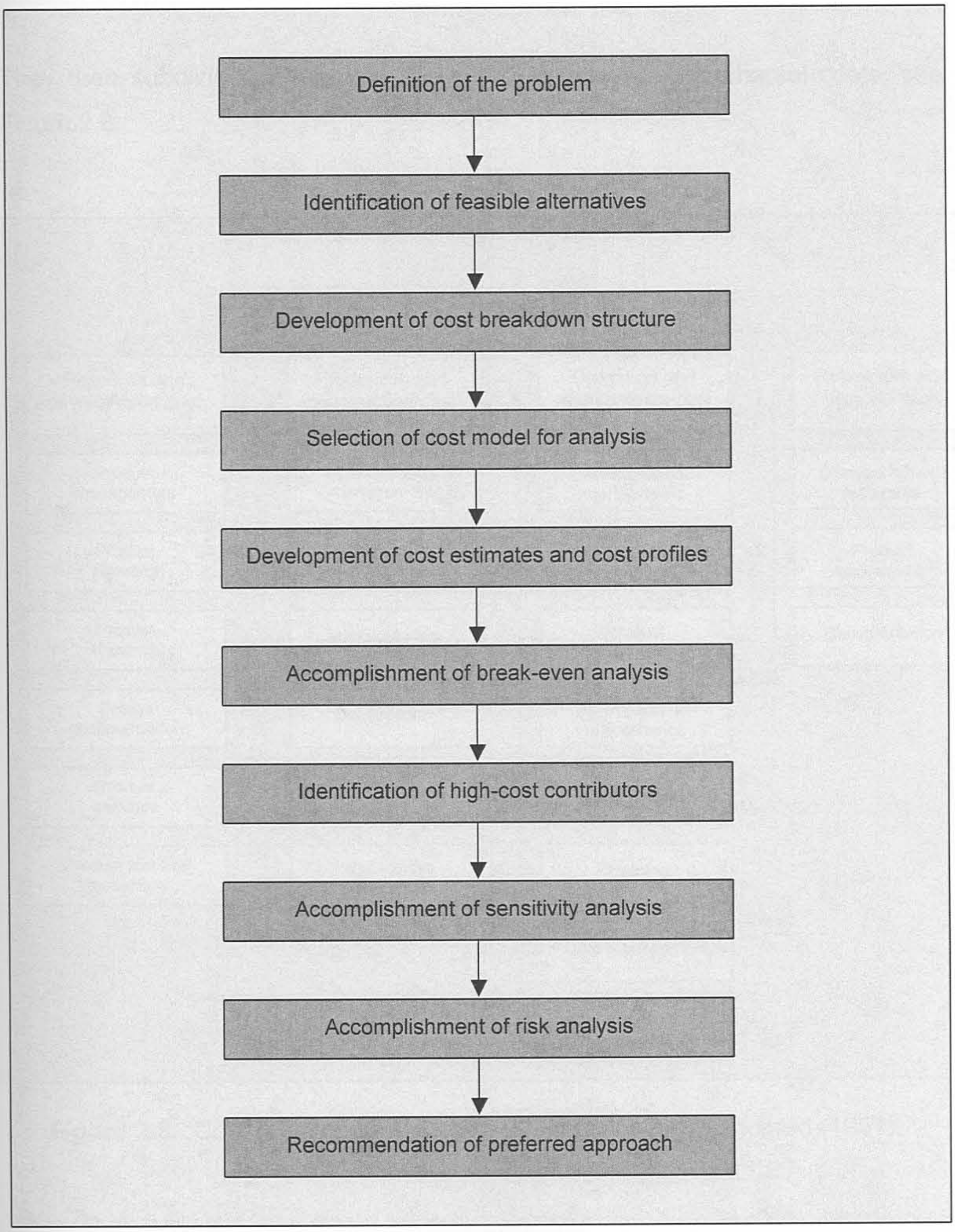


**Figure 2.7** The LCC methodology of Fabrycky and Blanchard.

Fabrycky and Blanchard (1991) divide the total cost of a product or a system into four categories that include:

- research and development costs,
- production and construction costs,
- operation and maintenance costs, and
- retirement and disposal costs.

They then subdivided each cost category into relevant incremental costs, see Figure 2.8.

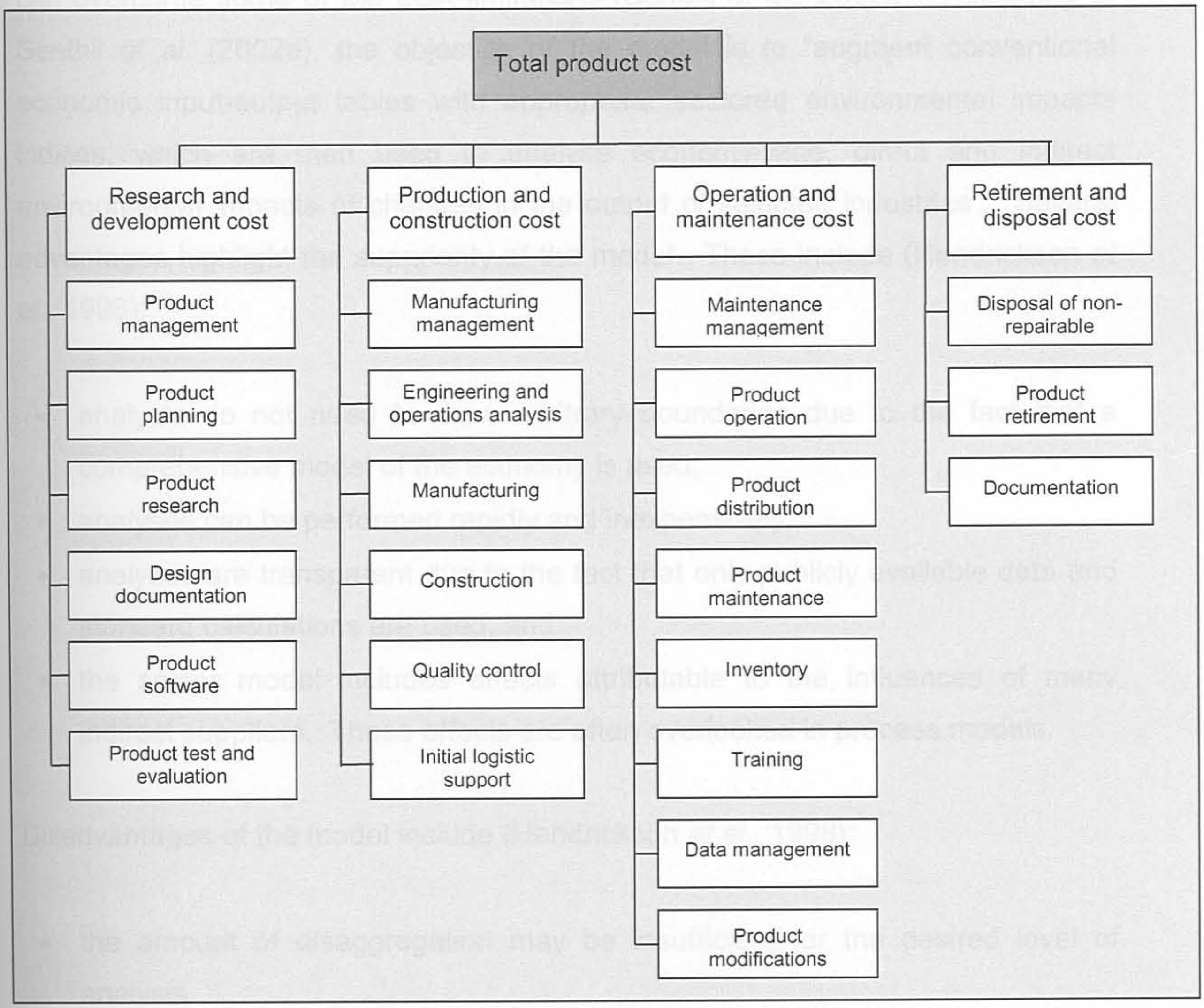


**Figure 2.8** Cost breakdown structure of Fabrycky and Blanchard (1991).

The model can be implemented to address a wide variety of high cost factors at different stages of a new product or project's life cycle (Asiedu and Gu, 1998). It also assists in the assessment of high-cost contributors and costly problem areas of existing products or projects. However, the accomplishment of life cycle cost analysis using this model is iterative and must be tailored to specific applications. Given its generality though, the model can easily be extended to include more recent costs into its cost breakdown structure for different applications.

#### *2.7.3.5 The Economic Input-Output LCA model*

The model complements conventional life cycle assessment (LCA) procedures and can overcome some of the LCA limitations (Senthil *et al.,* 2002a). According to Senthil *et al.* (2002a), the objective of the model is to "augment conventional economic input-output tables with appropriate sectored environmental impacts indices, which are then used to analyse economy-wide, direct and indirect environmental impacts of changes in the output of selected industries". Several advantages highlight the superiority of the model. These include (Hendrickson *et al.,* 1998):

- 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, and
- the sector model includes effects attributable to the influences of many indirect suppliers. These effects are often overlooked in process models.

Disadvantages of the model include (Hendrickson *et al.,* 1998):

- 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 refect the environmental impacts arising from product use and disposal, and

- it can interpret environmental impacts of products only in cumulative cost terms.

Despite the disadvantages of the model, it offers the ability to examine a product and suppliers in detail and so provides calculations of all of the indirect economic activity and environmental discharges.

#### *2.7.3.6 The Design to Cost model*

This model presents a generic methodology to combine cost modeling and quality function deployment (QFD) in order to assess the potential trade-offs between the cost and performance of competing product alternatives (Senthil *et al.*, 2002a). The model consists of a procedure to select a system design and has three main functions (Senthil *et al.*, 2002a):

- derivation of system performance,
- evaluation of system costs, and
- presentation of results and decision making.

This model is only limited to the early stages of production systems design (Asiedu and Gu, 1998).

#### *2.7.3.7 The Product Life Cycle Cost Analysis model*

The aim of the model is to calculate the life cycle costs of capital goods like machines and it focuses on single processes connected to a product's life cycle (Labuschagne, 2002). Cost reductions in the different product and project life cycle stages are achieved through a "conception directed towards the needs of the use phase. Similar dependency arises in the disposal phase." (Senthil *et al.*, 2002a). Asiedu and Gu (1998) states that the limitation of the model lies in the fact that various techniques need to be used to calculate all cost elements in every life cycle phase of the product or project.

### 2.7.3.8 *The Life Cycle Environment Cost Analysis (LCECA) model*

The objective of the model is to include eco-costs into the total cost of a product and defines eco-costs as all direct and indirect costs resulting from environmental impacts caused by the product over its entire life cycle (Senthil *et al.*, 2002b). The methodology of the model comprise nine steps of analyses, as reflected in Figure 2.9 (Senthil *et al.*, 2002b):

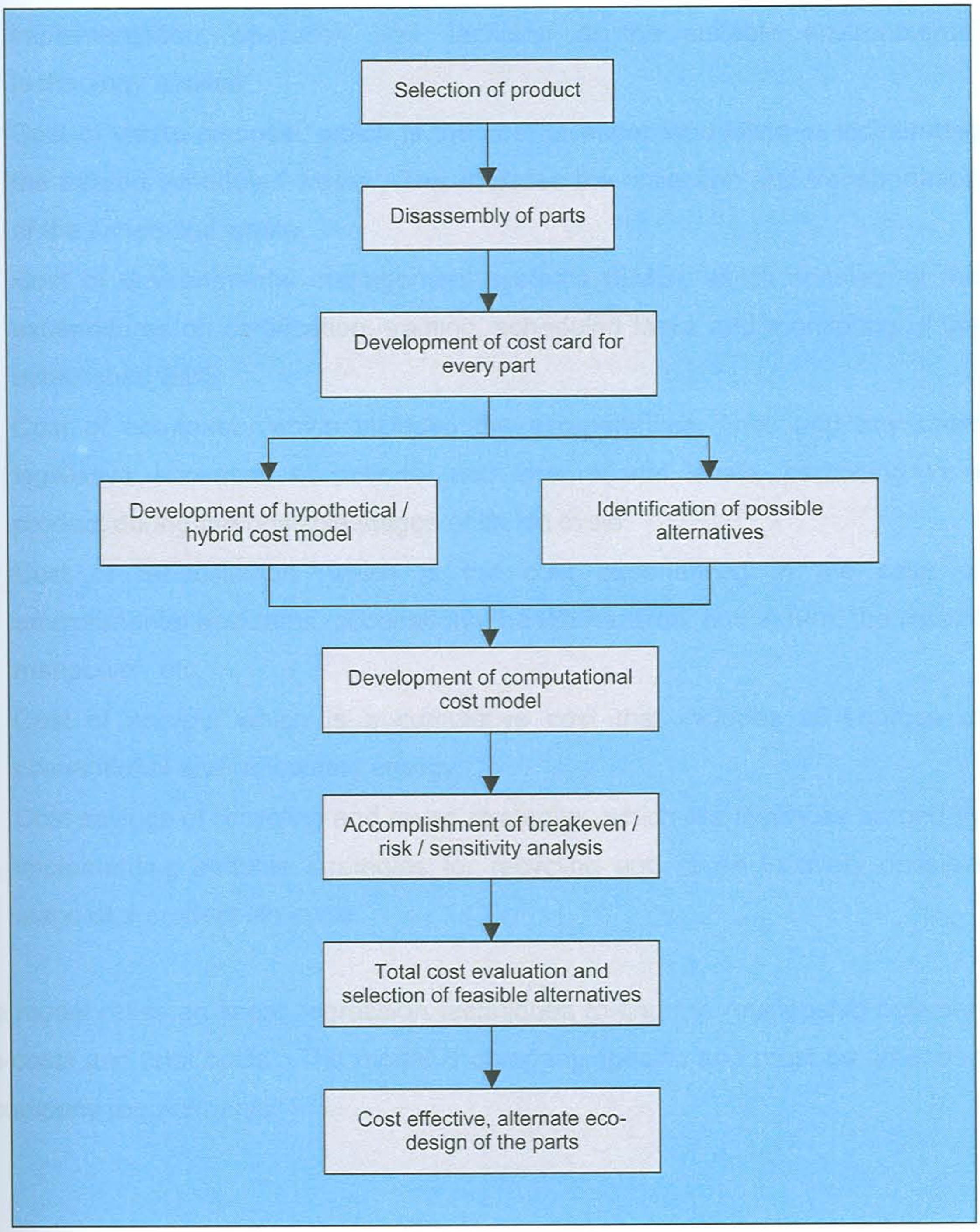


**Figure 2.9** Methodology of the LCECA model.

The model introduces a new generic cost breakdown structure for eco-costs. This cost breakdown structure includes (Senthil *et al.*, 2002b):

- Cost of effluent/waste control, which is the expenditure incurred towards the in-process effluent control in suitable stages of a product life cycle. This includes the installation, operation and maintenance of effluent control systems throughout the process.
- Cost of waste treatment, which is the expenditure in treating the generated wastes at the end of each life cycle stage of a product. This includes the implementation, operation and servicing of the suitable environmental technology applied.
- Cost of waste disposal, which is the cost of either land filling or incinerating the treated scheduled waste. This includes the collection and transportation of the scheduled waste.
- Cost of environmental management systems (EMS), which consists of the expenditures on certification, training, scheduled tasks and monitoring of the established EMS.
- Cost of eco-taxes, which includes the eco-penalties, fines and any other legislative expenses at national and international levels, pertaining to a product during the possible stages of its life cycle.
- Cost of rehabilitation, which is the cost experienced in the case of environmental accidents, occupational health hazards, and in turn, the loss of manpower, etc.
- Cost of energy, which is a cumulative cost that includes all sources of conventional and renewable energy.
- Cost savings of recycling and reuse strategies, which are revenues earned by implementing suitable strategies for recycling and reuse in every possible stage of a product life cycle.

The model relies on linear regression techniques to find the relationship between eco-costs and total costs. The model is company specific and must be amended to company requirements.

Characteristics of these LCC models are presented in Appendix A, Table A.1. External costs are often not considered in most of the developed life cycle costing models. The estimation of external costs, using these models, is difficult and does not provide much informative value due to the low quality and inconsistency of available data; therefore usefulness of these models is limited at present for environmental accounting purposes.

### 2.7.4 Full Cost Accounting

The full cost accounting system is important for government agencies that represent a variety of interests when deciding how to allocate public funds and/or natural resources and to inform decision makers on the trade-offs intrinsic in proposed alternatives (Carter *et al.*, 2001). The objective of full cost accounting is to identify all of the costs associated with providing goods and services, both direct and indirect, regardless of the period in which the related disbursements or expenditures occur (Government Finance Officers Association, 2000). Full cost accounting involves four steps of analysis that include (Carter *et al.*, 2001):

- Identification of stakeholders and relevant values.
- Generation of project alternatives.
- Evaluation of the effects of each alternative on stakeholders.
- Tabulation, adjustment, and reporting of results.

#### *2.7.4.1 Identification of Stakeholders and Relevant Values*

The first step is to identify all stakeholder groups that have an interest in the project or product being considered. A thorough inventory of stakeholders includes those with direct and indirect market interests, as well as those who have a stake in the non-market aspects of the project or product. The indirect stakeholders are affected by changes in the activities of the direct stakeholders after the project is implemented or the product manufactured.

An effort should be made to identify the stakeholders whose interest in the project or product cannot be expressed as changes in market values. Such interests could relate to non-market environmental or cultural characteristics that may be affected by the project alternatives under consideration. A careful assessment of the stakeholders in the early stages of an analysis assists to clarify conflicting interests and reveal potential areas for compromise as the analysis progresses.

#### 2.7.4.2 *Generation of Project Alternatives*

The next step is to create a list of feasible project or product alternatives based on recommendations by scientists and the stakeholders who are closely involved with the project subject matter. This list includes options that are feasible given the characteristics of the study area and the goals of the project. A complete list of alternatives also includes the 'no go' choice.

#### 2.7.4.3 *Evaluation of the Effects of Each Alternative on Stakeholders*

The third step of analysis examines the potential direction and magnitude of each alternative's effect on the recognised stakeholders. First, the potential physical and environmental effects of each project alternative must be identified. Second, to the extent possible, these physical and environmental effects are translated into changes in stakeholder values and compared across alternatives.

Full cost accounting identifies and quantifies four levels of environmental costs (ICF Incorporated, 1996):

- direct costs such as labour, capital and raw materials;
- hidden costs such as monitoring and reporting;
- contingent costs including fines and remedial action; and
- intangible costs including public relations and goodwill.

Companies can use full cost accounting not only to determine the financial impact of their environmental activities, but also to find less costly alternatives by changing process or product design, increasing prices and developing an exit strategy to eliminate environmentally costly products.

Whilst full cost accounting can assist in corporate decision making, the model can not be applied solely for informed business decisions. Full cost accounting is not a standalone environmental accounting tool and must be developed and implemented as part of a larger environmental management system. This system usually relates to a company's environmental management framework for sustainable development.

A comparison of the features of the environmental accounting systems discussed above is presented in Appendix A, Table A.2. From the table it is evident that no system has been developed as such to be utilised as a sole decision making tool, except for the Total Cost Assessment system to some degree, and much research still needs to be done before this will be possible in near future. The systems are useful though when incorporated in a company's overall environmental management system. At present, the systems have the purpose to highlight information about a company's environmental expenditures and revenues, environmental impacts and social impacts. Without using these systems, this information could well be disregarded without company incentives to reduce possible environmental and social impacts and its associated costs.

The Total Cost Assessment system proves to be superior to the other environmental accounting systems available in the world market. This is primarily due to its ability to account for external costs, with sufficient data input it can be utilised as an exclusive decision making tool and due to its ease of application. It has a rigorous approach and can easily be amended for company and country specific purposes.