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IDENTIFICATION AND ASSESSMENT OF CLEANER PRODUCTION TECHNOLOGIES AND APPROPRIATE TECHNOLOGY MANAGEMENT STRATEGIES AND METHODS IN THE SOUTH AFRICAN VEHICLE INDUSTRY

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Abstract

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Environmental degradation is a burgeoning problem owing to the continual expansion of industrial production and high-levels of energy and material consumption world-wide. CP (CP) is a preventive environmental approach, aimed at increasing resource efficiency and reducing the generation of pollution and waste at source, which is being implemented globally and in South Africa. CP is not just an environmental initiative; it also supports other productivity-oriented programmes and strategies.

This report deals with the development of an assessment model for CP to support the business process of a company using TM. A conceptual model for CP assessment including TM assessment of identified CP improvement options is derived.

The research investigates the possibility of improving the understanding of CP by using TM frameworks.

Through direct participation data was collected to compile case studies with in the South African automotive industry. Case studies identify CP focus areas and improvement techniques. Results from the CP assessments were used to forecast cost saving through the implementation of the CP techniques.

The CP improvement options were assessed using three different TM methods. The main reason behind the TM assessment of CP technologies was to develop a better understating of CP from a TM perspective.

Results derived from the TM assessment were used to suggest strategies to benefit managers of companies and other stake holders.

The research provides a different approach towards the understanding of CP technologies and improvement options. The study attempts to link the CP process to the business process in a company using TM methods.

The study contributes towards the understanding and growth of CP technologies in the South African automotive sector and states the challenges with regards to the implementation of CP in South Africa. Based on the TM assessment results, technologies strategies for CP implementation were proposed.

Keywords: CP, TM Framework, CP Audit, CP improvement options, Environmental Management Systems

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List of Acronyms/Definitions/Abbreviations

CP	-	CP
CSIR	-	Council for Scientific Industrial Research
CNCPC	-	Chinese National CP Centre
DANIDA	-	Danish International Development Assistance
DEAT	-	Department of Environmental Affairs and Tourism
EIA	-	Environmental Impact Assessment
EGS	-	Environmental Goods and Services
EMS	-	Environmental Management System
IWMSA	-	Institute of Waste Management of South Africa
NCPC	-	National CP Centre
NGOs	-	Non-Government Organisations
NORAD	-	Norwegian Agency for Development
NSW	-	New South Wales
OEM	-	Original Equipment Manufacturer
SA	-	South Africa
SMME	-	Small and Medium Enterprise
UN	-	United Nations
UNEP	-	United Nations Environment Program
UNEP DTIE:	-	UNEP Division of Technology, Industry and Economics
UNIDO	-	United Nations Industrial Development Organisation
WMC	-	Waste Minimisation Club

1. Background

The challenge of environmental degradation and the need for industrial sustainable development brings forth a growing awareness in the industrial sector to do more than clean up existing pollution. Environmental protection policy has traditionally included the pollution control technology that captures waste at the end of pipe and its disposal through dilution or burial. In recent years the limitations of this approach have become increasingly evident due to rising awareness of global environmental risks, growth of waste volumes, and the limits of waste disposal to land, sea and air, together with the realization that end- of-pipe solutions to pollution simply displace the problem elsewhere or create entirely new environmental hazards. This prompts leading firms and researchers to look for a new model of industrial activity based on the minimization of waste, energy saving and the reduction of resources used in production. This is through the concept of cleaner technologies, which is an integrated pollution control and prevention approach that conserves resources, minimizes waste generation and energy use, and is based on the comprehensive analysis of process and product impacts on the environment.

Environmental policies addressing industrial pollution cannot be separated from technological management. Realistic levels of pollution reduction will be achieved according to both reasonably, technically and economically achievable levels of performance for existing technologies and similarly reasonably achievable levels of technological innovation.

The automotive industry is one of the most dynamic and competitive industries in the world today. Technological innovation is the key to achieving competitive advantage and satisfying growing customer demand.

However, technological innovation shall not be limited to improvement in the quality of products and services provided to the end user, but also improving the environmental performance of companies in the value chain.

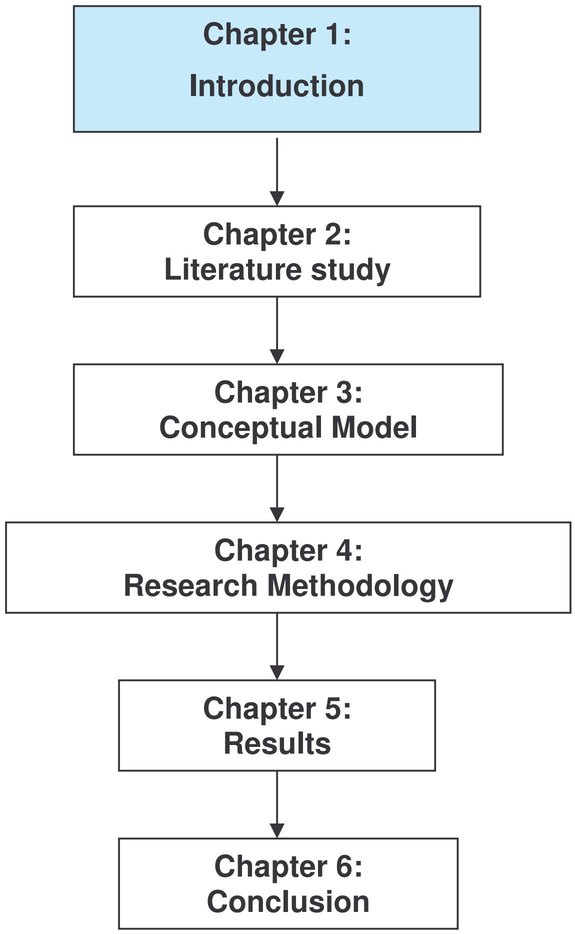
Pretorius M.W., de Wet G, 2000, suggest that, generally technology forcing regulatory instruments directly affect the management of technology, while economic incentives addressing exclusively economic variables influence technological management in a more indirect manner.

According to Phaal R., Farrukh C.J.P., Probert D.R, 2004, technology has been a fundamental driver for innovation throughout the development of human society. With advances in fields such as information and communication technology, biotechnology and nanotechnology, the pace of innovation and change is set to increase further in the 21st century. This poses multiple challenges, for individuals, society and organisations, where managers are faced with hard decisions concerning how best to allocate limited resources, in terms of the increasing cost, complexity and risk of technology investments, against a background of increasing global competition.

This research looks at identifying and evaluating CP technologies in the South African vehicle industry. The objective of the research is to identify CP innovation technologies and present a technology strategy for the sector.

The research was carried out by conducting assessments at various companies and the outcomes are presented as case studies.

The research is laid out as follows:



1.1. Cleaner Production

The United Nations Environment Program (UNEP) definition of "CP", and the one in most common use is, "*CP means the continuous application of an integrated, preventative environmental strategy to processes, products and services to increase eco-efficiency and reduce risks to humans and the environment*".

CP is a general term that describes a preventive environmental approach, aimed at increasing resource efficiency and reducing the generation of pollution and waste at source, rather than addressing and mitigating just the symptoms by technically “treating” an existing waste/pollution problem. CP addresses the problem at several levels at once, serving as a holistic integrated preventive approach to environmental protection.

In other words, CP avoids the end-of-pipe approach.

For processes, CP includes conserving raw materials and energy, eliminating the use of toxic raw materials, and reducing the quantity and toxicity of all emissions and wastes throughout the operational life of the processes.

For products, it involves reducing the negative effects of the product throughout its life-cycle, from the extraction of the raw materials through to the product's ultimate disposal.

For services, the strategy focuses on incorporating environmental concerns into designing and delivering services.

CP focuses on minimising resource use and avoiding the creation of pollutants, rather than trying to manage pollutants after they have been created. It involves rethinking products, processes and services to move towards sustainable development.

A basic CP assessment process is illustrated in Figure 1.1. The process aims to identify waste streams and provide action plan to reduce waste of energy and material.

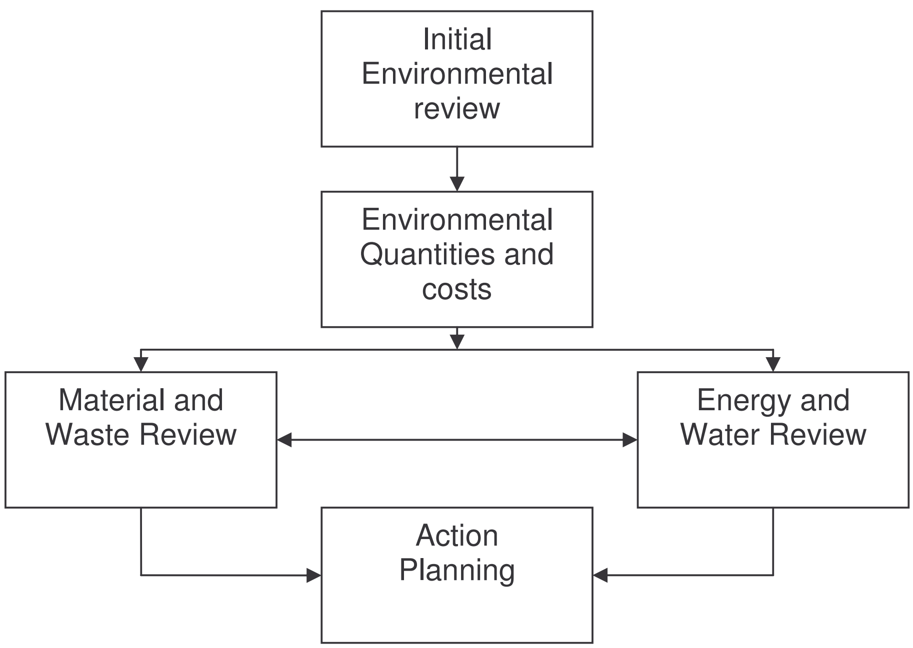


Figure 1.1. Basic CP Process (Centre of Excellence in CP, 2001)

CP is an important indicator of environmental performance of a company. Implementation of CP in an industry has long-medium and medium term financial befits for the company and demonstrates the proactive approach of the company towards environmental performance.

CP can be achieved in many different ways. The most important are:

- ***Changing attitudes*** and finding a new approach to the relationship between industry and the environment.
- ***Applying expertise and know-how*** by improving efficiency, adopting better management techniques, changing housekeeping practices, and revising policies, procedures and institutions as necessary.
- ***Improving technology*** or simply rethinking an industrial process or product in terms of CP may produce the required results without importing new technology.

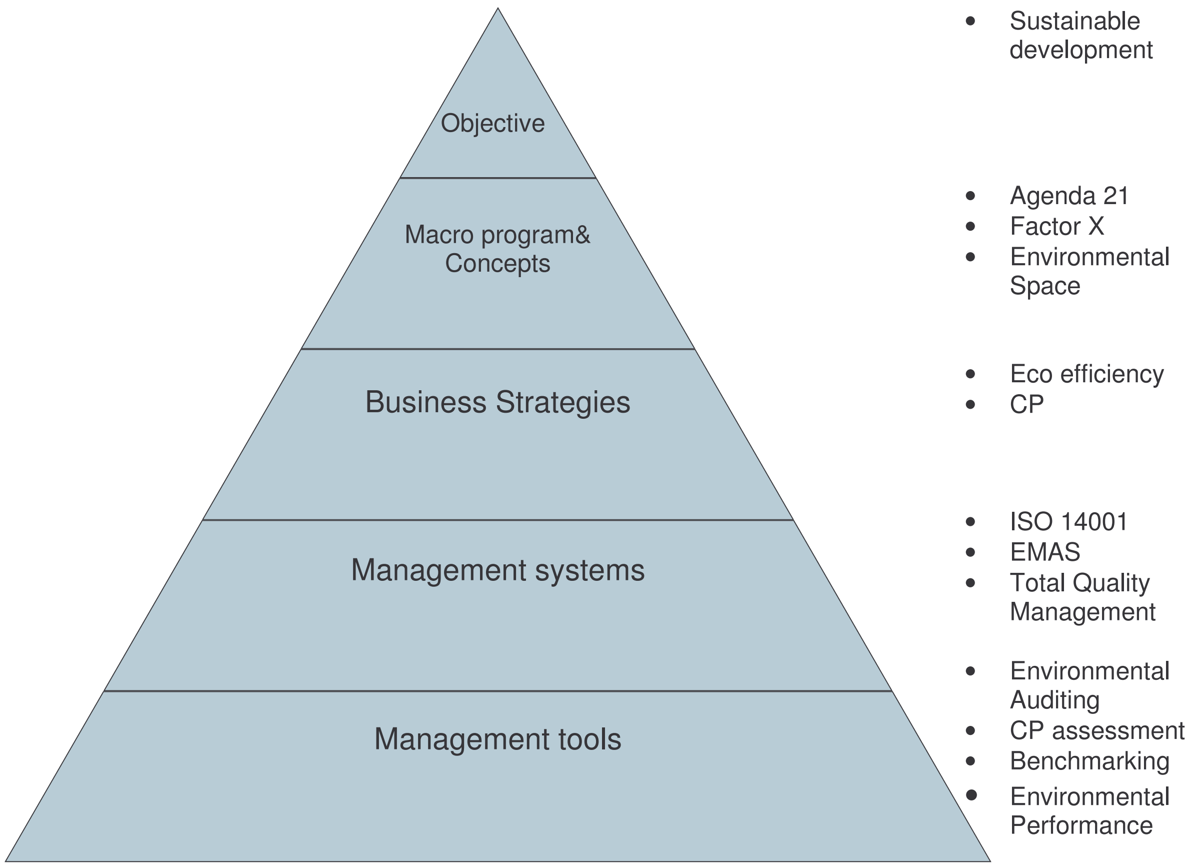


Figure 1.2. CP and Eco-Efficiency – An Approach to Sustainable Development (Department of Environmental Affairs and Tourism of South Africa, Final Report, August 2004)

The mechanism or tools used to implement CP include:

- Measuring and monitoring key performance indicators,
- Waste, pollution & resource efficiency audits,
- Environmental life cycle assessments,
- Process integration,
- Industrial symbioses,
- Green chemistry,

- Dematerialisation,
- Waste minimisation, and
- Design for Environment.

1.2. History of Environmental Management and CP

According to Centre of Excellence in CP, 2001, in the early days, environmental management took the form of dispersing pollution. It was considered that diluting a hazardous material until it was small component of a waste stream would prevent any damage to the environment and to people. With the realisation that substances actually accumulate in the environment, cleaning up or controlling pollution became the norm.

The international Agenda 21 (United Nations Conference on Environment and Development - UNCED, held in Rio de Janeiro, 1992) for sustainable development nominates CP as the methodology industry should use to develop sustainable development policies and strategies. Sustainable development will require large increases in the efficiency of resource use in the years ahead to accommodate increasing World population and consumption without threatening the Earth's natural system and human quality of life.

CP is an effective tool to address environmental problems in order to attain sustainable development. Figure 1.3. shows a simple over view of growing trend towards sustainable development.

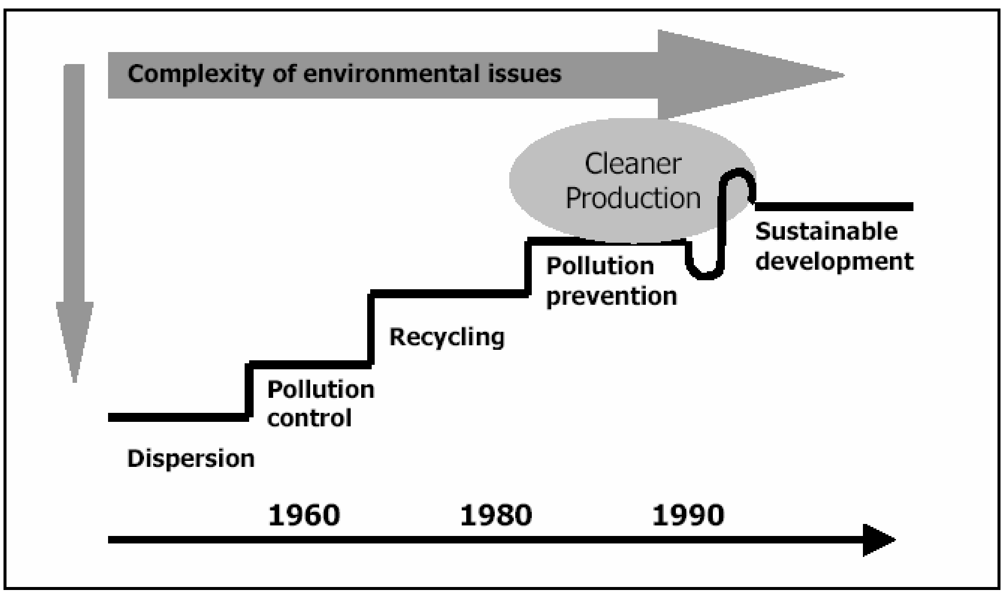


Figure 1.3. Environmental Management History (Centre of Excellence in CP, 2001)

1.3. International Trends

According to the Department of Environmental Affairs and Tourism of South Africa (Final Report, August 2004), environmental degradation is a burgeoning problem owing to the continual expansion of industrial production and high-levels of energy and material consumption world-wide. In the past 50 years the response of industrialised nations to pollutants and environmental degradation evolved as follows:

- Relying on self-recovery of pollutants,
- Ignoring the pollution problems,
- Diluting wastewater or dispersing air pollutants e.g. through higher smokestacks,
- Trying to control the pollution by implementing end-of-pipe technologies,
- Applying CP approach – preventing or minimising pollution at source,
- Applying sustainable consumption and production concepts – efficiently using non-renewable resources, conserving renewable resources, protecting the human environment and not exceeding the functional limits of the ecosystem.

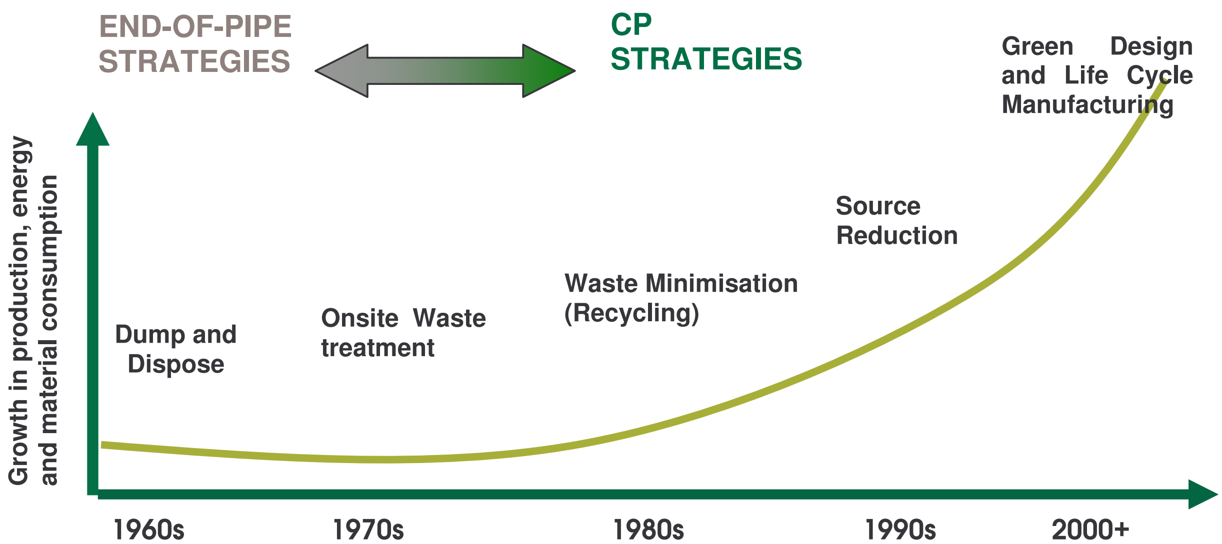


Figure 1.4. The shift towards CP (Department of Environmental Affairs and Tourism of South Africa, Final Report, August 2004)

Many of the World's industrialized nations are putting more and more emphasis on implementing CP within their own borders as well as supporting the implementation of CP in developing countries. The United Nations (UN) has produced a recent Status Report on CP implementation worldwide, with extensive details. Some of the key findings of this report are summarised in the review of International trends below.

In 1992, CP found mention at the Rio Summit (United Nations Conference on Environment and Development - UNCED, held in Rio de Janeiro) as an important strategy to take forward the concept of sustainable development. The commitment of governments to achieving Sustainable Development is set out in *Agenda 21* which made significant references to CP and has in fact served as a guiding framework for the implementation of CP. It also provided a direction and focus to the adoption of CP on a multi-stakeholder and multi-partnership basis (Department of Environmental Affairs and Tourism of South Africa, Final Report, August 2004).

The 20-year period from Stockholm to Rio saw huge changes to global understanding of the relationship between economic activity and ecological systems. By the Rio Summit in 1992, there was a sense of optimism that preventative strategies heralded the potential of a 'change of course', in which industrial and economic development would become compatible with sustaining the global environment (Department of Environmental Affairs and Tourism of South Africa, Final Report, August 2004).

The growing attention to issues of sustainable consumption is a natural outcome of decades of work on CP and eco-efficient industrial systems. It represents the final step in a progressive widening of the horizons of pollution prevention; a widening which has gone from a focus on production processes (CP), to products (eco-design), then to product-systems (incorporating transport logistics, end-of-life collection and component reuse or materials recycling) and to *eco-innovation* (new products and product-systems and enterprises designed for win-win solutions for business and the environment).

1.4. CP Activity in South Africa

According to Department of Environmental Affairs and Tourism of South Africa (Final Report, August 2004) CP is a subsidiary element of South Africa's commitment to sustainable development. The World Summit on Sustainable Development, held in South Africa during 2002, placed Sustainable Development high on International, Regional and Local agendas. The World and South Africa's commitment to sustainable development was contained in the Summit Declaration, entitled the 'The Johannesburg Plan of Action'[1] which South Africa is in the process of implementing. This plan encourages sustainable consumption and production.

One of the outcomes of the Summit was the formation of the United Nations Industrial Development Organisation (UNIDO) National CP Centre (NCPC), formed by an agreement between the dti**,** the CSIR, UNIDO and the donor countries of Austria and Switzerland. The objective of this Centre has been to stimulate wider use CP in South Africa with partnership between Government and other major role players, e.g. industry, agriculture, mining and the consumer.

However, prior to the establishment of the NCPC, a number of (not necessarily coordinated) CP initiatives – by government agencies (i.e. WRC, CSIR), industry bodies, universities, research organisations, and donor agencies (most notably Danish International Development Assistance (DANIDA) and Norwegian Agency for Development (NORAD)) – have taken place, mainly as the result of research and demonstration projects.

Overall, there has been a growing trend of CP related activities within the national economic development arena. Whereas the private sector is more focussed on the practical industry based implementation of CP projects, the public sector has been actively involved in a broad array of activities including research, policy formulation, project financing and implementation. Moreover, local academic, research institutions and privately owned consulting firms are also actively conducting CP related research, creating awareness and documentation of local and international best practices regarding the emerging CP phenomenon and its potential benefits to the participating industries.

There are no effective incentives to encourage all waste producers to adopt CP processes and minimise waste generation. Recycling and reuse are not systematically encouraged.

In the implementation of activities relating to international environment conventions such as the Kyoto Protocol of the United Nations Framework Convention on Climate Change or the Stockholm Convention on the Reduction and Elimination of Persistent Organic Pollutants, CP technologies have been identified as a priority in the Integrated Pollution and Waste Management Policy and the National Waste Management Strategy.

As regards the promotion of CP, the South African environmental legislative framework is generally fragmented, with no consolidated national statute relating specifically to waste management and the promotion of resource efficiency.

1.5. CP in South African SMME's

Small-, medium- and micro enterprises are defined in the National Small Business Act (NSBA, 1996:2) using a schedule based on the number of employees, annual turnover and asset value enterprises are grouped into specific sectors and classes:

Type Number of	Number of employees (max)	Annual turnover (in ZAR million)	Gross Asset value (excluding fixed property, in ZAR million)
Survivalist	0	Varying	0
Micro	5	1.5	0.1
Small	50	5	2

In 1999 a comprehensive survey of the status of environmental management in SMME's (Small, Medium and Micro Enterprise) in South Africa was carried out by Danish researcher Soren Jeppesen with a team of fieldworkers from the University of Port Elizabeth. The survey examined the nature of environmental management practices in 202 SMME's in the following manufacturing sectors in the Port Elizabeth Metropolitan Area (Department of Environmental Affairs and Tourism of South African Final Report, August 2004, pp 125):

- food, beverages and tobacco,
- textile,
- clothing and leather,
- wood and wood production,

- printing,
- chemicals, rubber and plastics,
- non-metallic mineral product,
- basic and fabricated metals,
- electric machinery,
- transport equipment; and furniture.

The survey found that the use of CP techniques and environmental management systems in SMME's is limited due to insufficient regulatory and market incentives. The survey found that the limited use of Cleaner Production techniques and environmental management systems in SMME's is due to insufficient regulatory and market incentives. Although this survey was limited to a particular geographic area, it is nevertheless suggested that it provides a very useful indication of the possible status of CP practices throughout SMME's more generally in South Africa.

The cross-section of industry sectors that was examined in the study, and the distribution of company sizes, is broadly reflective of the national situation. Following is a summary of some of the key conclusions arising from this investigation:

- Most SMME's have very low awareness of environmental costs, and moderate to low awareness of relevant environmental legislation;
- There is generally a very low level of legal enforcement and interaction, with less than 50% of SMME's receiving any information from local Government;
- Many SMME's are using old technology, are under severe economic pressure and are thus very cost and production focussed, with environmental performance generally being of a low priority;
- There is a very low level of interaction between the individual enterprises with only 25% of the SMME's obtaining information from their colleagues;
- There is a strong correlation between the size of a company and the extent to which it uses CP technologies and implements environmental management systems;
- Of the sectors that were analysed in the Port Elizabeth region, the transport equipment sector demonstrated the most widespread use of EMS; this is partly due to the fact that it forms part of a global supply chain. In the transport equipment sector nearly 70% of the companies were found to be using EMS, compared to 32% in the chemical, rubber and plastic sector and less than 10% in the remaining sectors;
- There appears to be increasing pressure on the medium sized companies, particularly in the automotive and the chemical, rubber and plastics sectors, to improve their environmental management practices and for example to implement EMS in response to international market demands; by contrast there seem to be limited driving forces on the micro and small enterprises to implement CP measures;
- There was no evidence of public pressure serving any impact on the environmental performance of the surveyed SMME's.

The South African automobile market is the 18th largest in the world, but accounts for less than one percent of the world market. There are approximately four million registered cars and two million registered commercial vehicles. This means that there are about seven people per vehicle (the United States has 1.3, Argentina 6, Europe 2). The SA automobile industry employs 250,000 people and accounts for approximately seven percent of GDP; the market is worth approximately R120 billion. South Africa is continually striving to reinforce its role as a global player, particularly in the supply of automotive components. This is evidenced for example in Motor Industry Development Programme (Department of Environmental Affairs and Tourism of South Africa, Final Report, August 2004, pp 70).

The major motor manufacturers in South Africa are centred in Port Elizabeth, Durban and Pretoria. The companies represented are BMW, Delta Motor Corporation, Daimler Chrysler (East London), Toyota (in Durban) and Volkswagen (PE).

The tyre industry is the largest of the automotive component manufacturers in South Africa. The market is estimated to be in excess of 10 million tyres per year. In 1996, the four local tyre manufacturers (Goodyear, Bridgestone Firestone, Dunlop and Gen tyre Industries/Continental) sold a total of 4.5 million car tyres. Foreign brands that have established themselves in the South African market are Michelin, Pirelli and Yokohama.

1.6. Waste Minimisation Clubs in South Africa

A key CP initiative that has occurred in South Africa is the establishment and implementation of WMC’s. These are voluntary partnerships that have been devised to promote the exchange of experience and information in the implementation of waste minimisation measures between geographically close manufacturers and/or service providers. They focus on promoting a preventative approach to environmental management by, for example, emphasising the reduction of waste at source. Some of them also focus on such issues as water and energy efficiency.

As a result of the success of the initial WMC (Department of Environmental Affairs and Tourism of South Africa, Final Report, August 2004) , most of which was set up with funding from the Water Research Commission and technical input from the University of Natal’s Pollution Research Group, there has been a significant recent growth in the number of clubs. Cape Town City Council has taken a leading role in promoting the development of Waste Minimisation Clubs in the region, having funded R2 million for establishment of seven clubs.

An automotive WMC was started in the City of Cape Town and ran successfully for over two years. The club consisted of five municipal workshops and two private sector franchises, namely Audi and Mercedes Benz. The majority of the members participated actively in the CP assessment and adopted the recommendations made by the consulting team. Though most of these recommendations had little to no financial benefits in the short term, the members realised the long-term benefits of accountability to the surrounding community regarding pollution prevention and creating a safer working environment for their employees.

The Rosslyn WMC in Pretoria, which is facilitated by BECO-ISB, has two major car manufacturers as members. These are BMW and Nissan. Several automotive components manufacturers are members of the Rosslyn Club. These include Inergy Automotive, The Faurecia Group and ZF Lemforder.

1.7. TM and Innovation

TM is a process, which includes planning, directing, control and coordination of the development and implementation of technological capabilities to shape and accomplish the strategic and operational objectives of an organization (Task Force on Management of Technology, 1987).

According to Wang (1993) TM includes: (1) planning for the development of technology capabilities; (2) identifying key technology and its related fields for development; (3) determining whether 'to buy' or 'to make', i.e. whether importation or self development should be pursued; and (4) establishing institutional mechanisms for directing and coordinating the development of technology capabilities, and the design of policy measures for controls.

Technology plays an important role in the ability of manufacturing enterprises to compete in international markets. In order to make optimal technological investment decisions, management need to understand how technology manifests itself in the business process and what impact it has on the manufacturing enterprise as a whole (Pretorius and De Wet, 2000).

Clearly, TM should not only fulfil the management needs of a specific set of technologies within a domain and inter-domain relationship, but it should also develop the implementation strategies according to the available resources, current technologies, future markets, and socioeconomic environment (Linn et al., 2000). Therefore, how to manage technology has become an important issue in the past few decades, and the TM community has developed a wide range of methodologies and applications for both academic research and practical applications.

1.8. CP technologies for Sustainable Development

Cleaner technologies are increasingly regarded as a key tool for achieving sustainable development. Table 1.1 presents possible concerns and opportunities regarding Cleaner Technologies.

Table 1.1.Cleaner Technologies for Sustainable Development

Possible Concerns	Possible Opportunities
Lack of a strategic approach for the development of a cleaner technology in South Africa.	Potential to promote locally-developed cleaner technologies
No clearly designated responsibility or coordination mechanism within Government for the management of clean production and development.	Potential for South African technology innovations to make inroads into the global EGS market
Possible trade-offs between investment in the development of innovative local clean technologies and making importation of environmental protection equipment easier and less costly.	Potential to take advantage of internationally- funded technology transfer promotion schemes, including mechanisms established under Multilateral Environmental Agreement

Expanding intellectual property rights regimes and international patent laws may hinder access to environmental technologies by increasing costs.	Intellectual property rights legislation protection to South African cleaner affords technology innovations.
There is a low demand for cleaner technology at present in South Africa	Potential to link cleaner technology implementation to job creation.
The effective evaluation of environmental technologies and dissemination of information to industry.	Request from Government for Best International Practice provides CP opportunities
The potential for outdated 'control-based' technologies to be sold or 'dumped' into the South African market.	
Some cleaner technologies are highly capital intensive.	

1.9. CP innovation in the South African Automotive industry

Hall J., 2002, points out that, the automotive industry is a major contributor to industrial and economic development. Established firms have been able to use the results of over 100 years of incremental innovation to deliver a highly functional and desirable product. These results include both technical functionality (i.e. low cost, utility, convenience) as well as non-technical appeal (perceptions of prestige, independence, sexiness, power, etc). Furthermore, the gas combustion engine is a well-established dominant design, in an industry with substantial competencies, with extensive network externalities (road systems, filling stations, repair facilities, etc) and complimentary innovators (oil and gas companies, tyre manufacturers, etc). An alternative technology or means of transportation must not only be able to compete ethically against such strong established entities, but must also be able to do so without radically 'destroying' the competencies of the present regime, consumers will be reluctant to learn new driving skills or change their habits, oil and gas companies may embark on predatory pricing or heavily invest in innovation to reduce prices. Furthermore, new radical innovations often undergo greater scrutiny than established ones. Stakeholders, especially those with sustainable development concerns, often perceive radical innovation as highly risky and therefore unacceptable.

According to the Department of Environmental Affairs and Tourism of South Africa (Final Report, August 2004), the following actions have been suggested with regards to CP technology development

- It is suggested that on the whole, environmental technologies and services are still predominantly influenced by end-of-the-pipe treatment technologies.
- There may be rural initiatives with respect to cleaner technologies (e.g. appropriate technologies using renewable energies) that could feed into a CP information network and assist with research, transfer & development of related technologies in urban areas.
- The EU Document for Best Practice on CP in Textile Industry is already in the process of being reviewed and summarized into a useful form for the South African Industry. A similar approach could be used for other industry sectors.

1.10. CP challenge in South Africa: Key issues and gaps

Department of Environmental Affairs and Tourism of South Africa (Final Report, August 2004) established that, while various CP related activities have (arguably) been undertaken by each level and at most departments of government in South Africa, there is still a lack of more widespread activity, a key reason for this being the poor level of know-how and capabilities in the field. In addition some companies do not widely disseminate their SCP success stories to the public or to Government for competitive and strategic reasons. This is despite the fact that elements of South African legislation and policy – on paper – may be amongst the best in the world being inclusive of key principles such as the precautionary principle, the waste management hierarchy and the polluter pays principle.

The gaps in policy and legislation lie in the lack of appropriate incentives (lack of effective economic instruments), the existence of disincentives for CP (such as low cost of electricity, water, effluent treatment and waste management), as well as the lack of enforcement of the legislation and implementation of policy. The lack of capacity to implement CP-related legislation and policy is being addressed at a limited level, but needs wider and more intensive effort, in addition to the development of partnerships and voluntary agreements to assist the process. In addition, it is easier to regulate an informed industry than to battle against an ignorant one and therefore, no legislation and policy will be effective without strategies to implement a significant effort in awareness raising, education and training on CP at all levels and in all sectors, including national and local government.

Some of the key gaps identified in the study that are impeding the more widespread adoption of CP at policy and legislation level are summarised below:

- The lack of appropriate ***incentives***, in the form for example of appropriate economic instruments
- The existence of ***disincentives*** for CP, such as low cost of electricity, water, effluent treatment and waste management; the experience of some waste minimisation clubs in the Western Cape has demonstrated that inappropriate revenue structures in municipalities has been an important disincentive for local authorities to promote CP, underlining the need to ensure the provision of CP considerations with resource pricing and taxation policies at national and local level and to identify and remove potentially conflicting subsidies
- The lack of ***enforcement*** of the legislation and implementation of policy; a key constraint in this regard is the lack of sufficient capacity and resources to implement CP-related legislation and policy; while this is being addressed at a limited level, there is seen to be scope for wider and more intensive effort, including the potential for the development of partnerships and voluntary agreements to assist the process, as well as a greater focus on technical training and capacity building activities
- Insufficient ***integration and co-ordination*** of CP issues within and between the policy activities of the various organs of state that have an impact on CP related measures; related to this there is seen to be scope for more effective integration of CP requirements within existing licensing and enforcement activities, building for example on the experience of the eThekwini municipality
- There is a general need to improve the availability of ***quantified data*** on the environmental, economic and social costs and benefits of implementing CP

practices; capturing such data will assist in motivating further CP practices, and will be a valuable means for providing effective training at tertiary level.

- There is scope for more effective integration of CP issues within ***EIA and licensing processes*** (building for example on the recent initiative of the Western Province), as well as ensuring provision for CP considerations within permit requirements. In this regard it is suggested that efforts should be taken to learn from and build on the policy and regulatory successes associated with the DANIDA projects, including for example the experience within the fishing industry project, where DWAF issues conditional licences with gradual adoptions of CP as a condition. The experience of the eThekwini municipality may be particularly instructive in this regard.
- There is significant scope for improving understanding and practical application of ***full cost accounting practices*** relating to environmental issues.
- There remains a continuing need for greater integration of CP issues at ***tertiary education*** level, not simply within engineering departments, but also at a multi-disciplinary level overseas (in Denmark) an environmental master of science has been implemented with success.
- There is potential for integrating CP considerations within the ***technical and financial assistance programmes*** aimed at SMMEs; these include working for example in co-ordination with organisations such as the National Manufacturing Advisory Centre (NAMAC) and the various regional Manufacturing Advisory Centres (MACS)
- A number of the projects in South Africa have highlighted the importance of reaching further into the ***supply chain*** and (for example in the case of textiles) to ensure greater involvement of retailers and buyers who in turn may have an impact on consumers
- There is potential for pursuing practical CP initiatives within the ***energy sector***, which in turn could have a beneficial impact on other sectors; the potential for integrating with related energy initiatives, and for building on recent commitments to renewable energy, should be further investigated
- There is scope for raising ***consumer awareness*** on environmentally preferable products and services; while many companies are able to meet EU eco-label criteria at reasonable cost, there is currently insufficient demand to do so
- ***Technical training*** is required to build capacity amongst local authorities on how to practically implement and enforce CP; such training could include the provision of practical guidelines on CP and best available techniques. Training should be reinforced through greater knowledge and awareness amongst political leaders, regulators and decision-makers regarding the nature and potential of preventative environmental practices and the role of appropriate designed and effectively enforced policy.
- Related to this, there is seen to be scope for ***more active participation of key sectors*** that have an important potential influence on the supply chain, for example the retail sector, through their procurement practices, or the financial sector through their lending and investment activities.
- Linked to the above issues is the serious ***lack of a National Waste Information System***; such a NWIS is required urgently to pinpoint opportunities for CP/SCP measures in industries and to encourage industrial symbiosis projects.
- There is merit in developing focused ***CP guidelines*** for government officials; these should build on and are co-ordinated with similar initiatives; these include

for example the recent development by the Western Cape province of CP guidelines for EIA reviewers.

1.11. Research Problem

CP is used as an EMS tool to improve the environmental performance of companies and not integrated with the business function of companies in the South African automotive sector.

1.11.1. Problem statement

CP assessments and audits do not adequately incorporate TM to support better understanding of CP technologies.

1.11.2. Sub-problems

The sub-problems addressed in this research are as follows:

- Can CP assessments be carried-out successfully in the South African Automotive industry (Large companies and SMME's) including the supply chain?
- Can CP audits identify improvement options in the South African Automotive Industry along with cost savings?
- What type of changes are proposed thorough CP assessments?
- How do CP technologies differ between SMME's and larger industries?
- Can TM frameworks be applied to CP technologies?
- Can TM assessment of CP technologies assist in developing a strategy for CP in the South African automotive sector.

1.11.3. Proposition

CP technologies can be better understood by the application of TM to CP assessments.

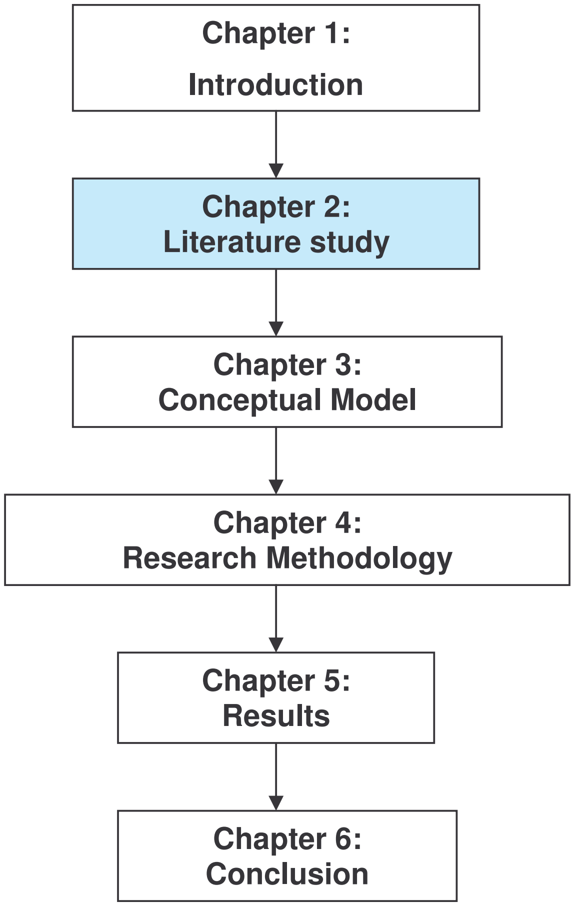
1.12. Research Objective

The main objective of this research is to identify CP improvement options for companies in the South African Automotive manufacturing sector and assess these technologies using TM frameworks. Two main outputs are targeted:

- CP audits are enhanced in the South African automotive manufacturing industry.
- Understanding of CP technologies is enhanced through TM assessments, which will assist in developing a strategy for CP in the South African automotive sector.

2. Literature survey

This chapter gives a primary overview of the relevant literature investigated and studied in the context of this research. CP assessment methods and TM assessments frameworks have been studies and discussed.



The literature review also looks at the differences between the CP innovation between developing and developed countries and between SMME's and Larger Companies.

While CP offers clear and quantifiable benefits to large enterprises economically and environmentally, it is still a relatively new concept to many SMME's. CP can clearly illustrate that industry development, growth and prosperity can be consistent with preservation of the quality of life and the environment.

The aim of this chapter is to study TM frameworks which can be applied to CP to enhance the understanding and application of CP in a business.

2.1. CP Projects

CP assessment is a systematic and planned procedure for identifying, quantifying and finding options to minimise wastes. Implementation of CP options will increase profits and simultaneously reduce the need for end of pipe pollution control (Cooray N).

The objective of a CP assessment is the following:

- Present all available information on use of unit operations, raw materials, products, water and energy.
- Define the sources, quantities and types of waste generated.
- Clearly identify where process inefficiencies and areas of poor management exist.
- Identify environmentally damaging activities and report on legislative compliance.

According to CNCPC (1995), a formal CP project should consist of the following seven steps:

- Planning and Organising,
- Pre-assessment,
- Assessment,
- Option generation and screening,
- Feasibility analysis,
- Option implementation, and
- Continuing CP.

2.2. Developing Countries vs. Developed Countries

According to Peltier N.P (1998), in developing countries and transition economies, additional considerations have to be raised when assessing existing environmental policies or establishing new ones. One of the most significant factors may be limited capabilities to innovate, which suggests that the focus in these countries should be on the diffusion of existing technologies. However, diffusion should itself be distinguished as either the diffusion of nationally adopted technologies, or the diffusion of new technologies imported from other industrialised countries (technology transfer). Requirements for a successful implementation of innovative policies in developing countries and transition economies should include a proper enforcement of regulations when considering the command and control approach, limited market failures for economic instruments, and the extent of social concern for voluntary environmental approaches. In countries with dramatic institutional failures, but progressively opening to a market economy, economic instruments may be preferred at first and be combined with capacity building, before strengthening environmental regulations.

Active CP programmes have been implemented in many developing countries like Mongolia, Sri Lanka, India and Zimbabwe among others.

Pretorius M.W., de Wet G.(2000) suggest that under developed countries lack economic growth as well as technology development. Some developing countries acquire technology from outside the country and use relatively cheap labour costs to create jobs. This is however a short-term strategy for the creation of wealth, with the longer term objective to invest the profit in technology development.

2.3. TM in South Africa

According to De Wet (1989), South Africa is a well developed primary product producer and exporter. R&D is mainly funded by Government at Universities and government institutions. There is low level of demand on utility of research effort. Thus the primary focus is on “what is topical on the international forums” per discipline, because of “publish or perish value system” .

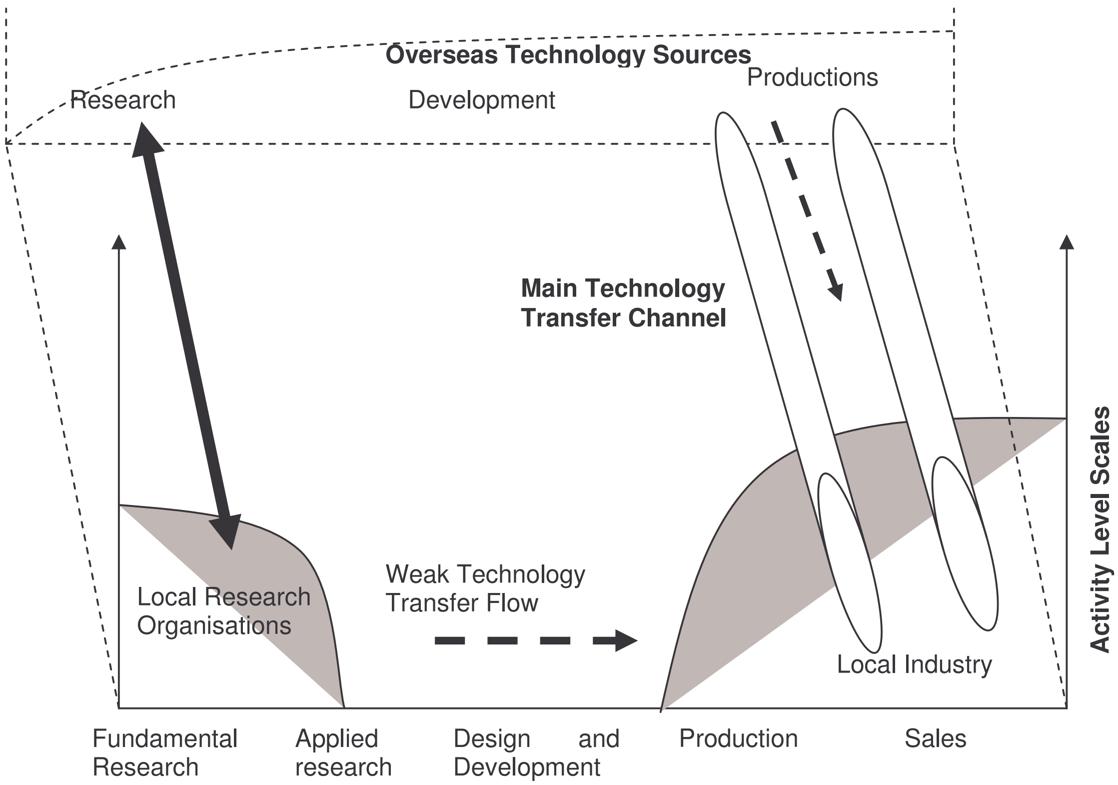


Figure 2.1. Technology Development Scale (De Wet, 2000)

2.4. CP technological Innovation

De Wet (2000) suggests the following strategy for survival:

- Government and industry must work as a team – each making its unique contributions.
- Government must provide objective infrastructure and support.
- Industry should provide technology expertise and agility to exploit opportunities.
- Education and training is known to be a cornerstone towards technological progress.
- Entrepreneurial management and privatisation are others.

De Wet’s (2000) model suggests that most sustainable technologies currently implemented in South Africa are borrowed from over seas sources. Local industry mainly focuses on production and sales of such technology.

Fresner (1998) found that in the course of conducting CP projects, in more than 40% of companies technological innovation was stimulated (changes in material recovery of exhaust heat, introduction of water based paints). For more than 60% of the consultant eco-auditing is more stimulating of innovation than control by instrumentation.

In Lithuania, CP projects resulted in the implementation of more than 200 CP innovations in more than 150 Lithuanian companies. It should be stressed that effective plant maintenance is becoming a higher priority than CP to plant managers. It is important to ensure cost-savings, at all levels that maximise productivity and the implementing energy-saving. Effective and efficient maintenance are not just desirable, but fundamental to profitable business operations. Therefore, central to the environmental view of sustainable development is the concept that economic and social systems are sub-systems of the global environment (Staniskis J.K., Stasiskiene, Z. 2005).

According to the results of monitoring implemented CP innovations, the database ‘‘Implementation of CP in Lithuania’’ was created in 2002. This database provides the information on 168 CP innovations in 74 companies implemented during the last decade in different Lithuanian sectors of economy (Kliopova, S.I., Staniskis, J.K, 2005).

CP projects take time, as it involves organisational, as well as technological changes. It is not enough for consultants to locate the technological options: they also have to be effective catalysts in a process that changes attitudes and organisation. Leadership of the management is a prerequisite for successful pollution prevention projects.

2.5. Classification of CP technologies

In a 1994 study commissioned by the UNEP at the Toxic Use Reduction Institute in Lowell, Massachusetts, proposed ‘CP’ to be classified into four different types of technologies. This study did not determine which quantitative elements should be used to measure the classification. The four types are:

Type 1—Business-driven technologies: In fairly sophisticated production systems, can improve production quality and/or efficiency and competitiveness by reducing costs. Such technologies improve eco efficiency within overall performance improvement and are highly beneficial.

Type 2—Clean technologies: In fairly sophisticated production systems, developed and adopted for the primary purpose of improving environmental performance, they are marginally beneficial (e.g. waterless printing).

Type 3—Appropriate technologies: In fairly simple production systems that improve environmental performance, but are adopted primarily for economic development purposes.

Type 4—'Low-fruit' technologies: In fairly simple production systems that modify existing technologies to improve environmental performance (e.g. waste heat recovery/recycling with special furnaces in aluminium smelting).

These categories are too general to effectively describe the different production situations which now exist or which may occur in the future; this study aims at contributing to a more accurate definition and evaluation of the types of innovations introduced with the aim of improving the environmental performance, and the magnitude of the improvement.

Barbiroli and Raggi (2003) proposed a quantitative method using technical and economical indicators to measure and classify technological innovations that can be adopted towards 'CP'. This method enables innovations to be enlisted according to their importance, each phase of the product life cycle. Results can be expressed either as the improvement of environmental and overall efficiency or as the advantage to the firm and overall economic benefit connected to the new production methods.

2.6. CP assessment based on size of company (Large Enterprises vs. SMME's)

While CP offers clear and quantifiable benefits to large businesses economically and environmentally, it is still a relatively new concept to many SMMEs. CP can clearly illustrate that industry development, growth and prosperity with preservation of the quality of life and the environment.

According to the requirements of ISO 14001 Standards (2005): "*The level of detail and complexity of the environmental management system, the extent of documentation and the resources devoted to it depend on a number of factors, such as the scope of the system, the size of an organization and the nature of its activities, products and services*".

The Bureau of Product Standards (BPS) and Association of Environmental Assessment Professionals (AEAP) suggest that, the implementation of an environmental management system entails costs which might be difficult for small and medium enterprises (SMME's) to shoulder.

Nihal Cooray (Environment and Industrial Engineering, Project SMED, Sri Lanka) states that, in all developing Asian economies the percentage of SMME's is well over half of industrial production. Although the waste from individual SMME's is small, the environment and health impact of these companies on the community can be quite high. Due to limitations in capabilities; SMME's undergo difficulties of complying with end-of-pipe treatment of effluents.

"Talking of environment to a person who doesn't have money to buy fuel to cook his dinner, he won't even address himself to the problem of deforestation, to the problem of green-house gas emissions or into the problem of toxic emission."

Under this scenario, CP remains the only solution that helps companies become competitive and environmentally friendly. As in many countries SMME's in Sri Lanka are slow in responding to CP. financial barriers are the most significant impediment for implementing CP.

2.7. Waste Minimisation and CP audits in South African Vehicle industry

Waste minimisation clubs have recently introduced a collective means of benchmarking and introducing CP and waste minimisation in the various sectors South African industry, such as metal finishing and automotive (see section 1.6.).

Waste minimisation clubs introduce a systematic method of auditing and calculating the total environmental cost of a waste stream.

A pre-assessment is followed by a detailed assessment of the high cost waste streams. Finally, recommendations are provided on how to reduce waste and costs.

2.8. Technology Management (TM)

The TM discipline is a process, which includes planning, directing, control and coordination of the development and implementation of technological capabilities to shape and accomplish the strategic and operational objectives of an organisation (Task Force on Management of Technology, 1987).

TM includes:

- Planning for the development of technology capabilities;
- Identifying key technology and its related fields for development;
- Determining whether ‘to buy’ or ‘to make’, i.e. whether importation or self development should be pursued;
- Establishing institutional mechanisms for directing and coordinating the development of technology capabilities, and the design of policy measures for controls.

Using the TM frame work, CP technologies can be analysed and managed to lead into sustainable growth.

2.9. Technology Management Tools

Phaal et al (2006) discusses the many approaches (‘tools’) that have been developed by managers, consultants and academics to understand the practical and conceptual issues associated with the management of technology.

Commonly used tools in TM are:

- Matrices
- Grids
- Tables
- Graphs,
- Checklists
- Taxonomies
- Lists
- Software
- Combinations of these forms

Table 2.1. Matrix Based tool Classification (Phaal et al, 2006)

Classifications	Description
Class: Matrix-based tools	Relatively simple two (or sometimes more) dimensional orthogonal structures, relating key dimensions of the particular management issue being addressed. The axes are divided into categories, or define variables that may be qualitative, quantitative, discrete or continuous in nature. The matrix may contain text, providing information or guidance structured by the axes and associated categories, or may be 'empty', enabling the user to explore the relative positioning of various options, or the relationships between the key dimensions and categories
Type 1: Matrices	Categories (if used) tend to be broad—i.e. several broad divisions are included for each axis. If the matrix is empty, the focus tends to be toward enabling the user to explore the relative positioning of various options (portfolio-type approaches). This is the most common type of tool in the catalogue
Type 2: Grids	The axes are divided into a number of distinct and specific categories, with the number and definition of these categories determined by the user. The matrix is empty, providing a structure that enables the user to explore the relationships between the axes and associated categories
Type 3: Tables	The axes are divided into a number of distinct and specific predetermined categories. The table typically contains text, providing information or guidance structured by the axes and associated categories.
Type 4: Scored profiles	One axis is divided into a number of distinct and specific predetermined categories, with the other specifying a scale, enabling the user to assess or audit performance in terms of the defined categories. The tool may take the form of a radial graph. This type has not been the focus of tool collection, although several have been included in the catalogue for illustrative purposes

Table 2.1 presents matrix based tool classification. The classic '2/2 matrix' is a common example of this type of tool, widely used by consultants and managers in business, as well as by academics.

Managers face a number of challenges when wanting to use of a tool:

- How to find appropriate tools?
- How to assess the quality and utility of the available tools?
- How to apply the tools in a practical setting or process?
- How to integrate tools with other tools, and with business process and systems?

Matrix based tools have a number of key advantages. Firstly, they are relatively simple, in terms of concept and application, supporting communication and buy-in. Generally the main aspects of such tools can be communicated in the form of a simple diagram. Secondly, matrix-based tools tend to be fairly flexible, in terms of being applicable to particular company situations, perhaps with some customization required. Finally, provided the axes and parameters are compatible, matrix-based tools have the ability to link together, forming more powerful integrated tool sets.

Typically a number of phases are involved during which the tools and frameworks evolve until they are mature and stable:

- Exploratory phase. Early testing of management frameworks and tool concepts in practical applications, to test utility and to ensure that key dimensions of the problem are captured.
- Development phase. Refinement of frameworks and tools in practical applications, assessing the utility of the approach at each step.
- Testing phase. Ensuring the frameworks and tools are stable and useful in a variety of contexts without significant changes.

Technology road mapping is an approach that is used widely in industry to support integrated strategic planning, both at the firm and sector levels.

There are many types of roadmaps, but the most common format comprises a graphical framework that shows how technology and product developments align with business and market goals, as a function of time.

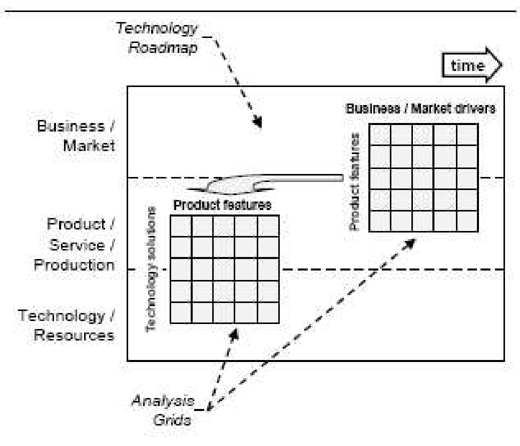


Figure 2.2. Linked analysis grids connect layers of the technology roadmap, providing both structure and a means for prioritisation (Phaal et al., 2001)

The technology road-mapping approach provides a useful integrating mechanism, acting as the focal point for company strategy and planning activities.

2.10. Technology Strategy and CP

Ford D (1988) points out, that technology strategy is that aspect of strategy which is concerned with exploiting, developing and maintaining the sum total of the company's knowledge and ability.

It is important to distinguish between a first technology audit and strategy undertaken in response to a major problem and the regular proactive technology strategy development which builds and maintains a technology position.

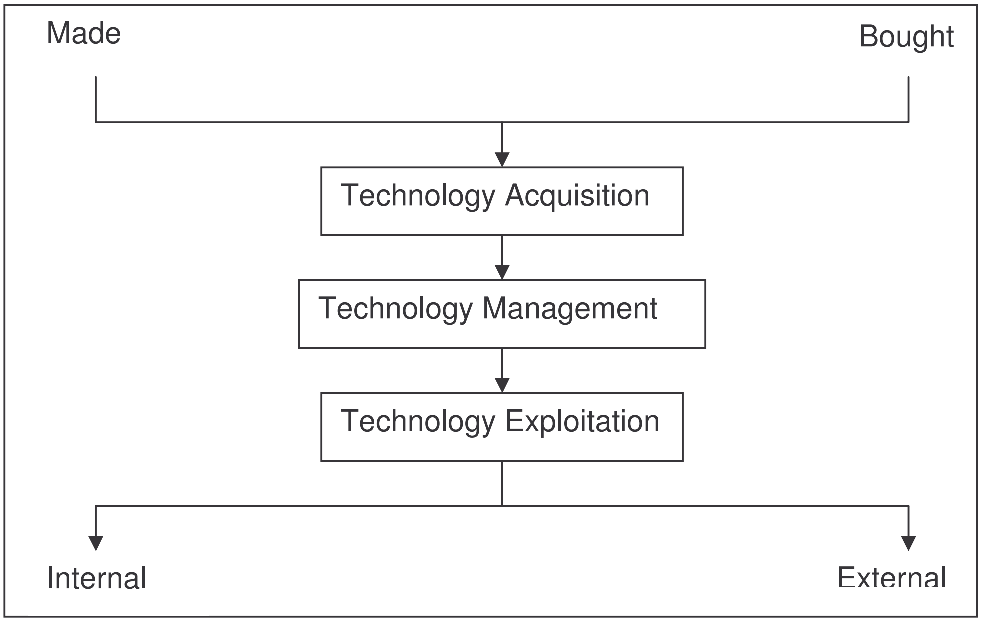


Figure 2.3. The elements of Technology Strategy

According to Peltier N.P (1998), Environmental policies addressing industrial pollution cannot be separated from technological management. Industrial pollution is intrinsically linked to the adoption and development of technology alternatives. Environmental policies from regulation to economic instruments, in industrialized nations as well as in developing countries and the transition economies, cannot ignore the technological dimension when they aim at controlling or preventing the pollution generated by industrialised activities.

Department of Environmental Affairs and Tourism of South Africa (Final Report, August 2004) also suggests that, In South Africa, environmental technologies and services is still influenced by end-of-the-pipe treatment technologies, and there is only very limited availability of know-how and equipment for preventative environmental technologies. If CP is to be promoted across South Africa, then the market must shift and change in composition, *promoting CP solutions ahead of end-of-the-pipe approaches*. This will require creation of enabling environments as well as building local capacity.

2.11. Technology Management Framework

Conceptual frameworks in management theory and practice support understanding of an issue or area of study provide. structure and support decision making and action. New frameworks for management of technology have been developed over a period of time.

Peltie and Asford (1998), presented a three-dimensional technological assessment management assessment model. The assessment distinguishes the three following dimensions:

1. **End of pipe versus CP approaches**
    a. Input substitution
    b. Process Change
    c. Waste recovery
    d. Product design
2. **Diffusion versus innovation**
    a. Incremental environmental innovation through diffusion of well known clean technologies
    b. The transfer of a clean technology commonly adopted in a particular industrial sector, to a new industry or an innovative combination of several incremental innovations.
    c. A truly new break through
3. **Targeting primary, secondary and ancillary process**
    a. Primary processes yield the basic functional form of the product such as forming or casting a part from material.
    b. Secondary processes involve the application of a functional finish, such as non-corrosive or aesthetically pleasing finishes.
    c. Ancillary processes do not affect the characteristic of the product and are usually less fundamental for the whole manufacturing process.

For environmental policy makers, the technological assessment methodology could allow the comparison of the performance of various existing policy alternatives. When certain categories of technologies are not sufficiently explored, extra incentives could be found to promote these alternatives. In the case of economic instruments, more favourable technical or financial assistance could be proposed to enterprises.

However, the model is too general and does not specifically guide the management team towards a technology strategy. The assessment specifically looks at the requirements for France (Developed country) and China (developing country).

Van Wyk (1988) discusses practical application of TM frame works. Two main methods are discussed:

1. **Framework for analysing individual artefacts**

    For the purpose of technology analysis, artefacts can be described with the aid of a framework of general technological features. This framework covers the following features of an artefact:

    - The technology function it fulfils,
    - The physical principle it employs,
    - The material it is composed of,
    - Its size,
    - Its structure.

    Their major outputs are matter (M), energy (E) or information (I). The outputs are the result of processing, in which inputs are changed into new forms: transporting, in which inputs are geographically displaced without necessarily changing their form or structure; or storing in which inputs are kept without necessarily changing or moving them.

Level of performance refers to the capability with which the artefact performs its function.

Physical principles refer to the fundamental manner in which artefacts perform their function. Similar artefacts could employ different principles.

Material composition is another feature that helps describe artefacts. Here the technology analyst would distinguish between essential materials (i.e. those directly associated with the principle according to which the artefacts operates) and non essential material.

For the technology manager the framework of features helps to get behind the more obvious customer-related product characteristics and to uncover the array of technological features that have to be understood and managed in their own right.

A nine cell classification matrix for artefacts based on the technological functions can be crated. The system combines the three categories of major outputs with the three manners of handling. A nine cell table is found which is illustrated in the table below.

Table 2.2 Table of functional categories

Output	Type of manipulator		
	Processor	Transporters	Store
Matter (M)			
Energy (E)			
Information (I)			

2. Chart of technology Limits:

With each technology category there are continuous improvements being effected to the capability of the individual artefacts. From individual descriptions of change a set of generally occurring trends are derived.
Six clear and quantifiable trends:

- Increasing efficiency,
- Increasing capacity,
- Increasing compactness i.e. reduce size.
- Increasing accuracy,
- Increasing the size range,
- Increasing complexity.

A 54 cell table relating each trend to each category of artefacts is developed in table 2.3. combining the nine cell classification and standard set of technological trends.

Table 2.3. A chart of technological limits

		Types of limits					
		Efficiency	Capacity	Compactness	Accuracy	Size	Complexity
Material handling device	Processor Transporters Stores						
Energy handling device	Processor Transporters Stores						
Information handling device	Processor Transporters Stores						

The technology manager can use the frame work to review his knowledge of ultimate technological limits and to keep track of new information on where these limits lie. Knowledge limits help decision in at least three areas:

1. The greater the difference between present technological parameters and those that are ultimately achievable, the greater the unconquered territory that the innovator can exploit.
2. For the technological forecaster, knowledge of where a limit lies helps him improve his prognosis of the future behaviour of a given technological trend. The further the limit, the steeper the graph that the forecaster will visualize.
3. The knowledge of limits helps the manager to target R&D. It helps to define more accurately those areas of performance that are achievable and those that are not.

Phaal et al. (2004) developed the elements of technology strategy (Figure 2.2) to present a framework developed to support practical and theoretical understanding of the management of technological innovation. At the heart of the framework are two (see Figure 2.4.) sets of business processes that are important for effective TM:

1. Core Business processes
   - Strategy
   - Innovation
   - Operations
2. TM processes (ISAEP)
   - <u>Identification (I)</u>
     Identification of technologies that are not currently part of the firm's technology base, but may be important in the future (for example, by attending conferences, reading journals, visiting trade fairs, questioning suppliers and conducting pure research)
   - <u>Selection (S)</u>
     Selection of those technologies that the firm needs for its future products and technologies (for example, by using portfolio-type methods, expert judgement, pilot studies and financial methods).
   - <u>Acquisition (A)</u>
     Acquisition of the technologies that have been selected (for example by R&D, Implementation, licensing, purchase of equipment, hiring of staff and acquisition of firms)
   - <u>Exploitation (E)</u>
     Exploitation of the technologies that have been acquired (for example, by incorporating into products and services and licensing).

- Protection (P)
  Protection of the technological assets of the firm (for example, by legal means such as patenting, contracts, trademarks, copyright, together with security measures and retention of key staff).

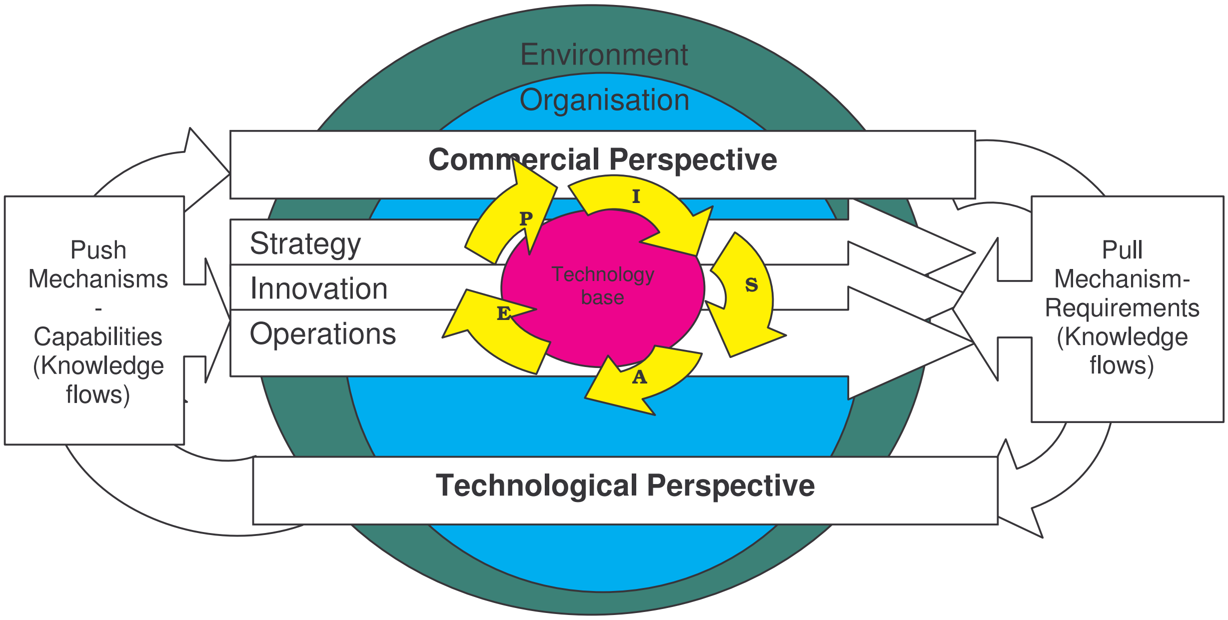


Figure 2.4. TM Framework (Phaal R., Farrukh C.J.P., Probert D.R., 2004)
Implementation of the ISAEP model requires the following aspects:

- Mechanism for *Business processes:* The ISAEP TM processes do not operate in isolation, and are generally not managed as separate 'core' business processes. The various activities that constitute these management processes tend to be distributed within other business processes (for instance, technology selection decisions are made during business strategy and new product development). Three core business processes of particular importance: *strategy, innovation and operations* (SIO). These operate at different business system 'levels' in the firm. The aim of effective TM is to ensure that technological issues are incorporated appropriately into these processes, to form a technological management system that is coherent and integrated across and beyond specific business processes and activities.

- Linking technological and commercial perspectives: The frame work emphasises that a dynamic nature of the knowledge flow must occur between the commercial and technological functions in the firm. These link the strategy, innovation and operational processes, if the technological management is to be effective. An appropriate balance must be struck between market 'pull' (requirements) and technology 'push' (capabilities). Various 'mechanisms' can support the linkage of commercial and technical perspectives, including traditional communication channels (for example, discussions and e-mail), cross functional teams/meetings, management tools, business processes, staff transfers and training.

- *Context:* The specific TM issues faced by firms depend on the context (internal and external), in terms of organisational structure, systems, available infra structure, culture, the particular business environment and challenges confronting the firm; all of which change overtime. In this regard, contingency theory is very relevant.

- *Time:* Time is a key dimension in TM, in terms of synchronising technological developments and capabilities with business requirements e.g. in the context of evolving markets, products and technology. Although time is not explicitly depicted in the frame work, it is implicit in SIO business and ISAEP TM processes.

The CP assessment method as presented in Section 2.1, shows that Identification and Selection (ISAEP) processes are followed during a CP assessment. However Acquisition, Exploitation and Protection of CP technologies does not form part of the basic CP assessment process.

2.12. Technology Assessment

Porter (1985) emphasises that technological change is a primary force behind competitiveness. His value adding chain concept provides a solid base for the implementation of technology in all facets of business and not only in isolated technology islands within the enterprise. He identifies various technologies within each phase of the value adding chain that must be used synergistically in order to optimise productivity. The impact of new technology should be measured against the requirements of current markets. These requirements include low product prices, high product quality, short product lead times, product variety and environmentally friendly products.

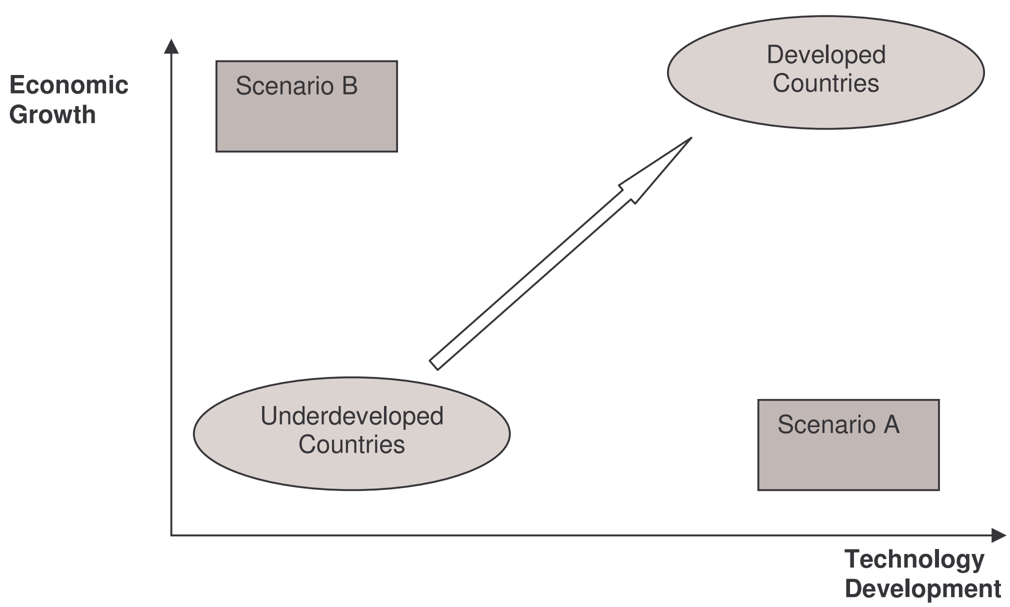


Figure 2.5. The ideal technology growth path (Pretorius and De Wet, 2000)

Two growth scenarios are pointed out in the Figure 2.5. Scenario A represents a high rate of investment in technology without a corresponding growth in economic strength. This scenario typically points to problems in the technology strategy. Scenario B, on the other side, represents a high growth in economy supported by a relatively low investment in technology. A typical Scenario B strategy would be to acquire technology from outside the country and use relatively cheap labour to create jobs. This is however a short-term strategy for the creation of wealth, with the longer-term objective to invest the profits in technology development.

Pretorius and De Wet (2000) present a 3 dimensional framework using the system characteristics, hierarchy, fundamental functions and life cycle. A basic framework is shown in Figure 2.6. This frame work assists the analyst in answering the following questions:

- Which basic functions should be done by the manufacturing system in order to satisfy the market requirements?
- When is the right point in time to perform a basic system function to ensure optimum results?
- Where in the system hierarchy should each of the various tasks be performed in order to be most effective in achieving economic growth?

Interpretation of the basic framework can be done as follows: a transformation function exists within each phase of the business life cycle, thus forming a chain of transformation activities across the life cycle dimension. At the same time, a specific set of responsibilities regarding the transformation functions exists within the hierarchy, for each phase of the business cycle. Exactly the same interpretation can be done for the other fundamental functions of information processing, measurement and coordination.

An important part of the technology assessment is the analysis of the relationship between a technology and the enterprise. Two analytical techniques can be used to quantify this relationship. First, the Technology Space Map quantifies the technological capability of people in the enterprise. The life cycle phases, the product breakdown and the organisational structure are evaluated. Second, the Technology Balance Sheet and Income Statement (de Wet, 1989) quantifies the relationships between technology, processes, products, markets and return on investment. Using the results of these two analytical techniques, the factors that influence technology transfer can also be evaluated. These factors include levels of technological development, amount of knowledge in each hierarchy level, the objectives of technology transfer and product information.

Pretorius and De Wet (2000) illustrate the application of a technology assessment framework by an example. Table 2.4 shows steps the analytical process, done for each of the alternative technologies.

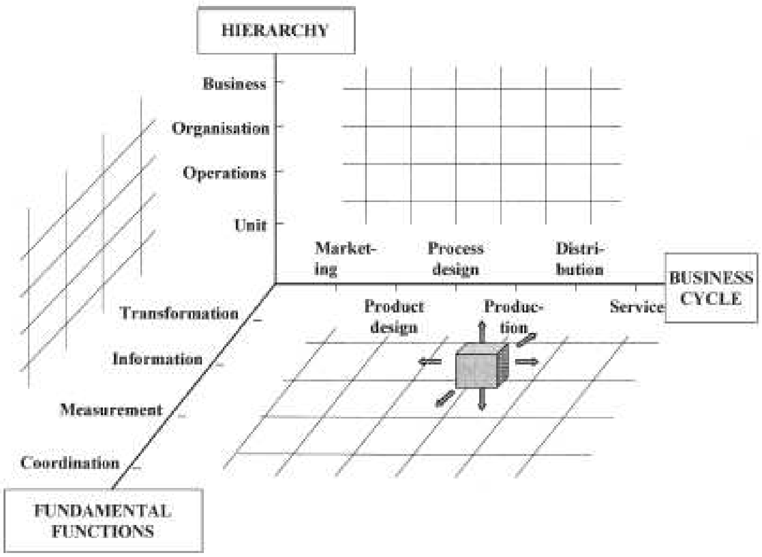


Figure 2.6. Basic Framework for Technology Assessment (Pretoris and De Wet, 2000)

The assessment frame work illustrated below (Table 2.4) shows many similar steps to the CP audit methods in section 2.1.

1. Step 1 of the TM framework analyses technology into sub process, which is also done during the CP assessment, by means of a process flow diagram.
2. Step 2 of the technology assessment is also followed during the CP assessment, quantifies all the inputs, out puts and waste through the process.
3. Step 3 is not distinctly followed in the CP assessment process. The focus of the CP assessment remains to establish techniques to reduce waste generated during the production process.
4. Step 4 does not form part of the CP assessment.

Table 2.4 Examples of steps in the manufacturing industry

Analytical Process	Example
Step 1	The material preparation process was broken down into all its various sub-processes and structured into the complete business cycle.
Step 2	The input and output relationships between the processes in the material preparation function itself were analysed and the interface specification determined. This analysis included the transformation, information, measurement, coordination activities and the current level of synchronization between the fundamental functions.
Step 3	The relationships of manufacturing processes and between business cycle phases were now analysed and relevant interfaces specified. These included, for example, specifications.
Step 4	The hierarchical structure relating to the manufacturing operations department was defined and all the required interfaces and responsibilities specified.

Use of the TM framework with the CP assessment can assist in the identification of improvement technologies. However, as the CP framework focuses primarily on pollution prevention and waste minimization technology options. The TM framework proves a more generic tool for assessment of technologies.

From a generic point of view, the technology assessment should follow the steps of defining the target of the analysis, structure the framework and process structure for the company under evaluation, specify the market requirements, assess the current technology status, evaluate alternative technologies and make the final technology choice (Peltier N.P., Ashford N.A., 1998).

The generic technological assessment framework supports manufacturing enterprises competitiveness in the international markets and improves productivity. This technology assessment framework could also be applied to CP technologies for pollution prevention and waste minimisation. Consequently, the total environmental cost (see section 3.1) could be reduced.

2.12.1. Use of the Technology Assessment Model

Because the characteristics of the technology assessment model, inlcude life cycle phases, fundamental functions, hierarchy and process structures, it can be used for various applications. Such as,

- **Focused technology analysis**
  Like in the example of the laser manufacturing cell, the framework can be used to analyse how a specific technology impacts on the structure and productivity of a manufacturing enterprise.

- **Holistic technology analyses**
  The framework can be used to assess the impact of a set of manufacturing technologies and their impact on the structure and productivity of enterprise. Various aspects of technology integration (For example see Figure 2.6)can be investigated, using the technique.

- **Incremental technology structuring**
  One of the important decisions managers need to make is how much money should be invested in new technology? The framework can be used to evaluate the impact at various incremental stages of technology implementation and thus structure a technology growth path for the enterprise. In a wider sense, the framework can be used as an analytical tool to develop an overall technology strategy for the enterprise.

2.13. Business process redesign

The dynamics of the TM framework lie in the process, it is a handy tool to use together with existing business systems analytical techniques, to analyse business processes with the aim of optimising the total business cycle.

CP technologies could be analysed using the TM model to yield any one of the above applications. CP assessment can be used to identify critical waste streams and improvements methods and techniques. These could be analysed using the TM frame work.

2.14. Technology Gap

Conventional CP approaches (waste minimisation, pollution prevention etc) have most influence at the operation levels (Figure 2.6) and little on the business processes. It is essential to integrate CP with the business processes including the strategic development, supply chain management and new products.

The literature study reveals that the CP projects often results in technological innovation and business process changes. However, little or no link exists between the CP process and business process.

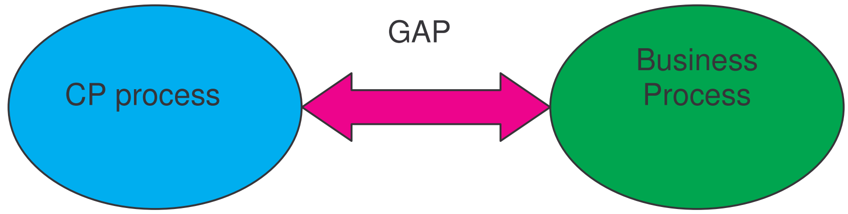


Figure 2.7. Gap between CP process and business process

In the current South African technological setup, most technologies are imported from developed countries (De Wet, 2000). Therefore, CP technologies are no exception, and could be viewed in the same light.

Figure 2.8. Linking CP assessment with Effective TM through TM assessment to develop a TM strategy

Therefore, a link needs to establish between CP assessments (resulting in technological innovations) and effective TM (Figure 2.7.).

The technology assessment model of Pretorius and de Wet (2000) along with the TM frameworks discussed in section 2.11 could be used for assessment of the identified CP technologies.

2.15. Conclusion

The literature survey reveals the following:

- CP assessments are being done in developing and developed countries.
- Most studies with regards to CP evaluation are technical in nature aimed at reducing waste generation through innovation, however little is being done with regards to TM of CP innovations.
- A gap exists between identifying a CP innovation technology and applying TM modelling to develop sustainable strategy.
- The TM framework as presented by Phaal et al. (2000) and Pretorius could be used for assessing CP technologies.

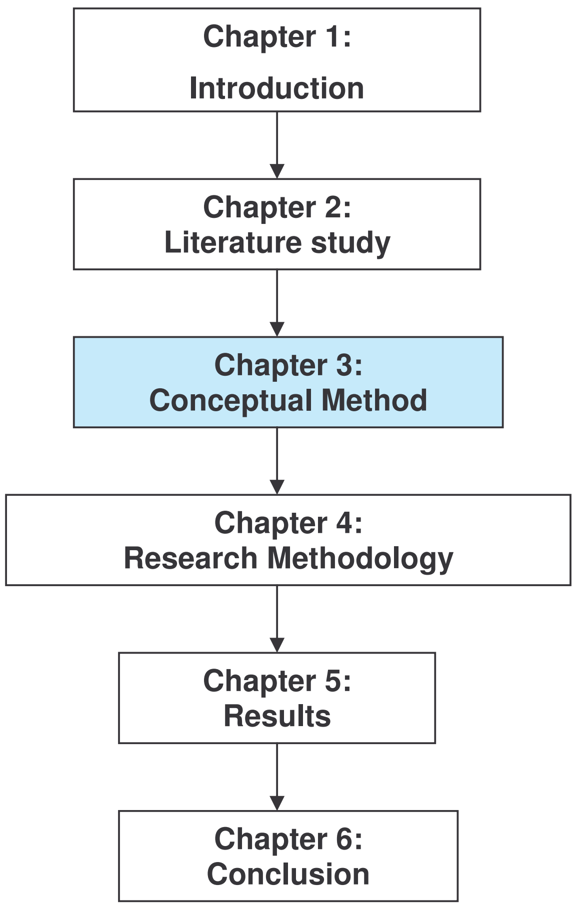
Most TM innovation research has focused on technical issues, and primarily focused on stakeholders that are only directly involved in the value adding activities or market relationship (such as customers, complimentary innovators, and suppliers). However, sustainable development encompasses a broader set of constraints that have until recently been largely ignored (Hall J., 2002).

Technology assessments, such as the three-dimensional assessment model used by Peltir and Ashford (1998), are good tools for technological assessment.

3. Conceptual method

This chapter looks at the conceptual method/model, which is used for the research. The conceptual model is based on the CP assessment tool used by Waste Minimisation Clubs in South Africa. The aim of the conceptual model is to identify innovations technologies and appropriate TM strategies and methods through CP audits.

The conceptual method/model is aimed at developing a method to fill the gap between the business function and CP audits.



The aim of the model was the following:

1. Develop a method to audit CP in companies.
2. Identify CP technologies.
3. Identify the type of innovation.
4. Identify the size of the company.
5. Propose a TM strategy for the company based on its classification.

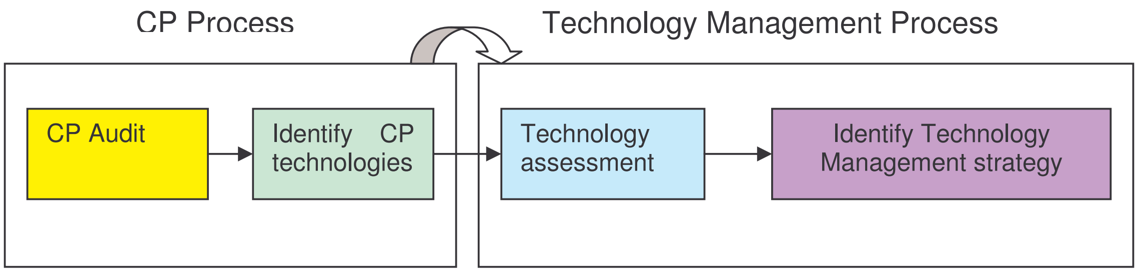


Figure 3.1. Model linking CP process and TM Processes

Figure 3.1, shows the process presented in Chapter 2 (Figure 2.8). The conceptual model is divided into two major parts.

1. CP Process
2. TM

Both the process parts are sub divided into 2 sub-parts. Finally the, model identifies a technology Strategy for the CP technologies/techniques/innovation to support the business process (Figure 2.8).

3.1. CP Audit

The fist step in this sub-part is to identify the target industry/sector. Then CP audits are performed in the operational facility and the following steps are followed:

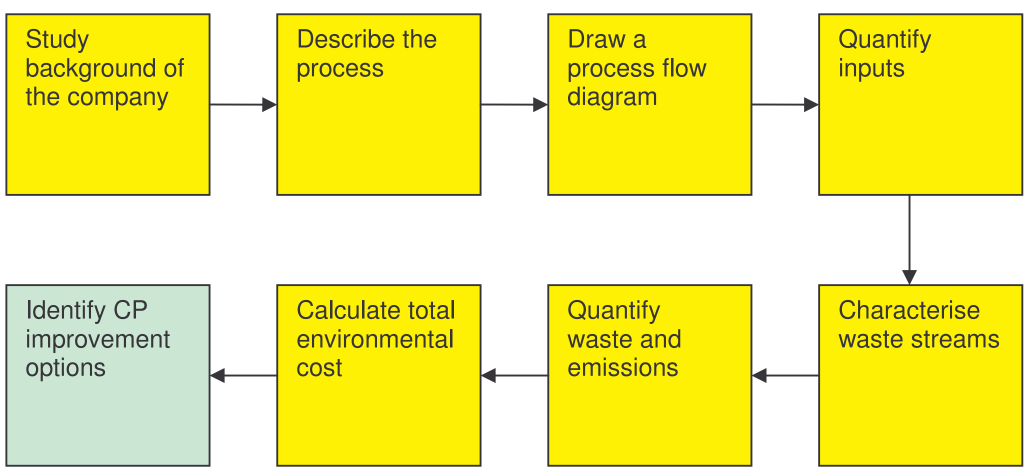


Figure 3.2. Steps for CP Audit

The CP process as shown in figure 2.2 is explained in detail below.

3.1.1. Obtain permission from the company to conduct the CP audit

Inform the management of the manufacturing enterprise of the CP audit and obtain permission.

3.1.2. Background of company

Get an overview of the business and the history of the company, i.e. size of the company, number of employees, organogram, process and product.

3.1.3. Describe the process

Review the process and product in the company, and develop an understanding for the inputs and outputs.

3.1.4. Draw a process flow diagram.

A process flow diagram for each process is drawn according to the basis shown in Figure 3.2.

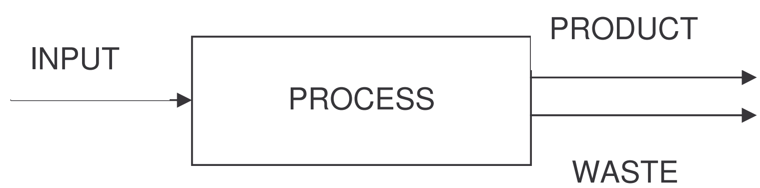


Figure 3.3. Process Flow Diagrams

3.1.5. Quantify Inputs

Based on process flow diagram inputs to the process (i.e. raw-material, energy and water consumption) are quantified for a period of e.g. year.

3.1.6. Identify and Qualify Waste Streams and Emissions

Based on the process flow diagram all waste generated for a period of one year is calculated.

3.1.7. Calculate the total environmental cost

Total environmental cost is calculated in the following manner:
Several types of costs can be connected with waste:

- **Internal costs**
  * Costs incurred by loss of raw material;
  * Costs incurred by loss of added value;
  * Internal treatment costs;
  * Labour costs incurred by waste handling.

- **External costs**
  * Costs for transport, treatment and disposal or revenue for sold waste (income by selling);
  * Other costs such as water and energy costs.

These costs are either calculated on the basis of known figures – such as unit prices, accounts, salaries and tariffs - or estimated. The costs are calculated for each waste stream and added to calculate the total environmental costs

3.1.8. Characteristics of Waste Stream

Each waste stream is categorised according to quantity, costs, environmental Impact and other factors. This criteria is explained in Appendix C.

3.1.9. Identify CP improvements

Once the total environmental cost of various waste steams has been calculated CP improvements are identified. The identified improvement options are aimed at CP and waste minimisation.

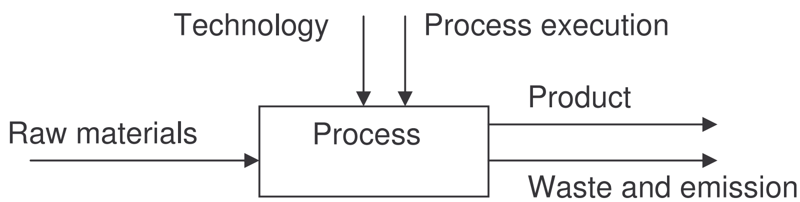


Figure 3.4. Process Parameters

Options for reducing wastes and emissions at source and then move on to onsite reuse are identified. Reduction at source comprises of product and process changes such as good housekeeping measures, technological changes and changes in input material. Onsite reuse relates to the reuse of raw material in the original process, material reclamation and useful application within the organisation

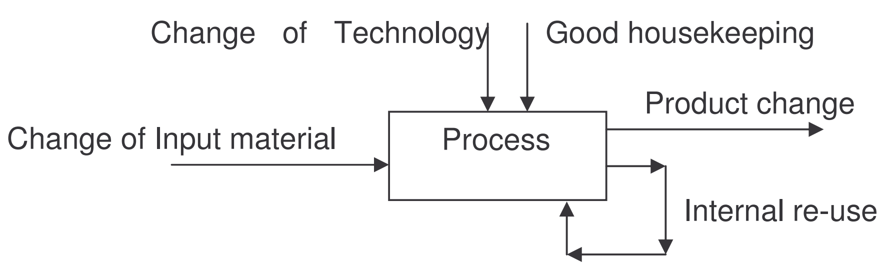


Figure 3.5. Prevention Techniques

Based on prevention techniques mentioned above (figure 3.5.) improvement options are suggested. Cost saving based on the praposed omprovement technologies are calculated.

3.2. Technology Assessment Model

In chapter 2 various TM Frameworks have been discussed (i.e. Van Wyk 1998, Pretoris and De Wet (2000) and Phaal et al., 2004). All the mentioned TM Frameworks and models could be applied to CP technologies in principle. However, a model (Tool) is required for industry (SMME's and Large Size Enterprises), should be simple to use and does not require companies to invest in special training or employing experts to conduct such an assessment.

For the purpose of this study the following Models/frameworks will be used to assess CP technologies:

- Van Wyk proposed a matrix of 9 cell classification of technologies with 54 chart of technological limits (Sections 2.11), this is simple to use and provide a good overview with the technological situation of the company. Therefore, this model could be used in house by SMME's without much investment.
- Pretorius and De Wet's (2000) 3 dimensional framework.

Once the CP assessment process is completed the technologies and artefacts identified for CP improvement can be assessed as follows:

- **Classification of technologies based on technology functions (nine cell table).**
  The table will offer a useful check list for arranging the results of a technological scan (Done during the CP assessment). It provides a TM frame work for reviewing product and processes, noting existing performance levels and targeting new ones.

- **Chart of Technological Limits**
  As discussed in Chapter 2 the Chart of technological limits provides a taxonomy of limits, based on the understanding of the various identified CP technologies, techniques and artefacts. However, for the purpose of this study the Chart of technological limits will not be used.

3.3. Conclusion

The conceptual model presented in this chapter gives a basic overview of a CP assessment model that could be applied in industry and then the identified technical improved options further assessed using a Technology Framework. It is model to assess the CP improvement options noted in section 3.2. and common elements between a CP audit process and a TM Framework.

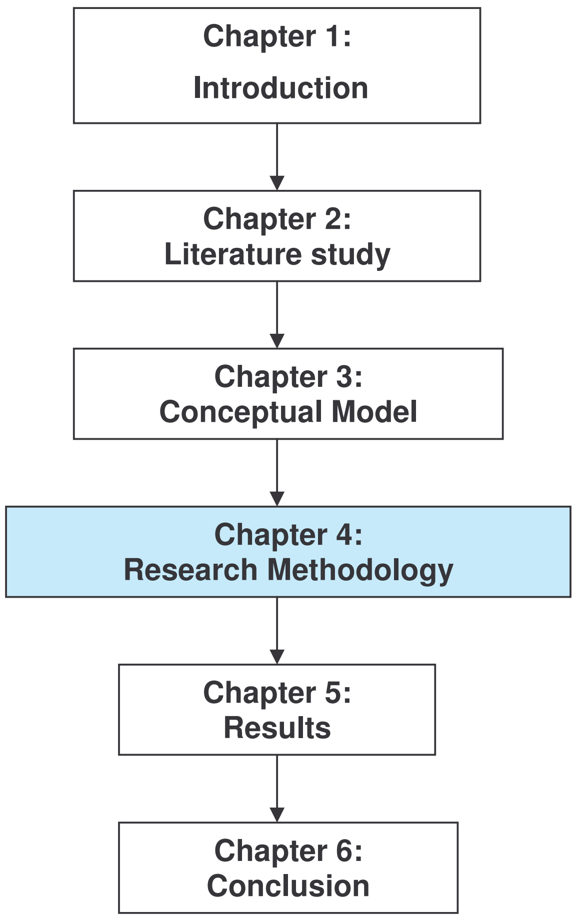
In Chapter 4 and 5 the approach from sections 3.1 and 3.2 is tested against actual data obtained from industry (Case Studies).

The assessment tool/model aims to provide the following benefits:
- Extend existing CP assessment methods.
- Improve level of understanding with regards to CP technological innovation in companies and encourage CP.
- Assist technology managers to develop strategies for CP technologies.
- Improve understanding of CP technologies.

4. Research design and methodology

This chapter focuses on the research methodology used for conducting the research. The conceptual model was tested against actual data obtained from industry. It is essential to obtain accurate information and therefore, a few sources were used to obtain and validate the information obtained (i.e. interviews of personnel, checking of company records, assessment of process by active participation). Companies in the South African Automotive sector was selected and used as case studies for this research.

The research is laid out as follows:



4.1. Case Study Research

Case study is an ideal methodology when a holistic, in-depth investigation is needed (Feagin, Orum, & Sjoberg, 1991). Case studies have been used in varied investigations, particularly in sociological studies, but increasingly, in instruction. Yin, Stake, and others who have wide experience in this methodology have developed robust procedures. When these procedures are followed, the researcher will be following methods, as well developed and tested as any in the scientific field. Whether the study is experimental or quasi-experimental, the data collection and analysis methods are known to hide some details (Stake, 1995). Case studies, on the other hand, are designed to bring out the details from the viewpoint of the participants by using multiple sources of data.

It is a frequent criticism of case study research that the results are not widely applicable in real life. Yin (1984) in particular refuted that criticism by presenting a well constructed explanation of the difference between analytic generalization and statistical generalization: "In analytic generalization, previously developed theory is used as a template against which to compare the empirical results of the case study."

Stake (1995) argued for another approach centred on a more intuitive, empirically-grounded generalization. He termed it "naturalistic" generalization. His argument was based on the harmonious relationship between the reader's experiences and the case study itself. He expected that the data generated by case studies would often resonate experientially with a broad cross section of readers, thereby facilitating a greater understanding of the phenomenon.

Yin (1994) presented at least four applications for a case study model:

- To explain complex causal links in real-life interventions
- To describe the real-life context in which the intervention has occurred
- To describe the intervention itself
- To explore those situations in which the intervention being evaluated has no clear set of outcomes.

4.2. Data Collection

Yin (1994) identified six primary sources of evidence for case study research. The use of each of these might require different skills from the researcher. Not all sources are essential in every case study, but the importance of multiple sources of data to the reliability of the study is well established (Stake, 1995; Yin, 1994). The six sources identified by Yin (1994) are:

- documentation,
- archival records,
- interviews,
- direct observation,
- participant observation, and
- physical artefacts.

No single source has a complete advantage over the others; rather, they might be complementary and could be used in tandem. Thus a case study should use as many sources as are relevant to the study.

Data collection for this study was done through direct involvement in the company. The researcher was directly exposed to the processes and personnel of the company. The following methods were used for data collection:

- Company records.
- Interviews of personal
- Interview of managers.

- Measuring and calculating input and outputs.
- Observing production process.

Actual input and output costs were calculated and based on buying and selling prices of goods and waste. Overall environmental cost of the waste stream was calculated to estimate the cost saving by each identified technology.

Information is gathered through active participation in the manufacturing, environmental and management processes of the company. The researcher spent 2-3 months at each facility and relevant information was gathered.

Face to face interaction on a daily basis was done with the personnel and managers of the manufacturing enterprise. All production processes were observed thought frequent plant visits and discussions with the production team.

Data was collected and recorded on a computer. Data relevant to the research was selected and analysed.

CP analysis mainly focused on the following area:
- Energy: Electricity, fuel etc.
- Water: Effluent management (discharge and disposal), water balance.
- Solid Waste: Cardboard, Process waste (Plastics, rubber), wood etc

4.3. Verify information

All information received was checked against actual observations and calculations.

4.4. Conduct CP assessment

Once the data had been captured, CP assessment process was carried out as per the CP assessment model in Chapter 3:
1. Process flow diagram
2. Identify all inputs and outputs
3. Quantify inputs, outputs and waste
4. Calculate total Environmental cost (See Appendix C)
5. Select most critical waste streams based on the following:
    a. Size or quantity
    b. Environmental cost
    c. Environmental impact
    d. CP and waste minimisation potential
    e. Other

Based on the total rating of each waste stream the focus areas in the manufacturing plant are selected. Figure 4.1 presents an example of the results. Any waste stream with a rating of above 12 is considered critical and should be attended to urgently. Waste streams with a rating less than 12 should be attended to in the medium to long term.

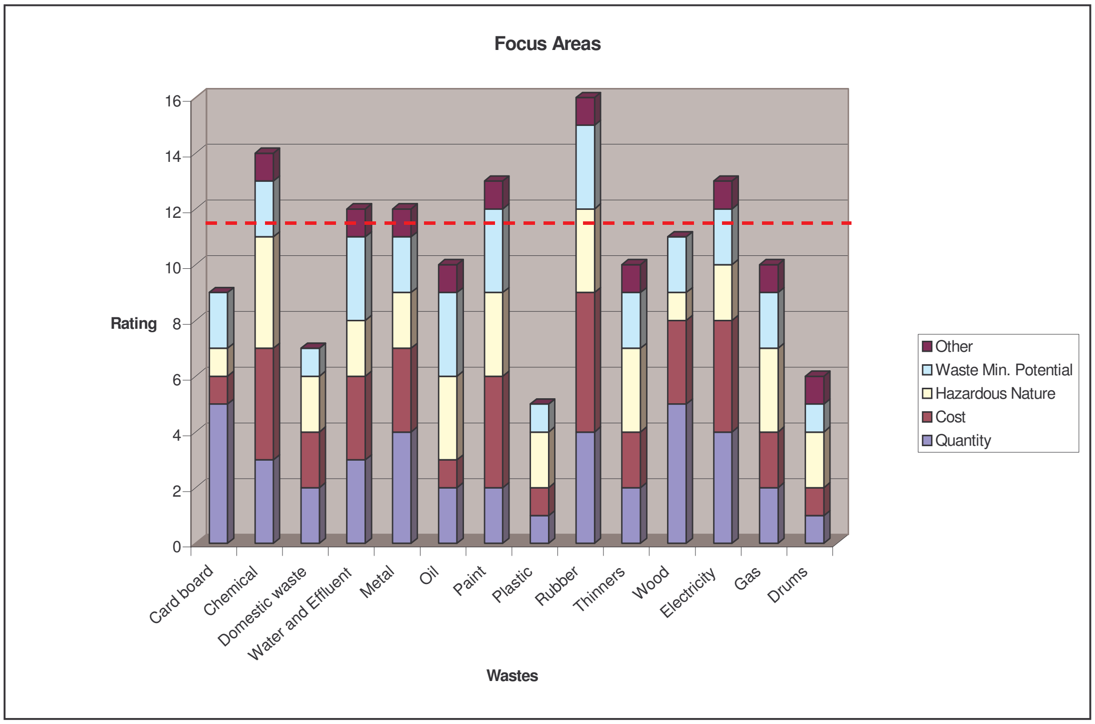


Figure 4.1. Example of rating various waste streams

4.5. Identify CP technologies

Once the waste streams / focus areas have been identified, improvement techniques are investigated. The following tools were used to find suitable techniques or technologies to reduce waste generation:

1. Technical books: Technical books were studied to understand and suggest improvement options.
2. Internet: The internet was searched extensively to search for technologies and suppliers.
3. Consultants : Technical specialists were consulted to investigate improvement technologies (i.e. Specialist consultants).
4. Suppliers : Suppliers and distributors were contacted via telephone to obtain more information with regards to the specific technology (i.e. Cost of acquiring the technology, specifications).
5. Production and Engineers teams: Operators and Engineers responsible for the specific waste stream were involved the process. Valuable practical solutions were proposed by the production and engineering teams of the manufacturing plant.

4.6. Technology Assessment Parameters

The impact of the new CP technology is measured against 5 parameters as listed in Table 4.1. The Parameters are listed in Table 4.1.

Table 4.1 Parameters for assessing impact of technology

Type of change introduced	As shown in Figure 3.5. 5 types of changes can be introduced for CP: • Change Technology • Change process • House keeping • Re-use • Change input
Size of the Company	This study uses the following definitions, which are related to the number of employees; • less than 9 persons - very small scale (VSSE) • 10 - 99 persons - small scale (SMME) • More than 100 - Large (LSE)
Innovation	• **Incremental innovation** Incremental innovation involves the adoption, refinement, and enhancement of existing products and services and/or production and delivery systems. • **Radical innovation** Radical innovations involve entirely new product and service category and/or production and delivery system. • **Architectural Innovation** Architectural innovation refers to reconfiguration of the system of components that constitute the product.
Process	What processes the technology or technique effects? As per the model Peltier and Asford (1998), three main types of processes were identified: • **Primary:** primary processes yield the basic functional form of the product such as forming or casting a part from a material • **Secondary:** secondary processes involve the application of a functional finish, such as non-corrosive or aesthetically pleasing finishes. • **Ancillary:** ancillary processes do not affect the characteristics of the product and are usually less fundamental for the whole manufacturing process.
Cost Saving	Total cost saving by implementation of the technology considering the total environmental cost for the waste stream is estimated.
Environmental Benefit	Environmental benefit from the application of the new CP technology is rated as follows (See section 1.5 for definition): • Low • Medium • High • Very High

4.7. Technology Strategy

The Technology Strategy will focus at improving the CP assessment processes to select and identify technology considering the business function.

Business strategies for innovation can be applied in various areas such as organisational innovation, process innovation, technology innovation, marketing innovation, product innovation and business innovation.

Often CP addresses process and product technologies. Innovation strategies relating to CP improvements can be developed by focusing on these areas.

Strategies will be focused on the South African industry, where economic growth is required along with technological development. It is also essential to use a method of assessment that is simple to use and provides insight into understanding CP technologies

4.8. Conclusion

Case study research can be used in this study to demonstrate the Conceptual Model discussed in Chapter 3.

Data collection at the selected companies can be used to identify CP improvement technologies.

The following Chapter presents the results for the various Case studies. The results are assessed using different technology assessment models to derive a technology strategy for CP technologies and techniques.

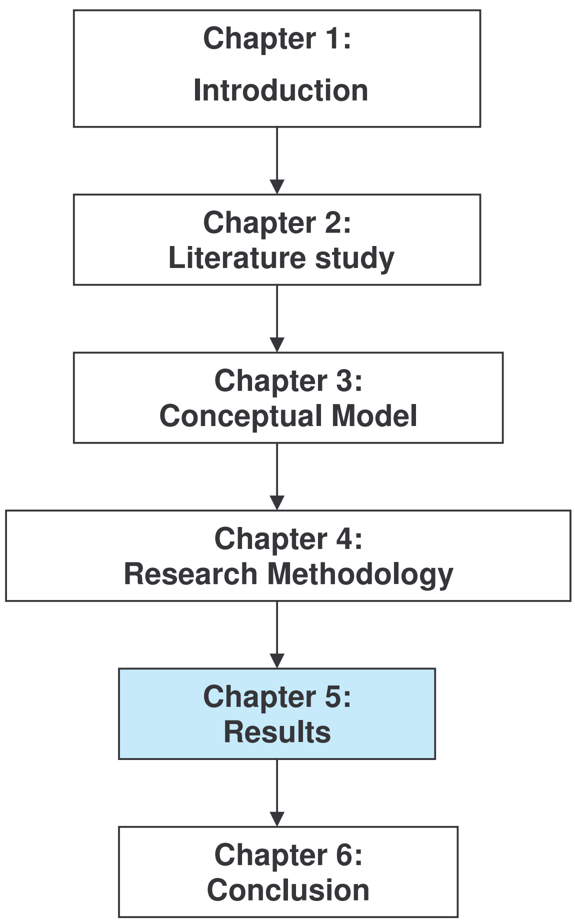
5. Results

5.1. Introduction

This chapter explains the results of the study. CP assessments were conducted in 5 selected companies and 21 improvement technologies/techniques were identified. The model proposed in chapter 3 was used to evaluate these technologies.

It should be noted that the research was specifically carried out in the South African automotive sector in 5 manufacturing companies that are identified as A, B, C, D and E to maintain confidentiality.

The information obtained from the companies was used for demonstration of the proposed conceptual model. The intention is not to reveal any confidential information or discuss technical details relating to the companies.



5.2. CP Assessment

CP audits were carried out in the five different companies, and 21 major improvement options were identified. CP audit process as discussed in Section 3.1 was applied. The 21 identified technologies have been listed and divided in to 5 parameters i.e. Size of company, type of innovation, type of process effected, Cost benefit and environmental benefit.(See section 4.6).

Table 5.1 and 5.2 presents the 21 technologies based on the five parameters. The 21 CP improvement techniques are identified by characters (A-U). The same alphabetical identification is used in Table 3 for categorising the techniques in the nine cell technological classification model (See Section 3.3).

5.3. Technology Assessment

The Assessment of CP technologies is conducted in 3 ways as discussed in Chapter 3. The aim of the assessment is to establish technology strategy for support of the business function.

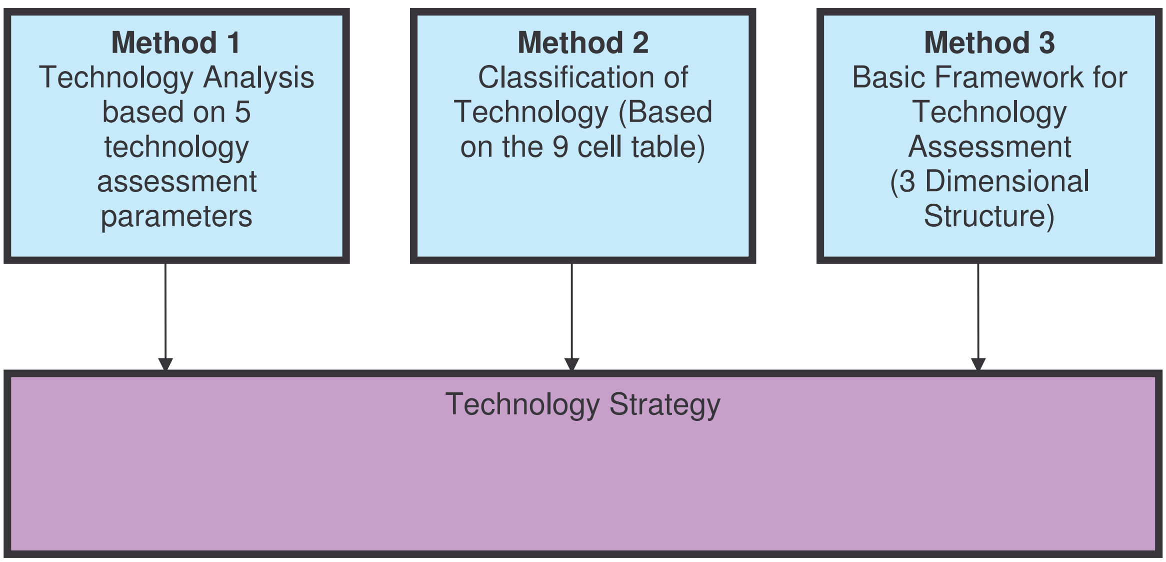


Figure 5.1. Technology Assessment

Figure 5.1. provides a basic layout of the technology assessment carried out in this chapter. Three different technology assessment methods are demonstrated in this chapter to show how TM tools could be applied to CP assessment. However, other technology assessment model such as technology road mapping could also be used.

5.3.1. Method 1

Table 5.1 List of CP options identified during the CP assessment

Type of Change introduced	Innovation	Process	Cost saving	Environmental Benefit
Change technology	Architectural	Primary	Low = 1	Low = 1
Change process	Incremental	Secondary	Medium = 2	Medium = 2
House keeping	Radical	Ancillary	High = 3	High = 3
Re-use				
Change Input			Very High = 4	Very High = 4

		Technology	Type of change (CP)	Innovation	Process	Cost saving (1-4)	Environmental (1-4)
		Company "A"					
1	**A**	Improve power factor	Change Technology	Combination of Incremental and Architectural	Ancillary	1	1
2	**B**	Change cooling tower design to reduce evaporation of water	Change Technology	Incremental	Ancillary	2	3
3	**C**	Change mould design to reduce flash	House Keeping	Incremental	Secondary	1	1
4	**D**	Use double sided printers to reduce paper	Change Technology	Incremental	Ancillary	1	2
5	**E**	Re-cycle used Cardboard	Re-use	Incremental	Ancillary	1	2

		Company "B"					
6	**F**	Modify dies to reduce rubber consumption during Injection moulding process	Process Change	Incremental	Primary	2	2
7	**G**	Change painting method to reduce wastage of paint	Change technology	Incremental	Secondary	2	2
8	**H**	Reduce effluent discharge	Change Technology and process	Radical	Ancillary	1	3
9	**I**	Improver storage of virgin rubber to reduce expiring of rubber before use.	House Keeping	Incremental	Primary	3	3
10	**J**	Re-cycle waste rubber	Change Technology	Incremental	Primary	1	3
		Company "C"					
11	**K**	Re-use packaging	Re-use	Incremental	Ancillary	2	2
12	**L**	Baleing of waste plastic (baleing machine)	House keeping	Incremental	Ancillary	2	2
13	**M**	Re-cycle waste tyres	House Keeping	Incremental	Ancillary	2	2

		Company "D"					
14	**N**	Electric/gas powered boiler	Change technology	Incremental	Ancillary	1	3
15	**O**	Use insulation to reduce heat transfer	House keeping	Incremental	Ancillary	2	2
16	**P**	Change Lubrication	Change process	Incremental	Ancillary	2	2
17	**Q**	Effluent control	Change Technology	Incremental	Ancillary	2	3
18	**R**	reduce metal off-cuts	Change input	Incremental	Primary	2	3
19	**S**	Change chemicals to bio degradable	Change input	Incremental	Secondary	3	4
		Company "E"					
20	**T**	Change for manual to automatic spraying of glue to reduce wasting	Change process	Incremental	Primary	2	3
21	**U**	Separate waste for proper disposal and recycling	House keeping	Architectural	Ancillary	2	3

Table 5.2. Assessment of CP options

Type of Change	**No. Techniques**	**Percentage (%)**
Change Input	2	9.52
Change Technology	8	38.10
Change process	3	14.29
Product Change	0	0.00
Internal re-use	2	9.52
House keeping	6	28.57
Innovation		
Radical	1	4.76
Incremental	18	85.71
Architectural	2	9.52
Process		
Primary	5	23.81
Secondary	3	14.29
Ancillary	13	61.90
Cost Saving		
Low	7	33.33
Medium	12	57.14
High	2	9.52
Very High	0	0.00
Environmental Benefit		
Low	2	9.52
Medium	9	42.86
High	9	42.86
Very High	1	4.76
Size of Company		
Large	12	57.14
SMME	9	42.86

Some key observations of the assessment are noted below:

- Changes in technology (8), housekeeping (6) and process (3) methods were the most common type of changes introduced.
- 85.7% of all the options proposed were incremental innovations.
- 61.9% of all process affected were ancillary.
- 89.6% of the improvement options were yielded medium to low cost savings.
- 85.7% improvement options showed medium to high environmental benefits.
- Two of the large scale enterprises yielded 12 (57.1%) of the improvement options suggested and 3 SMME's provided 9 (42.9%) improvements.

5.3.2. Method 2

Technologies assessment of the identified CP technologies / options is performed by classifying the technologies / options based on the nine cell model (Van Wyk, 1998). The simple and easy to use TM framework provides a field for technological scanning and developing a strategy. The identified CP options are projected in the nine cell framework as shown in table 5.3.

Classification of artefacts/technologies based on technology function shows that CP assessments mainly result in changes to matter and energy outputs. Although, energy outputs are seen to be few, they could increased by changing the focus industry (only the South African Automotive sector).

Table 5.3. Classification of artefacts based on technology functions:

Output	**Type of Manipulator**		
	Processor	Transporter	Store
Matter	A, C, D, E, F, J, L, M, R, S	G, H, K, P, Q, T	I, U
Energy	B	N	O
Information			

Note: Technologies have been identified by letters of the alphabet designated to each option in table 1.

Based on the above assessment it is noted that no information (output) processing, transportation and storage has is done to he artefacts/technologies. This could be done by having innovative means of informing the work force, and displaying the information on the company website, CP information outputs could be achieved.

The results of the analysis show a high focus on waste management and minimisation. Sustainable CP would require more emphasis on energy manipulation. The growing need for energy in local economy and the advancement in information technology it is essential that CP assessments focus on energy saving.

5.3.3. Method 3

The TM framework model presented by Pretorius and De Wet (2000) (see figure 2.6. in section 2.12.) is used to further assess the identified technologies. Due to Scope of this study two of the identified improvement options will be analysed. The 3 dimensional framework consisting of the business cycle, Hierarchy and fundamental functions is used for this analysis. In the context of the study the TM framework is not used as business analysis tool, but as a TM tool to identify the position of a CP technology in basic frame work.

Option "F": Modify dies to reduce rubber consumption during injection moulding process for company A

Almost 22% of total rubber bought in the company wasted as rubber trimmings in the injection moulding process. Since the rubber has been heated and expanded during the process it can not be reused for injection moulding. The trimmings are therefore disposed as waste. The rubber trimmings are then put into the general waste bins and disposed as general waste. The average value lost rubber is R 1 107 291 per year. Although it not possible to eliminate all the rubber scrap during the injection moulding process, it can however be reduces by applying efficient and effective measures i.e. new waste efficient moulds.

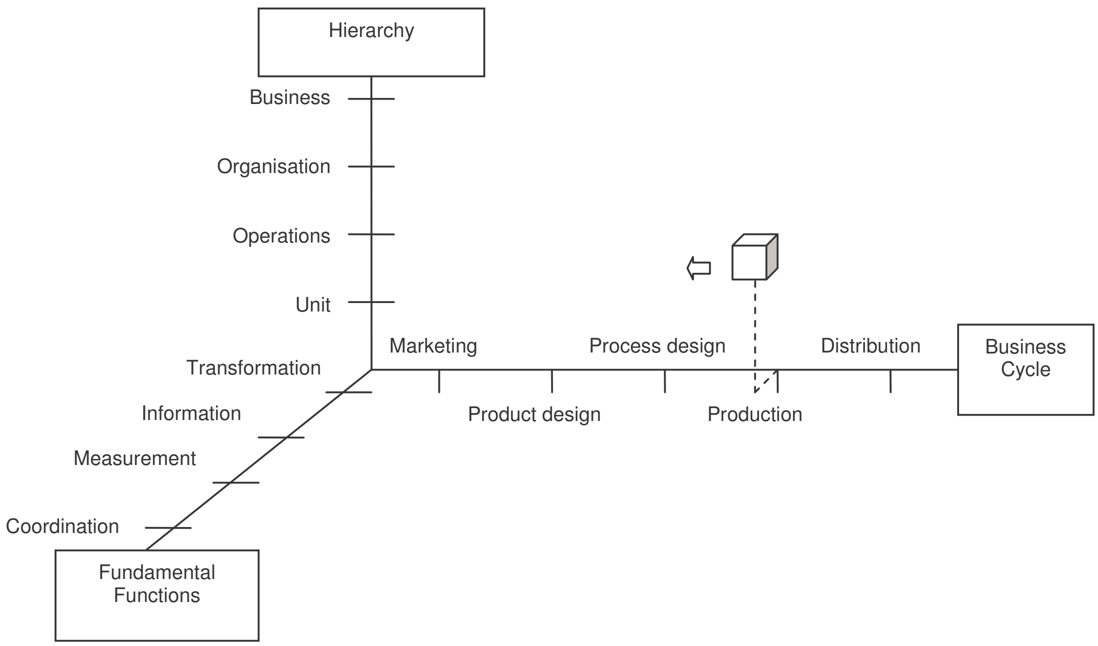


Figure 5.2. Option "F"

As per the CP assessment it is suggested that the amount of scrap rubber can be reduced by modifying the dies. Technology is changed at process design to affect the production. No changes are observed in the fundamental functions and hierarchy.

Option "G" :Changing spray painting process at Company B

Paint is sprayed on to the metal components using two methods: Manual spray and through automatic spray system. Paint and thinner is mostly wasted because of the method of spraying. Since the spraying method is not very efficient, all the paint and thinner mixture is not used on the components. About 30% of paint and thinner mixture is wasted during the automatic spray system and 50% during the manual spray process.

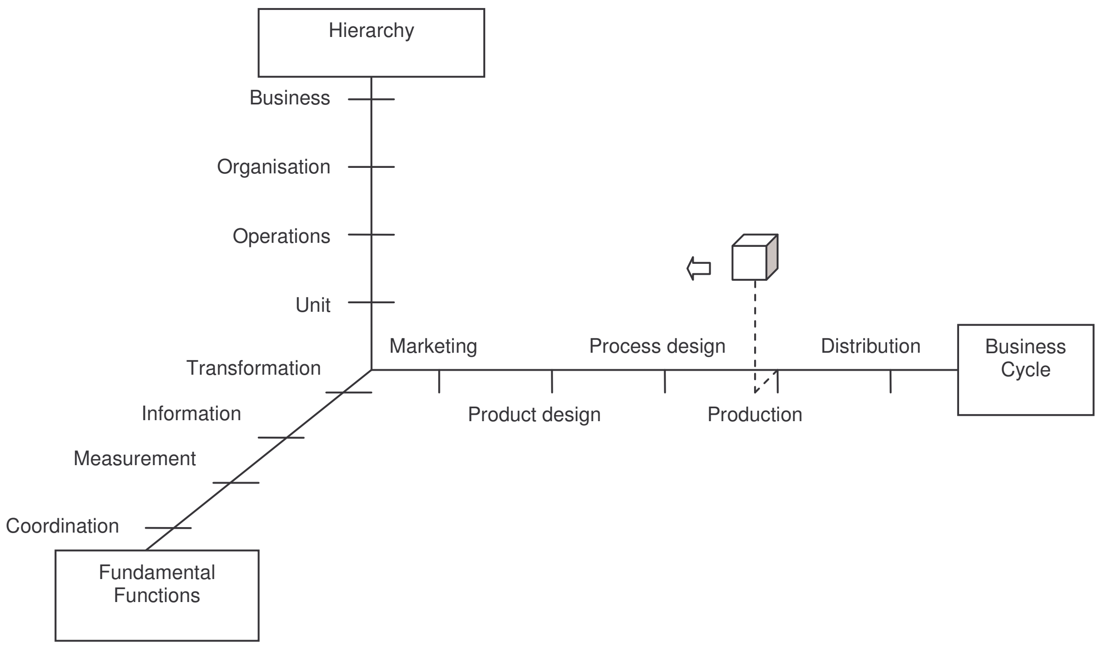


Figure 5.3. Option "G"

By using an automated spraying process the amount of waste paint can be reduced. However, this will not change the position of this technology on the plot above. The change introduced in the painting process will move the technology from production to process design. No change will be noted in the fundamental functions and hierarchy.

5.4. TM Strategy

Based on the CP assessment and the further assessment of technologies in the above model the following can be suggested:

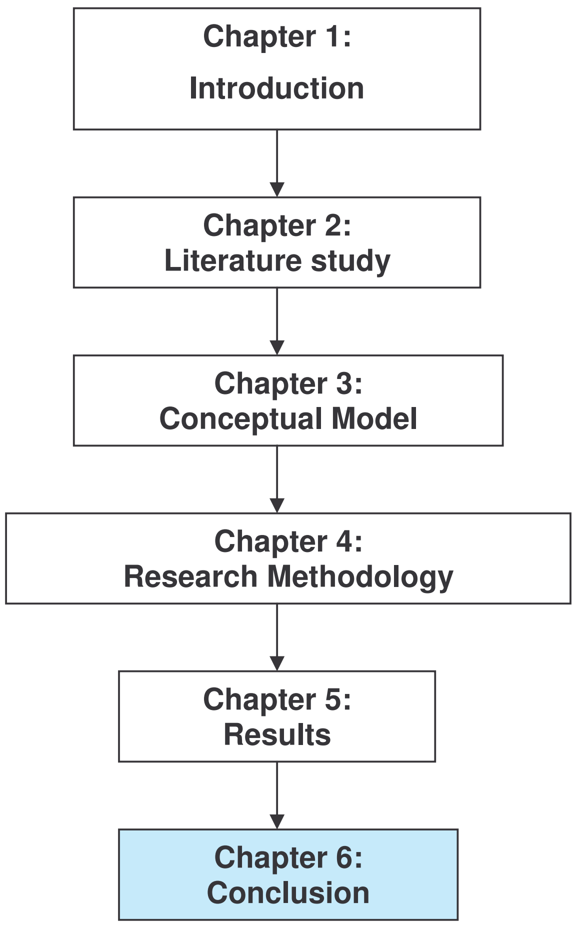
- More architectural and radical innovations options could be looked at in reducing process waste and waste minimisation.
- CP technologies should also look at influencing more at primary and secondary process level.
- Information and energy outputs of CP options (artefacts) should be looked at more.
- Higher cost saving initiatives should be investigated.
- Management to use CP as a strategic business tool righter than a EMS tool.

Most of the technologies identified through the CP assessments could be analysed using the TM framework model presented in Chapter 2. However, CP assessment methods could be modified to incorporate the requirements of the TM framework to yield a better understanding and sustainability of the identified technologies.

6. Conclusions and recommendations

The study deals with CP in the South African Vehicle industry and the role of TM with regards to CP technologies/options. However, the model presented in this study integrates CP assessment with TM and finally provides a TM strategy based on the analysis.

The research has looked at CP and TM to improve understanding of CP by technology managers. A methodology was presented in chapter 3 to integrate CP assessment with TM. Chapter 4 discussed the research methodology. Chapter 5 presented the results of the analysis performed as per the model in Chapter 3.



6.1. South African Automotive Sector

The study involved five companies in the South African automotive industry. Most CP technologies identified could be assessed using a TM frame work to provide better insight into the implementation, sustainability and growth of the technologies.

However, the assessment only covers a small section of the South African Automotive sector and application of CP assessment along with TM assessments of CP technologies should be carried out in other sections of the industry to develop a general strategy for the automotive sector CP technologies.

The model could be easily applied to CP technologies and techniques in industries other than the automotive sector. The Conceptual Model could be developed further to be applied in other sectors of the economy.

6.2. Technology Growth

As discussed in section 2.12 it is expected that enterprises in developing countries have low economic growth and technology development. Application of CP technologies in the various companies will assist in economic growth by cost saving and technological development by improving process technologies.

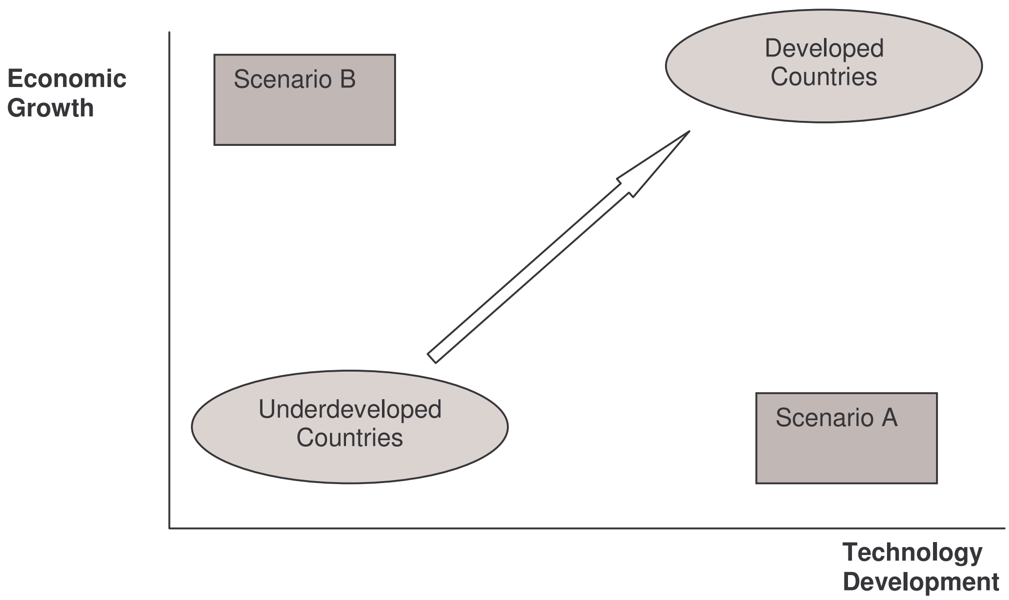


Figure 6.1. Ideal Technology Growth Path (Pretorius and De Wet (2000))

CP contributes to technological and economic growth by improving the production process and protecting the environmental. TM methodologies can assist in understanding CP technologies better and enhance technological and economic growth.

Assessment of the five parameters showed that CP improvement technologies lean towards the following:

- Type of Change - Technology
- Innovation - Incremental
- Process - Ancillary
- Cost Saving - Medium
- Environmental Benefit - Medium / High
- Size of Company - Larger

The results show that the technological growth through mainly incremental innovations in secondary process can be achieved through CP. However, some radical changes have also been proposed and primary process also improved.

6.3. Environmental benefits

Only identifying CP technologies and innovations does not ensure reduction in environmental impact of the waste stream. The practical implementation and sustainability of the identified options with the buy-in from business is essential. Therefore, it is helpful to use a technology assessment model in order to develop a TM strategy for the manufacturing enterprise.

6.4. Legislation

Whilst there are no legislative instruments to directly enforce CP at present, there are a number of policy initiatives in which this approach is proposed and which are likely to be incorporated into legislation in the near future.(See Appendix D for related list of legislation in South Africa)

The model presented in the research does not directly address any legislation or related concerns. The study mainly looks at CP technologies and assessment of such technologies to develop a strategy for the South African Automotive sector.

The TM assessment of CP options will improve the understanding of CP and provide better guide lines for formulating environmental legislation. The application of the proposed model to a larger number of CP technologies nationally, could assist policy makers in developing effective CP legislation.

The set of data used in this study is limited and is not expected to effect policy and legislation.

6.5. Application in SMME's

It is not expected that SMME's would have a technology manager with skill and training to carryout CP and TM assessments. Networking with larger companies and benchmarking will greatly assist in developing collective understanding of CP and related technologies.

CP assessment could be carried out by in house experts and TM assessments contracted out to identify CP technologies and innovations. The basic nine cell classification model could be easily used. The idea is to keep the model simple for non technical managers to be able to understand a basic scan of the CP technologies.

Expensive technology options relating to process and product change could be assessed using the TM frame work presented by Pretorius and De Wet (2000). However, for basic understanding of CP technologies, simpler methods of analysis should be used.

Depending on the skill and knowledge with the SMME, external experts might be required to conduct the CP audit and suggest improvement techniques. The assessment results will assist SMME's in the implementation of CP and save costs.

6.6. Effects on domestic and export markets

A close link exists between clean technology development and the EGS sector. The market for environmental equipment and services will be affected by a shift away from conventional pollution control to pollution prevention and CP processes. This shift will have repercussions for both environmental companies and manufacturing firms. Manufacturing firms using CP processes will seek to reduce compliance costs and, in some cases, production costs. An EGS industry that develops more cost-effective approaches to reducing pollution will fare better in both local and global markets.

In the long term, cleaner technology and production may have the potential to generate more export-related growth and jobs than conventional pollution control equipment. Government technology and export promotion policies aimed at strengthening environmental industries need to take into account the technical possibilities and commercial opportunities in CP, as well as CP manufacturing costs, especially the gap between the quality required for domestic and the specified quality for overseas markets.

6.7. Technology Management Assessments

An assessment of CP technologies from TM point of view provides some insight into the nature of the technologies. However, such assessment fails to provide a total growth solution to the business. The TM assessments of CP technologies have been limited to the process and production cycles of the business and looking mainly at the transformation function. Such an assessment falls short of proving a full business improvement strategy.

Technology Assessment Models used in the study are simple and do not provide detailed assessments. A simplified approach has been used to demonstrate the Conceptual Model.

Further Technology Assessment could be carried by looking at following:

- Process Integration to optimise productivity over the total life cycle.
- Association of Technologies.
- Technology Balance Sheet
- Technology Space Mapping.

TM assessment tool could be modified to integrate with CP assessment. Although, a CP assessment and the 3 dimensional TM frame work are tools to identify effective technologies, a combined assessment model is required.

6.8. Sustainable development

CP provides a practical way to take clues from the conceptual framework of sustainable development towards action. It is more of a preventative strategy and curative and not reactive approach to address the global pollution problem.

Technology assessment of CP enhances the understanding of CP from a TM point of view, encouraging in better management participation and awareness of CP.

6.9. Conclusion

Through the literature survey it was identified that CP processes should be connected to the business process in a company for effective implementation of CP options. It was therefore proposed that a TM framework be used to fill this gap and provide a strategy for CP technologies.

The answers to the research finds are as follows:

- *Can CP assessments be carried-out successfully in the South African Automotive industry (Large companies and SMME's) including the supply chain?*
  Yes. This was demonstrated in the literature study and in the conceptual model. The study was conducted in 2 larger companies and 3 SMME's which from part of the supply chain to the OEM's.

- *Can CP audits identify improvement options in the South African Automotive Industry along with cost savings?*
  Yes. At least, 21 CP improvement options were identified through CP audits in 5 companies (Case studies).

- *What type of changes are proposed thorough CP assessments?*
  Table 5.2 presents a list of changes and functions that are affected by such technologies.

- *How do CP technologies differ between SMME's and larger industries?*
  More CP technology options were identified in larger industries compare to SMME'S. However, literature study suggests that both large and small scale industries actively participate in CP through out the world.

- *Can TM frameworks be applied to CP technologies?*
  Yes. Three different methods of TM assessments were applied to CP technologies in Chapter 5.

- *Can TM frameworks aid in understanding CP technologies and assist in developing a TM strategy for CP in the South African automotive sector?*
  Yes TM frameworks do aid in understanding CP technologies as shown in Chapter 5. Based on the TM assessment of the 21 CP technologies, some strategies for management and other stake holders have been suggested.

Due to low focus on environmental protection and high focus on economic growth in developing countries (like South Africa) the developments of cleaner technologies is slow. It is essential to conduct CP assessments in companies to identify high risk areas and develop technologies to improve environmental performance along with cost savings.

The research demonstrates a TM approach towards CP technologies. CP options are identified through a systematic CP assessment/audit process and assessed using TM Methodologies. However, detailed technological assessments over a larger sample of CP technologies would yield a more generalised technology strategy for industry (Quantitative).

Other sectors of the economy could also be studied to understand the differences and similarities of CP audits and CP technologies. The approach presented in the study paves the way for further research of CP technologies using TM methods/frameworks.

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APPENDIX A: LIST OF IDENTIFIED CP OPTIONS

Company "A"

1. **Use capacitors to Improve power factor** –
   A saving of almost R75000/year could achieved by improving the power factor form 0.8 to 0.95.

2. **Change cooling tower design to reduce evaporation of water**
   Cooling tower could be modified to reduce rate of evaluation. 70% of water in the plant is lost to evaporation

3. **Change mould design to reduce flash**
   By changing the mould design, flash generation could be reduced and process waste saved. Almost 45-50% of plastic is cut off as flash after blow moulding.

4. **Use double sided printers to reduce paper**
   By using double sided printers almost 5 to 6 tons of paper can be saved.

5. **Re-cycle used Cardboard**
   Cardboard packaging could be reused at least once more before being re-cycled.

Company "B"

6. **Modify dies to reduce rubber consumption during Injection moulding process**
   Almost 300 tons of rubber is wasted at an average value lost rubber is R 1 107 291 per year. This could be improved by using modified dies with reduced runner quantity.

7. **Change painting process to reduce wastage of paint**
   Almost R 350000 worth of paint and thinner mixture is wasted each year, due to method of spraying as process waste. The spray painting process could be automated fully to reduce the spillage of waste.

8. **Reduce effluent discharge**
   Effluent discharge can be reduced by improving dipping and rinsing times. Chemicals could be recycled and reused in the process, reducing the consumption of chemicals.

9. **Improver storage of virgin rubber to reduce expiring of rubber before use.**

   About 6% of total rubber bought expires in the rubber store before it is used for production. By improving the ordering and estimating process only the required amount of rubber will be ordered. The storage facility could also be improved to protecting rubber from expiring.

10. **Re-cycle waste rubber**
    Off cuts and trimmings from the production process could be re-cycled and used in other processes.

Company "C"

11. Re-use packaging
Packaging could be re-used before sending for recycling.

12. Bailing of waste plastic (bailing machine)
A baleing machine could be used to compress and bale waste plastic. This kind of waste is readily purchased by recycling companies and easy to transport.

13. Re-cycle waste tyres
Waste tyre could be cut in ballets and re-used as rubber enforcements.

<u>Company "D"</u>

14. Electric/gas powered boiler

A 96 ton coal is used in a coal fired boiler. Electric or Gas powered boiler could be used as a cleaner source or energy and improve efficiency.

15. Use insulation to reduce heat transfer in boiler
Insulation should be used around the boiler to retain heat and reduce heat transfer to atmosphere.

16. Change Lubrication
By changing petroleum based lubricant to water based lubricant the following advantages can be achieved: Less steps in degreaser stage, clean effluent stream, reduced waste usage (Ph almost neutral), better functioning of oil water separator, because less caustic solution will result in oil separation (emulsify oil).

17. Effluent control
Formation of floating slug in the rinse and wash baths could be controlled by using absorbents before disposing into mobile drum.

18. Reduce metal off-cuts
Almost 1800 tons of steel is sold as scrap by company D every year as off cuts. This could be improved by ordering steel in smaller sizes and re-used off-cuts to produce smaller usable parts.

19. Change chemicals to bio degradable
Using bio-degradable chemicals will reduce the environmental impact of the effluent.

<u>Company "E"</u>

20. Change for manual to automatic spraying of glue to reduce wasting
Almost 3300 kg of glue is wasted due to a manual spraying process used. This could be reduced by using a automated glue applying spray.

21. Separate waste for proper disposal and recycling
By separating the process waste into different bins, waste could be correctly disposed. Un-contaminated waste will be easy to re-use and re-cycle.
The above is definitely too much detail in the text for a TM thesis.

APPENDIX B: BACKGROUND ON CP AND WASTE MINIMISATION

TM Assessment

Management of Technology (MOT) has become a high priority area and is seen as one of the most important factors in international compositeness. CP assessment often from part of Quality systems or Environmental Management systems of the company. Such systems could be governed by standards such as ISO 9000 and 14001, in some companies. However, many SMME in the South African vehicle industry do subscribe to any formal standard. In house, audit tools are used and give some indication of the level of waste generated and disposed.

Information Networking

CP has been one of the major themes of discussion at the regional and international arena. A momentum to international efforts focusing on CP was given by UNEP DTIE through its High-level Seminars on CP. Across all the regions, several roundtables are now operated on CP. Prominent amongst these include the National Pollution Prevention Roundtable (NPPR) in the US and the European Roundtable on CP (ERCP). The NPPR operated a number of P2 roundtables in the US and also in Mexico. The Asia-Pacific region has organised three CP roundtables. Apart from holding CP roundtables, the Mercosur region has proposed the formation of a CP network. The African region has initiated the regional consultation process by organising Roundtables on Sustainable Consumption and CP 2000 and 2002, and very recently in May 2004.

Most of these roundtables are now operating websites. The experiences of CP networking, world-wide, catalysed several other agencies and programmes to set up their own CP networks. Many of the themes for networking shared a common vision to CP. Examples include the Greening of Industrial Networks, International Green Productivity Association (IGPA), O2 International Network of Sustainable Design, CDG's Latin American Network, Canadian C2P2 net-work, O2 international network of sustainable design, PREPARE for Europe etc. UNEP DTIE developed the International CP Information Clearinghouse (ICPIC) that has information on technical and policy sources of information. Other important web-based initiatives on CP include the International CP Co-operative launched by US Environmental Protection Agency, and the websites of Environment Australia, the Chinese NCPC and the Canadian Centre for Pollution Prevention. Several environmental *electronic information networks* have been developed internationally and provide extensive coverage of issues.

In South Africa, information networking has formed key parts of the demonstration projects in the metal finishing and textile industry, but generally restricted to within the respective industry sectors only. For example, the Cleaner Textile Production project has set up an information dissemination network ranging from publications in relevant industry press, to presentations at conferences, meetings and trade shows. The project has published a number of training and guidance manuals, including a summary of the European BREF document on Textile Industry presented to South African companies as a useful CP guide. In addition, a website was set-up through the University of Natal, to provide valuable practical information for implementing CP practices. A CP idea catalogue is included in the site, and shows how they apply to the textile-manufacturing sector. Comprehensive ideas for CP options have been added to the database.

Although, such websites are an excellent tool to make available, there is no readily available indication regarding the extent to which it has been used by industry. This underlines the importance of ongoing awareness raising and the provision of incentives for CP to be adopted. It is important to ensure that companies can use this information.

The Waste Minimisation Clubs have developed newsletters for information networking which have a general format, but are adapted to suit the specific Club.
Some individual and commercial service providers have set up useful databases and libraries relevant to CP as have some academic institutions – (e.g. the PRG). The NCPC has endeavoured to build up its information base, including a useful website, but there is room to set up a greater CP information network, especially on the Internet, which would be a database of case studies, fact sheets, manuals and guides on CP relevant for specific economic sectors as well as for cross-sector options such as water and energy saving. Much information already exists, but it needs to be brought together. Also, if new manuals/ case-studies are developed then they should follow the same format as those already developed for other industry sectors. The generic Guide on CP as well as the wet-textile specific Guide for CP published by the DANIDA CTPP is useful models for further work. Similarly, the Guide for including CP considerations in EIAs generated for Western Province DEA&DP could be a model for similar guides in other industry sectors.

The national CP strategy should include activities to set up a central information network, most probably at the NCPC. It is highly recommended to set-up a national information network where for example different organization could be allocated responsibility for updating the information on specific industry sectors or cross-sectoral issues. The P2RX (Pollution Prevention Resource Exchange) in the US is a good example of such an initiatives, where different states have the responsibility to focus on updating the information and resources on different industry sectors. This could include something similar to the US Toxics Release Inventory which requires public disclosure of toxic waste and emissions from industry.

APPENDIX C: CRITERIA TO CATEGORISE WASTE STREAMS

QUANTITY

Quantity	Point Value
>100,000 kg or L per year	5 = very high
25,000 – 100,000 kg or L per year	4 = high
5,000 – 25,0000 kg or L per year	3 = average
1,000 to 5,000 kg or L per year	2 = low
0 – 1,000 kg or L per year	1 = very low
0 kg or L per year	0 = none

HAZARDOUS NATURE / ENVIRONMENTAL IMPACT

Hazardous nature	Point value
Very low	1
Low	2
Medium	3
High	4
Very high	5

ENERGY CONSUMPTION

Quantity	Point Value
Fuel oil:	
0 – 10,000 kg	1 = low
10,001 – 20,000 kg	2 = medium
20,001 – 50,000 kg	3 = high
>50,000 kg	4 = very high
Electricity:	
0 – 500,000 kWh	1 = low
500,001 – 1000,000 KWh	2 = medium
1000,001 – 1500,000 KWh	3 = high
>1500,000 KWh	4 = very high
Also kVA	Add 1

COST

Cost	Point Value
>R100,000 per year	5 = very high
R25,000 – R100,000 per year	4 = high
R5,000 – R25,0000 per year	3 = average
R1,000 – R5,000 per year	2 = low
R0 – R1,000 per year	1 = very low
R0 per year	0 = none

WASTE MINIMISATION POTENTIAL

Does the assessment team believe that there is potential for waste minimisation (based on a good knowledge of waste minimisation options for the process)?	No idea = 1 High potential = 3 Low potential = 2

OTHER

Compliance with present or known future regulations or charges?	Yes = 0 No = 1
Potential environmental liability?	Yes = 1 No = 0
Safety hazards to employees & surrounding areas?	Yes = 1 No = 0

APPENDIX D: DETAILED EXAMPLE

An example demonstrating the model is presented below:

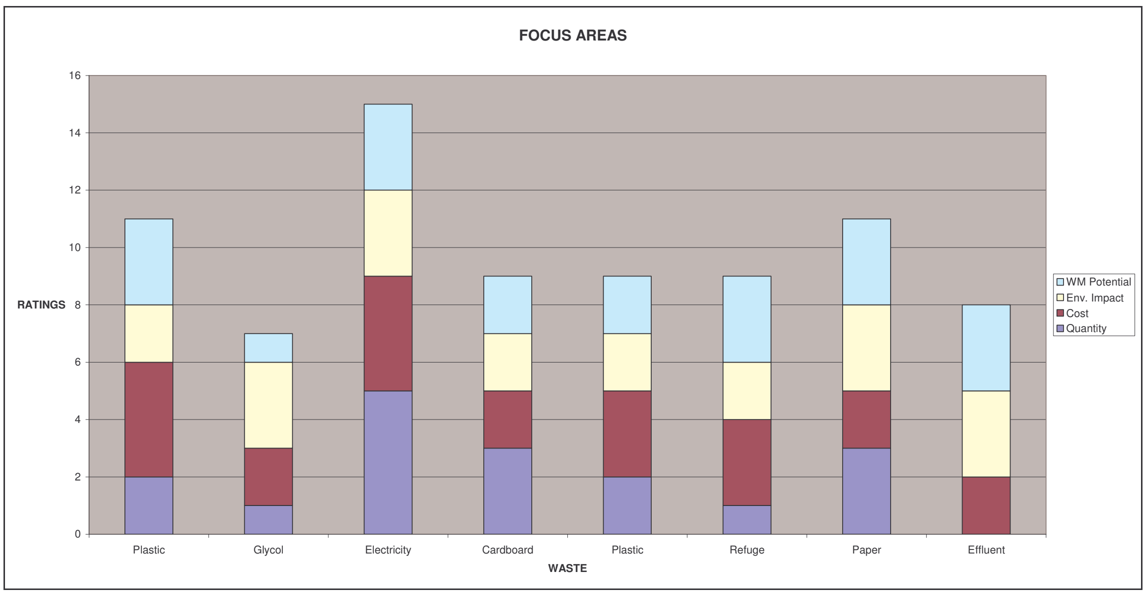
Action plan for CP at Company A:

NO	ACTVITY	RESPONSIBLE PERSON	TARGET DATE	OUTPUT
1	Study of process	A. Pandey	07/11/2003	1. Process flow diagram 2. List of inputs to each process 3. Description of Process
2	Study of raw material, water and energy consumption	A. Pandey	11/11/2003	1. Quantify all raw inputs 2. Cost of raw material
3.	Waste stream and emissions	A. Pandey	12/12/2003	1. Identify all waste 2. Quantify all waste 3. Calculate external and internal cost of waste per year 4. Characterise and rate waste stream 5. Identify critical areas
4.	Study Critical areas	A. Pandey	02/01/2004	1. Formulate projects for each critical area. 2. Provide improvement options for all critical area
5.	Recommendation	A. Pandey	08/01/2004	1. Present improvement options to management. 2. Show expected saving and costs of implementation
6.	Implementation		17/01/2004	1. Implement suggestions 2. Follow up and verification

Using total environmental cost to identify focus area:

	Quantity/year	Score	Total costs/year	Score	Env. Impact	Score	WM Potential	Score	Total
Waste/emission	(kg/m3/kWh etc)	5	(Rand)	5		5		5	20
Plastic	6000	2	R 50330	4	Low	2	Medium	3	**11**
Glycol	210	1	R 3000	2	Medium	3	None	1	**7**
Electricity	163021	5	R 56962	4	medim	3	medium	3	**15**
Cardboard	15000	3	R 5083	2	low	2	Low	2	**9**
Plastic	4640	2	R 23200	3	Low	2	Low	2	**9**
Refuge	807	1	R 36320	3	low	2	Low	3	**9**
Paper	15403.6	3	R 11908	2	Medium	3	Medium	3	**11**
Effluent	771	1	R 2900	2	Medium	3	Medium	3	**9**

Identify focus areas:



Following technologies to were identified to reduce the environmental cost of main focus areas:

A. Use capacitors to Improve power factor – Electricity
B. Change cooling tower design to reduce evaporation of water - Water
C. Change mould design to reduce flash - Plastic
D. Use double sided printers to reduce paper - Paper
E. Re-use Cardboard before recycle – Cardboard

Technology Analysis 1: based on 5 technology assessment parameters (See table 5.1):

Technologies	**Type of change**	**Innovation**	**Process**	**Cost saving (1-4)**	**Environmental (1-4)**
A	Change Technology	Combination of Incremental and Architectural	Ancillary	1	1
B	Change Technology	Incremental	Ancillary	2	3
C	Change Technology	Incremental	Secondary	1	1
D	Change Technology	Incremental	Ancillary	1	2
E	Re-use	Incremental	Ancillary	1	2

Classification of technologies in a 9 Cell Matrix:

Output	**Type of Manipulator**		
	Processor	Transporter	Store
Matter	A, C, D, E		
Energy	B		
Information			

APPENDIX E: CP RELATED LEGISLATION

This section briefly reviews existing legislation most relevant to CP in South Africa.

Constitution of the Republic of South Africa, Act 108 of 1996
In terms of the Bill of Rights (Chapter 2 of the Constitution), everyone has a right:

(a) to an environment that is not harmful to their health or well-being; and

(b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that –

i) prevent pollution and ecological degradation;

ii) promote conservation ; and

iii) secure ecologically sustainable development and use of natural resources

while promoting justifiable economic and social development".

This right imposes an obligation on statutory bodies to promulgate legislation to give effect to this right. One aspect of this obligation is to prevent or at least limit anticipated negative impacts resulting from new developments.

National Environmental Management Act 107 of 1998

Section 2 of the National Environmental Management Act (NEMA) comprises a number of national environmental management principles, including the following which are of direct relevance to waste management:

- Avoid or, where it's not possible to altogether avoid, minimise and remedy pollution and degradation of the environment [Section 2(4)(a)(ii)].
- Avoid waste, or where it cannot be avoided, minimise and re-use or recycle where possible, and otherwise dispose of it in a responsible manner [Section 2(4)(a)(iv)].
- Use non-renewable resources in a responsible and equitable way, taking into account the depletion of the resource [Section 2(4)(a)(v)].
- Use renewable resources in such a way that it does not exceed the level beyond which their integrity is jeopardised [Section 2(4)(a)(vi)].
- The "precautionary principle", whereby a risk-averse and cautious approach is applied, which takes into account the limits of current knowledge about the consequences of decisions and actions [Section 2(4)(a)(vii)].
- Responsibility for the environmental, health and safety consequences of a policy, programme, project, product, process, service or activity exists throughout its life cycle [Section 2(4)(e)].
- The "polluter pays" principle, whereby the costs of remedying pollution, environmental degradation, consequent health effects….must be paid for by those responsible for harming the environment [Section 2(4)(p)].

Section 24(7) of NEMA stipulates the minimum procedures for investigating, assessing and communicating potential impacts of activities where they may have a significant impact on the environment, and where such activities have to be authorised in terms of existing legislation. These minimum requirements include:

- Investigation of potential impact, including cumulative effects, of the activity on the environment [S24(7)(b)].
- Investigation of mitigation measures to keep adverse impacts to a minimum [S24(7)(c)].

Section 28(1) of NEMA states that every person who causes, has caused or may cause significant pollution or degradation of the environment must take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring, or, to minimise and rectify such pollution or degradation.

The Environment Conservation Act 73 of 1989

The EIA Regulations (R1182 and R1183 of 5 September 1997, promulgated in terms of this Act) require that specific procedures are followed, and reports (scoping and/or EIA reports) prepared, for those activities listed in Schedule 1 likely to have a "substantial detrimental effect on the environment".

Occupational Health and Safety Act 181 of 1993

In terms of this Act, an employer must minimise any substances on site that could be injurious to employee health (section 10 (2)(a)) and recycle all hazardous chemical substances waste wherever possible (section 15 (a)).

Regulations for Hazardous Chemical Substances (GN. R. 1179 GG16596 of 1995) published in terms of Occupational Health and Safety Act 181 of 1993

These regulations require that an employer must control the exposure of an employee to hazardous chemical substances (section 10.(2) (a)) by *"limiting the amount of an HCS used which may contaminate the working environment"* and as far as reasonably practical, "*recycle all HCS waste"* (section 15. (a)).

National Water Act 36 of 1998

With regard to excessive use of water, this Act states that:

> *"S22(2): A person who uses water as contemplated in subsection (1)-…(d) may not waste that water…."*.

The promulgation of the National Water Act, 1998 (Act 36 of 1998) saw a change in the legislative framework governing the use of water in South Africa. For the first time the Act recognised the need to integrate the management of water quality and quantity through the need to promote efficient, sustainable and beneficial water use in the public interest.

The Act, in section 21, clearly defines the water uses to be controlled and the different methods of disposal of wastewater are dealt with as follows:

1. Sec 21(e): Engaging in a controlled activity as defined in terms of section 37(i) of the Act, namely the irrigation of any land with waste or water containing waste from an industrial activity (Sec 37(1)(a));

2. Sec 21(f): Discharging of waste or water containing waste into a water resource;

3. Sec 21(g): Disposing of waste in a manner which may detrimentally impact on a water resource; and

4. Sec 21(h): Disposing in any manner of water containing waste from, or which has been heated in, any industrial or power generation process.

The Act, in section 22, goes further and defines a permissible (legal) water use as a water use that is:

1. Exercised in terms of schedule 1 of the Act;

2. A continuation of an existing lawful water use as defined in section 32, or declared as such in terms of section 33 of the Act;

3. Generally Authorised in terms of section 39 of the Act;

4. Licensed in terms of section 22(5) of the Act; and

5. Exempted from the requirements of a licence, by the responsible authority, in terms of section 22(3) of the Act.

The responsibility for complying with these legal requirements lies solely with each individual water user. The Department has adopted a co-operative enforcement approach as opposed to a confrontational one in order to assist the different water users in complying with the legal requirements. However, the Department will take legal action where the water user(s) wilfully or negligently violate the requirements of the Act.

Mineral and Petroleum Resources Development Act (Act no 28 of 2002)

One of the objectives of the Act is to make provision for equitable access to and sustainable development of the nation's mineral and petroleum resources. Furthermore the Act affirms the State's obligation to protect the environment for the benefit of present and future generations, to ensure ecologically sustainable development of mineral and petroleum resources and to promote economic and social development.
Although CP is not explicitly stated as one of the intended objectives of the Act, the Act does make certain provisions to accommodate environmental management principles and public participation in the mining development processes. It is these provisions that will guide the mining industry towards the CP imperative.

- These principles have been included in the Act as clauses 37 – 47:
- Environmental management principles – Clause 37;
- Integrated environmental management and responsibility to remedy – Clause 38;
- Environmental management programme and environmental management plan – Clause 39;

- Consultation with State Departments – Clause 40;
- Financial provision for remediation of environmental damage – Clause 41;
- Management of residue stockpiles and residue deposits – Clause 42;
- Issuing of a closure certificate – Clause 43;
- Removal of buildings, structures and other objects – Clause 44;
- Minister's power to recover costs in event of urgent remedial measures – Clause 45;
- Minister's power to remedy environmental damage in certain instances – Clause 46;
- Minister's power to suspend or cancel rights, permits or permissions – Clause 47.

In line with the Government's 10-year strategy to reduce energy consumption by 12 percent the Minister for Minerals and Energy has released a draft proposal. The aim of the draft is to reduce energy consumption in the key demand sectors, which is a burden to the economy, thereby lessening the impact of greenhouse gas emissions and promoting sustainable development.