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CHAPTER 1

General background

1.1 INTRODUCTION

As third world countries evolve into more industrialised economies, rapid urbanisation results in more development in urban rather than in rural areas. These rural communities are usually isolated and the isolation is reflected in their lack of access to services (Jazairy *et al.,* 1992). One such service, health care provision, is faced with managing health care waste (HCW), despite its lack of resources and procedures.

Safe management of HCW will not only reduce the uncertainty and risk associated with poor practices in public health, but also improve the value of the environment (Asante-Duah, 1993). As English *et al.* (1999) argue, it is vital that environmental decision-makers apply appropriate decision-making tools to overcome difficulties in setting priorities as the result of uncertainties of impacts resulting from changes to environmental and public health systems, as well as uncertainties in budget/costs. The use of appropriate tools can also ensure that problems arising from the mismanagement of HCW are systematically analysed and subsequently solved, even with limited budgets. It is the general aim of this research to identify technologies and best practices in HCWM that are environmentally sound, by the application of a specially developed tool.

1.2 HCWM TRENDS IN DEVELOPED AND DEVELOPING COUNTRIES

1.2.1 HealthCare Waste Management (HCWM) in Developed Countries

Proper HCWM, ideally, is integrated and is based on the hierarchical approach illustrated in Figure 1.1.

Avoidance	**Cleaner production**
Minimisation	
Recycling	
Treatment	
Disposal	

Figure 1.1: The hierarchy of waste management

The figure shows that the first hierarchical steps can be clustered into the cleaner production concept, which is well established in developed countries. Cleaner production mostly entails waste reduction and material recovery (UNEP IETC, 1996). In developed countries, waste management is governed by legislation, which was based on end-of-pipe regulations and strategic targets. After a realisation that end-of-pipe regulations do not bring about major positive changes, focus has been redirected to strategic targets, which define ways of managing waste in the future (McDougall *et al.,* 2001).

Waste management systems in developed countries are characterised by an ever-increasing use of sophisticated technologies due to the availability of capital for major investments (Friend, 2001). With low unemployment rates typically between 5% and 9.9% (ILO, 2004) and high per capita incomes averaging US$32,040 (World Bank, 2004), the public can afford the externalities of healthcare, which include cleaner waste production.

1.2.2 HCWM in Underdeveloped Countries (The Case of Lesotho)

The nature of problems experienced by developed countries differs significantly from those of developing countries (Palmer Development Group, 1996). Developed countries deal with the fine-tuning of their already established systems while developing countries are faced with the difficulties of setting up systems that work.

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Effective HCWM requires a systems approach, which enables the effective use of available human resources and development of environmentally sound technologies. Also, financial allocation towards HCWM is a major determinant towards the establishment of working systems for HCWM. For these two reasons developing governments borrow funds to establish working systems and thus accumulate national debt. A huge national debt, however, lowers the possibility of investment in technologies and best practices. Developing countries need to establish affordable systems.

Furthermore, governments of developing countries are slow in agreement at national and regional levels on the appropriate waste management options that must be selected to implement changes in current practices (Rogers *et al*, 2002). There is a need to facilitate decision-making processes in order to speed up the design and establishment of systems

In realisation of how the previous HCWM system is suffering from incompetence, Lesotho has started to change to a new system (Lesotho MoHSW, 2005). The major step has been the identification of existing problems. These were identified by the Ministry of Tourism, Environment and Culture (MoTEC), the Ministry of Health and Social Welfare (MoHSW) and the Christian Health Association of Lesotho (CHAL) during a workshop (Siimane *et al.,* 2005) (report attached as Appendix 2) as follows:

Problem definition:

- HCW is highly infectious (high potential of transmitting HIV and Hepatitis B), but it is not being well managed.
- There is a low awareness of the hazard of HCW by health care staff and the public.
- Remote clinics are under-resourced in terms of funding and skills; therefore there is lack of infrastructure and equipment.
- There is a lack of legal framework on HCWM and the enacted law (Environment Act of 2001) is not operational yet.

- Absence of policies to guide HCWM often leads to non-integration and lack of responsibility at national and sub-national levels.

The health care delivery system in Lesotho is relatively well developed with Non-Governmental Organisations (NGOs) and the churches playing a key role in the most inaccessible areas (Lesotho Ministry of Development Planning, 2000). There are a total of 18 hospitals and 172 health centres (clinics) that are operational (LMoHSW statistical tables, 2003).

A national study on the medical waste situation was conducted (LMoHSW, 2004) to assess the magnitude of the HCWM problem. The findings proved that there is a lack of training in waste handling, absence of funds to construct desired technologies and an overall high but non-quantified risk to waste handlers at facilities. The low level of standardisation also observed in HCWM proves the lack of integration. There is no monitoring and evaluation of HCWM activities in the country. The conclusion from this study is that affordability and feasibility, rather than public health and environmental protection, have been the criteria for selection of HCW handling methods and technologies.

The Lesotho MoHSW has also formulated National Healthcare Waste Management Plans (LMoHSW, 2005), the benefits of which are yet to be reaped. Lesotho is also a signatory of the Basel Convention, requiring that less hazardous waste be generated and that waste is disposed as near to the source as possible. Section seven of the national environmental policy (Lesotho Ministry of Environment, Gender and Youth Affairs, 1996) sets up the intention of promulgating national laws that will implement this convention.

Connelly (2003) points out that movement of political power leads to a change in conceptualisation and commitment to environmental aspects and sustainable development. This has proved to be true for Lesotho's health sector. A change of ministers in the past has brought a new perspective to the way public health protection is perceived. Health care facilities have begun to be seen as nuisance generators regarding waste management and thus their operation is of growing concern.

The issues mentioned above are evidence that improvement is occurring in Lesotho's health care waste management system. It is at this early stage that key priorities must be set and sustainable alternatives selected.

1.3 LEGISLATION AND INSTITUTIONAL ARRANGEMENT IN LESOTHO

1.3.1 Governing Legislation

The constitution of Lesotho

Chapter 3 (section 36) of the Constitution of Lesotho gives direction to the process of sustainable development. It sets out the role of government in ensuring adoption of policies for environmental protection and endeavouring to ensure that present and future generations live in a healthy environment for safety, health and well-being. One such policy is the environmental policy (1996).

Environmental Policy

The policy specifies the country's priorities for protecting and promoting human health as well as the safety of their working places. Section 3.17 requires monitoring the effects and control of all phases of the life cycle of all substances likely to have an adverse impact on human health and the natural environment. Also included is the determination and use of environmentally safe and technologically sound techniques for the disposal of hazardous substances.

Health and Social Welfare policy

The health and social welfare policy identifies environmental health services as the addresser of all potential and actual threats to human health and welfare, by influencing environmental conditions and occupational health and safety of all workers. It does not, however, focus on HCWM as a completion to the cycle of health care provision. The policy lacks a strategy of action for HCWM.

The Environment Act (2001)

The Environment Act of 2001 does not directly address HCWM but hazardous waste in general). It gives the right to a clean and healthy environment for the people of Lesotho. The act stipulates the formation of the Lesotho Environment Authority (LEA) whose activities include the control of HCWM. Applicable sections fall under:

- Pollution control: Prohibition of discharges of hazardous waste into the environment and issuing licenses for pollution (across all media), ionising radiation and effluent discharge.
- Environmental Impact Assessment (EIA): EIA's are required for scheduled activities including treatment of HCW and constructions in health facilities.
- Environmental Quality and Standards (EQS): The LEA can establish EQS for waste as well as air and water quality. Monitoring and auditing of such are the duty of LEA.
- Environmental management: The LEA is mandated to issue guidelines for the management of hazardous waste.

Public Health Order 1970

The Public Health Order (order No.12 of 1970) deals with nuisances in public and private places and specifies the obligation of polluters to pay for the nuisances that they cause. The law is outdated and requires reform to accommodate the current economic activities in the country.

Labour Code Regulations (2003)

The right of workers to a safe and healthy working place is controlled by the Labour Code (Chemical Safety) Regulations of 2003. Although it does not address exposure of chemicals to the public through the environment, certain clauses can be applied to HCW. These clauses address among others, personal protection, labelling and packaging, and training and information for workers.

Urban Government Act (1983)

This Act defines the responsibilities for municipalities and has only been thoroughly implemented in Maseru by the establishment of the Maseru City Council (MCC). The Act mandates urban councils to provide sanitation and refuse collection services within their municipal boundaries. Since the Act does not define hazardous waste, the city's waste disposal system handles mixed hazardous and general waste. The Act is confined to operate in urban areas, which are not the focus of this study.

Sanitary Services and Refuse Removal Regulations (1972)

The regulations were promulgated under the outdated but not repealed Local Administration Act of 1969. Section 14 of the regulations stipulates that waste should not be deposited or stored within public view so as to become a nuisance, injurious or dangerous to health.

A time-line summary of the regulatory framework is presented below:

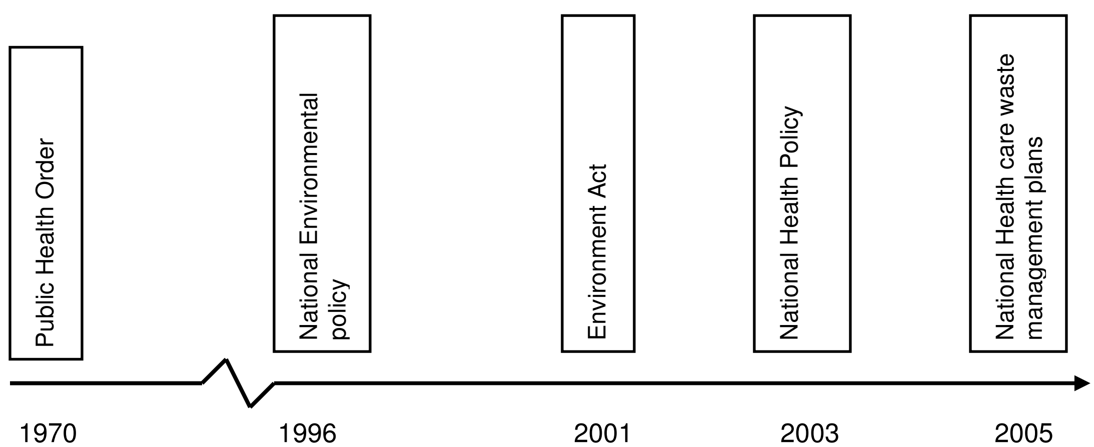

Figure 1.2: A time-line of national legal and regulatory framework for general and healthcare waste management

In summary, there is no legislation in the country to specifically address HCW and its management as well as the consequences brought about by waste treatment technologies; for example, air pollution by incinerators. There has also been no official adoption of foreign standards and guidelines e.g. SABS code of practice for HCRW. The challenge with present laws lies in enforcement of these laws, which is minimal.

1.3.2 Lesotho Institutional Setup and Present Inter-Linkages

All tiers of government should have the responsibility to ensure cooperative governance in order to ensure optimum use of resources and enforcement of accountability (Gauteng Department of Agriculture Conservation Environment and Land affairs, 2004). This calls for the integrated function of government ministries. In Lesotho, hospitals and clinics have traditionally managed their own waste streams through the activities of the diverse departments of the Ministry of Health and Social Welfare (MoHSW). Integration is lacking within the ministry. At district level, the District Health team, which forms part of the District Development Coordinating committee (DDCC), is the responsible body and applies public health interventions like environmental health to address waste management.

The MoHSW has a long-standing partnership with CHAL, which coordinates with government the provision of public health services provided at the health facilities that are owned and managed by churches. In terms of HCWM, there is little collaboration between the two institutions (Brent *et al.*, 2005). Private surgeries are coordinated by the Lesotho Medical Council. They manage their own HCW and very minimal monitoring of their HCWM activities is done (MoHSW, 2005).

The Ministry of Environment and Tourism is mandated with the responsibility of developing policies, action plans and guidelines to protect the environment and assist other ministries dealing with protection of the environment, which includes waste management. This is implemented by the National Environment Secretariat (NES). The line ministries include the Ministry of Local Government

(MoLG), Ministry of Natural Resources (MoNR), and the Ministry of Labour and Employment (MoLE) for the protection of workers.

An advisory committee called the Committee on Waste Management (COWMAN) operates under the NES. Members of the committee represent line ministries, NGO's and parastatals. The COWMAN has no legal power, but advises the LEA, and thus the MTEC, on all aspects relating to waste.

A Committee for Environmental Data and Management Authority, (CEDAMA) has a function of collecting and disseminating environmental data to relevant organisations. It has members from government ministries, parastatals and NGO's. Another important link that exists between the above-mentioned organisations is in the form of a Chemicals Management Committee (CHEMAC) also established under the NES. It is an advisory committee, which deals with environmentally sound management of chemicals in the country.

The HCWM system at hand thus identifies the MoHSW as having an internal role regarding HCW while the MoTEC has an external role. This joint responsibility on a single waste stream does not encourage an integrated approach because their activities are not coordinated via rules of behaviour and allocation of responsibilities. A body with authoritative power needs to coordinate HCW issues between all relevant bodies including bilateral and multilateral agencies.

1.4 SAFETY AND RISK IN HEALTH CARE WASTE MANAGEMENT

1.4.1 Occupational Health and Safety

Environmentally Sound Technologies (ESTs), as part of the HCWM system, should use human and financial resources in a sustainable manner [Agenda 21] (United Nations, 1992). In order to achieve this, employers should protect workers from occupational injuries. The South African code of practice for handling health care waste (SABS, 1993) requires an occupational health programme. Waste workers are evidently still ignorant of the laws in their countries that protect them and still work in conditions that are unacceptable

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according to WHO standards (Pruss et al, 1999). Specially, the use of personal protective clothing is still not practiced in Lesotho. The set of apparel will either be incomplete or the wrong type and material is used (Ministry of Health and Social Welfare, 2004), e.g. the use of clinical latex gloves instead of heavy-duty plastic gloves.

1.4.2 Public Health

According to the Technical Guideline On The Environmentally Sound Management of Biomedical and Healthcare Waste, human health should take first precedence in waste management decisions (Basel Convention,2003). In this way risks posed by HCW to the public should be minimised. Direct risk of injury by sharps transmits disease and if injury can be avoided, infections can be controlled. There are, however, indirect risks involved. For example, treatment of HCW by incineration, which is common in developing countries, releases particulate matter and other atmospheric emissions, which have detrimental human-health effects. It is worth mentioning that developing countries do not have the facilities to monitor and regulate certain, if not all, emissions, especially at the low levels set by the western world (Mc Rae and Agarwal, 1999). Hence setting a strict standard for such emissions becomes a theoretical exercise, and can only be avoided through the adoption of cleaner technologies, processes and practices that promote waste minimisation.

1.4.3 The Risk of Health Care Waste

Health care waste (HCW) poses risk by virtue of having one or a combination of the following characteristics: infectious, flammable, toxic, corrosive, and radioactive or having high oxidising potential (Prüss *et al.*, 1999). Health care waste poses both direct and indirect risks to public health. Wilson (1991) points out that the mere existence of a risk does not imply a problem, but an uncontrolled risk source represents the primary problem.

In Lesotho, the percentage of people infected with HIV/AIDS is 31% (Phaladze *et al*., 2005). Treatment of such patients poses a risk of transmission of HIV to health and waste workers in case of skin puncturing by sharps, e.g. needle pricks. Table 1.1 below summarises the infection risk due to needle prick.

Table 1.1: Infection risk based on needle pricks in sub-Saharan Africa (Kane, 1999).

Disease	Percentage In Sub-Saharan Africa Infected	Infection Risk Based On One Needle Prick	Percentage of HealthCare Workers exposed to viruses*
Hepatitis B	10.0 %	30.0 %	40.0 %
Hepatitis C	2.0 %	6.0 %	40.0 %
HIV/AIDS	> 3.5 %	0.3 %	2.5 %

* (International council of nurses)

A study conducted by Gisselquist (2003) suggests that in Africa, about 10% of the transmission of all HIV is due to the re-use of syringes. Healthcare related exposure is therefore be playing a huge role in HIV transmission.

Almost 85 % of sharps injuries occur between usage and subsequent disposal and more than 20 % of handlers encounter needle prick injuries (McRae and Agrawal, 1999). Table 1.2 below summarises the results of a study done in Jordan. In Lesotho technicians are equivalent to Incinerator operators.

Table 1.2: Needle injury by waste handler category (Mc Rae and Argawal, 1999)

Occupation	Percentage Injured
Staff nurses	34.6 %
Environmental workers	19.0%
Interns	15.7%
Practical nurses	8.5%
Technicians	60.0 %
Residents	11.7%

Technicians and Staff nurses are the groups at greater risk of injury and thus exposure to transmittable diseases. Interventions to avoid injury need to be addressed more towards these groups.

No studies have been conducted in Lesotho on injuries to HealthCare workers related to HCWM.

1.5 RISK ASSESSMENT TOOLS FOR HCW

Risk estimation involves developing quantitative measures of risk (Merkhofer, 1999). Current tools that have been used for risk estimation and assessment include the World Health Organisation Rapid Assessment Tool (WHO RAT) and WHO decision trees. The latter uses procedure based on qualitative approach to minimise the overall risks from managing HCW. It also describes HCWM options that are cost effective. The limits to these tools are their non-user friendliness at practical level for day-to-day application (Rogers *et al.*, 2002).

The WHO RAT quantifies and qualifies waste amounts and general HCWM practices at a facility. The tool was designed such that it encompasses only some aspects of a working system but is low on financial matters. These include budgeting and financing, training needs of staff or equipment requirements. The data thus gathered calls for expert assessment and interpretation in order to provide environmental and budget costs (Rogers et al, 2002). Contrary to the suggestions of Omachuno and Khalil (1988) on factors for evaluating technologies, the RAT does not assess socio-cultural, political, economic and policy alignment of current technologies and practices.

Practices used in HCWM in Lesotho differ widely and cost drivers and feasibility often influence their selection. Each has differing risks of infection to workers, patients and the public (judging from Table 1.2). It is therefore required to place weights and thus calculate risk factors for options such that decision-makers can rank the options and determine the best and most practicable option. This can be achieved by the application of WasteOpt (Rogers and Brent, 2002), which comprises of the WHO RAT and the Analytical Hierarchy Process (AHP).

1.6 THEME OF THE RESEARCH

1.6.1 Research Problem

Lesotho's HCWM system is still in its infancy and opportunities exist for contributions to develop the new system so that it can work in a sustainable manner. A gap has been identified in that there is a lack of appropriate tools that can be effectively applied in Lesotho and other developing countries. A tool is subsequently needed whereby Environmentally Sound Technologies (ESTs) and best practices can be selected to reduce the risk of infection to health care workers and the public due to exposure to HCW.

1.6.2 Rationale and Objectives for the Study

The motive for this research is to fill the gap in knowledge of the risk of HCWM practices in rural clinics. Since very little work has been done on HCW management in Lesotho, it is thus vital that, as strategies are made in the future, they are based on a solid foundation of knowledge. The development and application of the tool, termed WasteOpt, has been proposed (Rogers and Brent, 2002) so as to highlight problems, risks and costs associated with the available options for management of HCW and thus enable the best use of meagre resource available in Lesotho.

The research is based on the following questions:

- Is the developed tool (WasteOpt) suitable for the establishment of HCWM systems that minimise the risk of infection in rural clinics in a cost-efficient manner?
- How can the WHO RAT be modified to supply data inputs that are required for the application of WasteOpt in the field?

The research was therefore driven by the following objectives:

- To develop a tool for sustainable HCWM that is appropriate for developing countries.

- To establish prerequisites for its effective adoption.

These objectives will be achieved by implementing the following activities:

- To apply the workshop component of WasteOpt with experts in waste management in Lesotho.
- To add and modify questions in the RAT so as to improve its assessing capabilities.
- To conduct case studies of rural clinics which assess levels of risk due to HCWM practices.
- To compile the cost for the implementation of EST's and best practices for HCWM in Lesotho.

The major emphasis is on theory application whereby WasteOpt is developed and applied to Lesotho. Theory testing is also researched whereby WasteOpt is tested as a tool to aid decision-making.

1.7 CONCLUSIONS AND RESEARCH STRATEGY

This chapter outlined the background of HCWM in Lesotho as a third world country, in terms of institutional setup and legislative framework in the context of public health protection and occupational health and safety. Thereby, the research problem and rationale has been defined, i.e. there is a lack of appropriate tools that can be effectively applied in Lesotho, and other developing countries, to minimise the risks associated with HCW in a cost-efficient manner. The development of a new tool, termed WasteOpt, is subsequently proposed; by incorporating an existing HCW risk assessment method, i.e. the WHO RAT. The aim is to inform decision-makers on the risk of working with health care waste and the cost effective solutions that can be implemented within a HCWM system.

In Chapter 2, the evolution of waste management from *ad hoc* practices to integrated waste management is discussed. The gap between developed and developing countries is identified in terms of knowledge and approaches to WM.

Lastly a SWOT analysis of applying developed world models and approaches in developing countries is presented.

In Chapter 3 a systems approach and the use of WasteOpt is proposed as a start to the solution of the identified problems.

Chapter 4 outlines the methodology used to carry out the research. After analysis and a discussion of the results in Chapter 5, the thesis closes with conclusions and recommendations in Chapter 6.

CHAPTER 2

Literature review

The scope of this study is restricted to the management of health care waste (HCW) in rural areas of developing countries. The subsequent literature review, however, touches more on general waste. This is due to the extensive research done in the field of general waste, while there is little documentation on HCW, especially in developing countries. There is a correlation between general and health care wastes since they have been managed in unison from as far back as 500 BC (Barbalace, 1999) up until the 1970’s in the developed world. In developing countries there is often no distinction between the different sources of waste; it is simply all mixed (International Solid Waste Association, 2002).

2.1 THE EVOLUTION OF WASTE MANAGEMENT

Since the days of primitive society, man has used earth’s resources to support life and then disposed of waste (Tchobanoglous *et al.*, 1977). Historically, the amount of waste generated by human population was very insignificant. This was due to the small size and the wide spread of population around the world. There was also very little exploitation of natural resources. Waste was changed into harmless products by the natural assimilative capacity of the earth. When this capacity is exceeded then waste disposal should be controlled so as to ensure sustainable development.

Waste disposal problems can be traced back from the time when humans began to congregate in tribes, villages and communities. At first *ad hoc* disposal onto streets and the countryside led to the breeding of vermin and odour. This situation of medieval Europe can be likened to the situation in most developing countries today. The subsequent bubonic plaque epidemic, cholera and typhoid fever killed half of the European population in the 14th century and caused many other epidemics and high death tolls (Tchobanoglous *et al*., 1977). The year 1750 began the period of industrial revolution. Mass movements of people to the cities led to increasing amounts of waste.

Much activity on waste management came in the 19th century. By the 1800s, households and industries began to have ash pits or ash heaps where onsite open burning of commercial and industrial waste was practiced (Hickman and Eldredge, 1999). Waste generators selected the simplest and least costly method. The link between filth and diseases was made in England in 1842 and in 1888 the English parliament barred waste disposal in public waterways and ditches. The Public Health Act of 1875 was introduced to keep households clean in the UK. The public health approach was then adopted as the motivation to remove waste from the human habitat. In the US the first incinerator for waste treatment was built in 1889 (Barbalace, 1999).

In the 1920s, landfills with semi-controlled burning became a popular method of waste disposal. However, as stated by Hickman and Eldredge (1999), "*A smoking dump is like a smoking gun. It is clear that a crime is being or has been committed*". Hickman and Eldredge further point out that the burning dumps' impact on local air quality was a primary reason that early efforts after World War II were directed towards putting out the fires to control the problem of dumps. Disposal options in the 1950s included incineration, composting, recycling and the sanitary landfill. In the 1960s private contractors came into partnership for collection of waste (Waste Watch, 2004).

It is evident that the bias was still towards end-of-pipe interventions as solutions to pollution. Re-use and recycling were practiced in the middle of the 20th century.

The evolution of a separate category of clinical (health care) waste within the municipal waste stream dates back to the late 1970s, when clinical wastes, including syringes and bandages, were washed up on US east coast beaches (Mc Rae and Argawal, 1999). In many contemporary literatures HCW is still excluded in hazardous waste classification or mentioned in passing. It can be concluded that HCW has not been receiving the attendance it requires.

This history demonstrates that with time man has realised the damage caused by unmanaged waste. He has attempted to remedy the damage (with great costs) and is ultimately shifting paradigms from remediation to prevention. Figure 2.1 illustrates this phenomenon. While the cost of indiscriminate disposal has been constant and low, the costs of remediation and end-of-pipe treatment have been steadily increasing. Remediation is the most costly of all the strategies. Prevention strategies began late in the twentieth century, but their cost has decreased. Hirschhorn *et al.* (1993) explain that by developing new 'control' waste management strategies, short-term improvements in waste management have been achieved.

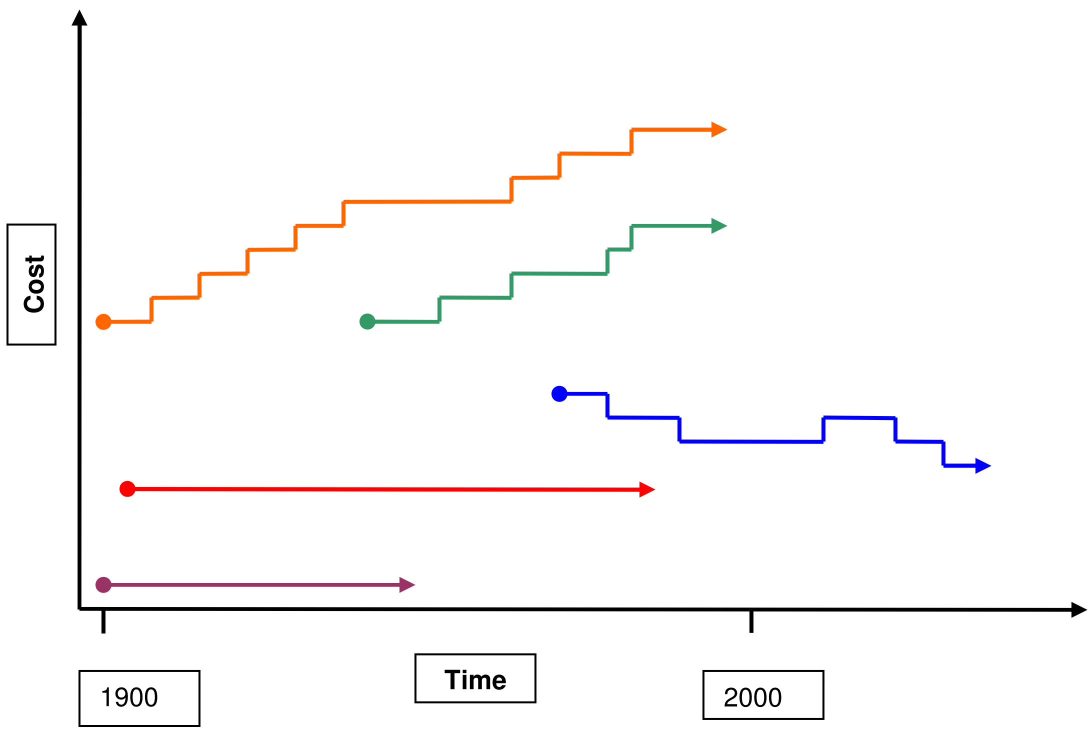

Figure 2.1: Waste management paradigm shifts

Remediation — End-of-pipe treatment —
Prevention — Re-direct and sequester/dispose —
Laissez faire disposal —

Adapted from Hirschhorn, Jackson and Baas (1993)

It should be recognised that despite the different conditions in which industrialised and developing countries must work to solve waste management problems, there are similarities between these countries. In neither case does the public want WM facilities near residential areas and the amount of waste generated is increasing (UNEP IETC, 1996). In developed countries this can be attributed mainly to improved waste statistics collection (ISWA, 2002). In both developing and industrialised countries adopting an integrated approach to waste management is vital (UNEP IETC, 1996).

Cleaner production and consumption has been practiced for more than 12 years in industrialised countries (Kjaerheim, 2003) and this is the field in WM where a major difference exists between the first and the third world countries (UNEP IETC, 1996). It is apparent that one of the best ways to reduce waste is to limit consumption of goods and increase the rate of recovery and re-use of goods. Recovery is not practical in HCWM due to the risk of infection, both in developed and developing countries.

2.2 THE APPLICABILITY OF FIRST WORLD APPROACHES TO THE THIRD WORLD

The first solid waste management models were optimisation models and dealt with specific aspects of the problem (Morrissey and Browne, 2003), for example, the location-allocation model for transfer station siting (Wilson, 1981). Morrissey and Browne (2003) explain that these early models suffered from several shortcomings such as having only one time period, recyclables rarely being taken into account, having only one processing option of each type, or having a single generating source. The limitations thus made them unsuitable for long-term planning.

The following tools and approaches have been used in the developed world and some adopted by developing countries.

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2.2.1 Legislative Tools (End-Of-Pipe and Strategic Targets)

Waste management in developed countries is governed by legislation, which are either end-of-pipe or strategic targets. End-of-pipe regulations, such as emission controls for incinerators, operate as 'fine-tuning' of the waste management system (White *et al*, 1995) because it promotes the use of the Best Available Technologies and practices. Such regulations, however, do not bring major changes to the way that WM systems operate. For this reason, strategic target legislation is increasingly being used to set future strategies based on the hierarchy of waste management (White *et al*., 1995). Such legislation includes the Environmental Protection Act (1990) of the UK and the Medical Waste Tracking Act of 1988 of the USA (Woodside, 1993), which are national laws, and the Packaging and Packaging Waste Directive operating in the European Union (European Commission directive on packaging and packaging waste, 1994) emphasise cleaner production and are backed by enforcement. These legislations, driven by educated pro-active environmental pressure groups and the general public, dictate that waste generators, including health care facilities, operate within acceptable standards. Proper enforcement of these stringent laws makes them highly effective. Due to adherence to legislation, the member states of the European Union (EU) have reached the most advanced state in waste management in the world (ISWA, 2002).

Whereas many countries like Lesotho are still in the process of promulgating specific legislation for waste management, South Africa as a developing country has a number of first world regulations ands standards, e.g. the Environmental Conservation Act (1989), the National Water Act (1998) and the National Environmental Management Act (1998). Standards include Water quality standards. However, the biggest challenge facing the country is the lack of enforcement. Hill (2004) and Friend (2001) agree that this is due to insufficient funding. Hill also blames weakness in governance and corruption.

This approach therefore can only benefit developing countries if more people and institutes become aware and strive for positive publicity and become threatened by negative publicity. This will increase compliance.

2.2.2 Economic/Market-Based Tools

The application of economic tools for waste management uses the proverbial carrot while legislation relies on the stick. These two work best when put together. This approach better summarised as "the polluter-pays principle" offers a system of penalties and rewards. Taxes and fees are paid to government and service providers respectively for environmental degradation (pollution) and for services rendered for the disposal of wastes (SA DEAT, 1993).

Cost-benefit analysis (CBA) enables decision-makers to assess the positive and negative effects of a set of scenarios by translating all impacts into a common measurement, usually monetary. The tool estimates the costs of avoiding a negative effect, e.g. the cost of pollution control or to establish how willing individuals are, to pay for an environmental improvement (Morrissey and Browne, 2003). The problem with CBA lies in the uncertainty of using monetary units on environmental and social impacts. Assumptions of prices may also change with time, impacting on the waste management programme. CBA is being used in developed and developing countries like South Africa.

Green marketing is also a relevant tool that focuses on the environmentally educated consumer. Products that are packaged in recyclable or refillable materials decrease the amounts of waste disposed of and are thus preferred. This concept is linked to Environmentally Preferable Purchasing (EPP) for Health Care Facilities and is widely used in the western developed world (USEPA, 1999), in realisation that correcting a problem close to its source is safer and less costly than taking action downstream. By purchasing products/services whose environmental impacts have been considered and found to be less damaging to the environment and human health, health care providers benefit by:

- providing a healthier environment for patients, workers and employees through reduced exposure to cleaners, solvents, paints, and other hazardous materials;
- reducing costs by lowering overheads, avoiding waste disposal, liability and occupational health costs; and
- significantly improving their impact on the overall quality of the environment while also leveraging positive publicity (USEPA) .

Purchasing, being a money transfer stage and contract development is an effective point to apply actions to improve public health safety and environmental impact because suppliers can best be influenced.

Economic tools are not widely used in developing countries due to lack of appropriate goals and policies. Also, heavy taxes on large populations that can ill afford to pay for basic needs may be regressive to them (Hanks and Hobbs, 1991).

2.2.3 Mathematical Models

Models such as location-allocation and selection-allocation have been proposed in the past as an aid to waste management primarily for strategy evaluation (Wilson, 1981). Location-allocation has been used to determine optimal sizes, numbers and location of hazardous waste management facilities, given transportation and processing costs. This model thus compares the cost of having large, centralised facilities against the cost of smaller, decentralised facilities (Sewall, 1990). Many of these models are complex and a lot of time is spent trying to solve the model more than relating the results thereof to the problem (Wilson, 1981). Such models are also data intensive, which makes them unsuitable for third world countries where there is a large deficit of data. Wilson goes on to point out that this data deficit leads to waste coefficients being estimated from a small survey sample or analogy into national averages, giving unreliable results.

2.2.4 Life Cycle Analysis Models

Life cycle analysis (LCA) as a comparative tool for environmental impacts is recently being used to compare waste management strategies (Morrissey and Browne, 2003). Powell (2000) has shown that decision-makers who use LCA models end up focusing more on financial issues due to the complexity of such models. The failure of Environmental LCA (ELCA) to assess health impacts, social, economic and time dependent impacts make it inadequate for WM strategy choices in developing countries. Environmental Impact Assessments cover these impacts but are also difficult to perform. Despite the shortcomings of LCA-based models, they tally with integrated waste management by attempting a holistic approach.

2.2.5 Models Based On Multi-Criteria Decision-Making

When used in WM, these models have focused on the decision-making process rather than identifying the problem (Morrisey and Browne, 2003). ELECTRE, an integrated solid waste management model, has been used in Finland by Hokkanen and Salminen (1997) in choosing a solid waste management system. It is helps in decision-making for multiple criteria in identifying alternative WM strategies that meet cost, energy, and environmental emissions objectives. Karagiannindis and Moussiopoulos (1997) applied AHP in integrated municipal waste management. The application of AHP in developing countries has been encouraged by Alphonse (1996) but application has not been wide.

2.2.6 Integrated Waste Management

Integrated Solid Waste Management (ISWM) was first grasped by the developed world in the 1600s. However, it was seldom used in the developing countries of Africa until the 1900s when the Zabbaleen family of Egypt first integrated recovery and recycling of waste (Mvuma, 2002). Since the publication of 'Our Common Future' (WCED, 1987), waste management issues have been examined within the broader context of sustainable development, which attempts to reconcile the concerns of environment, economy, and society (White *et al*,

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1995). Existing waste management hierarchies like the four R's (reduce, reuse, recycle, and recover) have dealt with the physicochemical, energetic, and material conservation aspects of waste management effectively, but have not dealt well with the socio-political and biotic aspects of waste management very well (Brown, 1999). These concerns include informal sector waste-pickers whose low earnings from waste can support families. In order for a waste management system to be effective it should be environmentally, socially and economically sustainable and it is likely to be integrated. According to Watkins (2000), in an integrated system, units at different levels should plan simultaneously and together because decisions taken at one level will usually affect other levels. ISWM entails the establishment of one system which :

- management of all types of waste;
- impact assessment across all media (water, air and land); and
- involvement of all stakeholders including the includes public.

The UNEP supports this approach and mentions that this approach has become important because it allows for full utilisation of resources and thus helps in achieving economies of scale. It incorporates all sectors, including informal ones and ensures coordination of all waste management activities.

2.2.7 Informative Instruments

There is a continuing need for research and technology transfer between countries (ISWA, 2002). Exchange of experience has mainly been taking place between developed countries, or between developed and developing countries. Wassersug (1998) also points out that European countries have learnt much from the practices and mistakes of the western developed world. A need arises also to share information between developing countries.

In many countries, education and awareness raising initiatives are launched as part of public participation. ISWA (2002) emphasises the importance of public participation in projects before their realisation. Special consideration is to be given to those projects that will impact on the lives of the public. An informed citizenry would result in pressure upon facilities to act where reliable data warrants such action (Wassersug, 1998).

It is crucial for a country to have an effective and competent workforce at all levels of waste management. The problem with developing countries is the lack of academic programmes to achieve qualifications in waste management (ISWA, 2002).

Of equal importance (for information acquisition and dissemination) for developing and developed countries is the issue of environmental reporting (ISWA, 2002). This clear and systematic manner of reporting is a crucial way of sharing information between companies and government and between countries at country level to encourage improvement in diverse environmental fields, including waste management.

The issues mentioned above have worked for developed countries. Many developing countries are adopting this information strategy. South Africa and Lesotho are examples. South Africa has learnt lessons regarding the selection of inappropriate approaches and techniques in involving stakeholders in projects. They have therefore prepared guidelines and best practice manuals for different stakeholders. The South African Department of Environmental Affairs and Tourism (2002) has realised that *"[a]pproaches and tools should be selected to achieve effective….stakeholder engagement and not only to meet minimum regulatory requirements*."

The following are examples of projects that tried to adopt first world approaches but were unsustainable (Palmer Development Group, 1996):

Lagos, Nigeria (1977)

The Lagos state refuse disposal board was established to deal with escalating waste problems. New vehicles and expatriate technical assistance were procured to manage the operation. In 1984 the expatriate contract expired and Nigerians who had limited engineering and waste management design knowledge ran the board. Due to inadequate funding, staffing and equipment, the board's operations became less planning oriented and ended up only dealing with day-to-day crises management.

Antananarivo, Madagascar (1984)

A World Bank project was destabilised due to differences between government and an overseas supplier of waste collection vehicles. The government charged duties and taxes on the import of these vehicles leading to the supplier refusing to provide spare parts for maintenance until it was reimbursed the taxes. Three years later 11 of the 23 trucks were out of service due to lack of spare parts.

Cairo, Egypt

The Zabbaleen contractors had been practicing waste recovery by house-to-house collection in Egypt. However, they discovered it was more profitable to collect refuse from wealthy neighbourhoods and thus neglected the poorer ones. This inequity in service provision resulted in inefficient resource recovery.

The cases above depict the difficulties facing developing countries: the option to apply first world approaches and technologies is attractive because of project funding from first world countries as well as the success of the application of the approaches in the developed countries. But the necessary know-how, know-why and the partnership for monetary gain as the primary focus require large investment/resources (Khalil, 2000).

2.3 A SWOT ANALYSIS OF APPLYING DEVELOPED WORLD MODELS AND APPROACHES IN DEVELOPING COUNTRIES

The SWOT analysis is divided into internal and external analyses. Tables 2.1 and 2.2 present the strength, weaknesses, opportunities and threats that result from applying the models and methods in the developing country context from a government and community perspective, while Table 2.3 analyses the same factors from the perspective of external assistance by bilateral and multilateral agencies.

Table 2.1: Government (internal) analysis*

Factor	Strengths	Weaknesses	Opportunities	Threats
❑ Development implementation	1. Implementing such approaches exposes poorly knowledgeable officers of the trends within the developed world	1. Stringent laws are not set in developing countries due to the difficulty of law enforcement, which requires monitoring and evaluation. Present laws are fragmented	1. The restructuring of government administration from centralised to de-centralised approach	1. National and local governments often adopt strategies in a vacuum before they examine their own waste streams and cap-abilities
❑ Process for legal reform	2. There is usually a solid support, either financial subsidy or technical expertise from bilateral and multilateral aid agencies	2. There are often no clear roles or functions of the various national agencies defined in relation to WM and also no single agency or committee with authority designated to coordinate projects or activities	2. New acts can be formulated and old ones updated	2. Action to adopt certain strategies is very slow
❑ Planning and integration	3. Top-down planning is continually being strengthened for more focused decision-making	3. Lack of integration of waste management practices and unclear jurisdiction boundaries causes systems not to	3. Private-public partnerships are being encouraged and can be adopted	3. Funding is highly competitive for the likes of health, infrastructure, national security, etc

		have clear decision-making powers and feedback		
❑ Implementation and strategy action plans	4. The government has the sole power to formulate new rules, acts and new ordinances for strict implementation of proper MSWM	4. Research and development activities in waste management are often a low priority due to lack of plans in developing countries		4. Lack of plans and integration encourages piece-meal assistance from donor agencies
❑ Training	5. Some governments like Lesotho have started training personnel in different disciplines of environmental sciences and engineering to deal better with waste management issues	5. At local level there is particularly little or no training in engineering or management		
❑ Value systems		6. Low work ethics and thus poor work quality are often exhibited by waste workers due to social perceptions of the job		
❑ Technology use		7. In technology transfer from industrialised countries, highest technology is sought		

		where medium –level technology would be appropriate to the available resources [1]		

*Adopted from Ogawa (1996) and Srivastava *et al* 2005
[1] Omachuno and Khalil (1988)

Table 2.2: Community (internal) analysis (modified from Srivastava *et al*, 2005)

Factor	Strengths	Weaknesses	Opportunities	Threats
❑ Community-Based Organisations	1. Many communities have community-based organisations (CBO's) in place who aim to develop society	1. People depend on the government to take action	1. Non-governmental organisations (NGO's) usually support many CBO's	1. Poor inter-sectoral communication and coordination confuses and demoralises the public
❑ Community groups	2. Youth and students have active groups which can participate	2. Some communities are unwilling to participate in waste management	2. Unemployed community members can participate and gain knowledge	2. Community programme or project sustainability is poor in developing countries
❑ Community groups	3. Housewives and the active elderly groups are easily involved	3. Lack of information and environmental awareness in the communities leading to misunderstanding and apathy	3. Self-help and self-reliance can be achieved	

			4. Mobilisation can be achieved by awareness training and information, education and communication (IEC) leaflets	

Table 2.3: External support analysis (adopted from Ogawa 1996)

Factor	Strengths	Weaknesses	Opportunities	Threats
❑ Donor agencies	1. There is an abundance of technical expertise and human re-sources in waste management in external donor agencies	1. Human resource base lacks experience and knowledge of WM for developing countries	1. Developing countries are striving towards global cleaner production and thus external donor agencies have an interest to assist	1. Communication between external support consultants and local counter-parts is often a problem (no common spoken language)
❑ Technology transfer		2. There is a tendency of donor countries to support technologies available or invented in their countries regardless of its applicability e.g.	2. Research and development activities in external donors may be focused on waste management in developing countries	2. Waste management may not be a priority sector for some donor agencies

		obsolete equipment		
		3. Many technologies are tested and designed under developed country conditions, e.g. dependability on electricity, leading to unsustainable use of such in developing countries		3. Recipient countries often receive what-ever aid is rendered even if it is in-appropriate
❑ Integration coordination and finances		4. External support agencies are often not coordinated in a country due to organisational mandates		4. Solid waste management does not often generate revenues and the risk of a loan for such a project is seen as high by external lending agencies

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The biggest problems arise from the weaknesses due to the country's internal operation. The pressures from external agencies further worsen this. There seem to be less opportunities and strengths. These are the areas that need attention in waste management planning: creation of opportunities and elimination of sources of weaknesses and alteration of threats into opportunities.

2.4 THE WASTE MANAGEMENT GAP BETWEEN DEVELOPING AND DEVELOPED COUNTRIES

Developing countries are at an advantage by being followers of developed countries' initiatives, since they can try to avoid the mistakes made by the pioneering countries. However, due to the more rapid advancement of WM in developed countries relative to the developing world, a gap in knowledge is realised. Third world countries can learn to minimise this gap to make WM successful. Wassersug (1998) mentions the following points as critical issues for effective development of waste management systems in developed countries that can be used to show the way forward for developing countries.

2.4.1 Information

Today the developed world has information that enables better decision-making by managers. Improvements in science and technology allow better monitoring of waste management and research has yielded a better understanding of health and environmental impact. Compliance to set regulations requires comprehensive information e.g. waste quantities, qualities, sources, etc. and this information has been used to develop effective waste management strategies in developed countries. The sharing of information within regions also strengthens waste management.

Developed countries manage their information better in order to avoid its scattering and poor organisation. This makes information easy to access (Omachuno and Khalil, 1988)

2.4.2 Enforcement and Compliance

Solutions to waste problems are often costly, and therefore do not lead to voluntary compliance. To be successful, compliance programs are based on sound principles and benefits. Legislation and control play a pivotal role in developed countries. The trade-off that exists between costs and risk are balanced by policies and legislation.

2.4.3 Private-Public Partnership

In the Western world, some of the success of hazardous waste management depends upon the existence of a private sector that makes its profits from handling and managing wastes. This increases the competition to do business, while in the process waste is effectively managed.

2.4.4 Public Involvement

Information gathered by facilities and governments to define environmental impact is routinely required and freely available to the public. Communications between all the diverse interest groups exists and is frequent. They are given information for environmental awareness and frequently are able to on an informal basis to develop and plan individual compliance strategies.

2.4.5 Technology

Before a country can adopt a technology it has to perform systematic analyses to assess financial affordability, capability of present infrastructure so as to develop national priorities (Eldin, 1988). This requires extensive information on technology that is often lacking in developing countries. Developed countries are at an advantage because of an abundant skilled workforce who can perform the analysis of technology without the assistance of expatriates. Unlike the developed world, some developing countries do not have abundant skills to assess and acquire foreign technology as it suits donors (Omachuno *et al*, 1988). This often leads to the acquisition of inappropriate technology. Furthermore, as the result of trends that shorten of the technologies' life cycle sees transfer of outdated/inefficient technologies to the developing world (as donations or products on the market) these can work against countries' environmental objectives for sustainability.

Developed countries have skilled labour and capital, which render their technologies appropriate. The lack of these factors in developing countries sees them opting for inappropriate technologies. Labour-intensive unsophisticated technology is appropriate for such countries although lack of skills hampers their optimal use (Omachuno *et al*, 1988).

2.4.6 Financing

Proper budgeting for waste management is vital in the integrated system. To assist financing these activities, developed countries have the advantage of using locally made equipment, which can be cheaper and be more appropriately designed for prevailing conditions. They can also evade the cost of import and other taxes. Rich countries have high labour costs and sometimes importing equipment may be cheaper due to currency strength.

2.4.7 Implementing strategies

Omachuno and Khalil (1988) mention the divergent conditions prevailing in different developing countries. There is therefore no single pattern, technology or approach that can be considered as appropriate for all. Seen in this light, it is evident that waste management models and approaches from the developed world are not necessarily applicable to developing countries. It is vital, therefore, to devise strategies of either

- updating current waste management standards to those of developed countries; or
- developing new approaches and tools that are applicable and sustainable in poor countries.

In summary, many models recognise that, for a waste management model or strategy to be appropriate, it must consider environmental, economic and social aspects. No model or approach examined here has considered all three aspects together as well as the intergenerational effects of the strategies proposed (Morrissey and Browne, 2003). Furthermore, these models rarely consider the involvement of all stakeholders, including communities.

2.5 CONCLUSIONS

Many tools have been developed and applied effectively in the first world. They do not necessarily prove to be perfectly applicable to developing countries due to the different conditions under which they are applied. Therefore, an effective model for WM in developing countries must be developed following the key principles mentioned above.

In addition, for such a model some tools developed in the first world can be modified for use in a developing country, i.e. the WHO Rapid Assessment Tool (see Section 1.5 of Chapter 1). The formulation of the model and its applicability is described in Chapter 3.

CHAPTER 3

Theoretical setup

3.1 INTRODUCTION

This chapter presents the WasteOpt model which is applied to realise the ultimate goal of the research. The systems approach to problem solving is introduced first and its relation to WasteOpt is highlighted. Emphasis will be put on the Analytical Hierarchy Process and life cycle management (LCM), which constitute WasteOpt. At the end of this chapter, the conceptualisation of the model (consolidation of AHP and LCM) is elaborated in detail.

3.2 THE SYSTEMS (HOLISTIC) APPROACH

A system has been described as " *a set of parts coordinated to accomplish a set of goals*" (Churchman, 1983), and "*a group of interacting, interrelated or interdependent elements forming a complex and unified whole that has a specific purpose*" (Lannon-Kim, 1994). Both these definitions acknowledge two vital points about a system:

- It is composed of a group of parts or elements; and
- the parts or elements work in unison towards an ultimate, realisable goal.

The system can be considered as an input-output model as shown in Figure 3.1. Superimposing feedback onto the basic model (Figure 3.2) renders the system controllable in terms of inputs (Wilson, 1974). The viability of the system also depends on the capability of the system to respond to threats and opportunities from its environment, regardless of whether these were foreseen at the design of the system (Jackson, 2000).

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Figure 3.1: The basic input-output model (adopted from Wilson, 1974)

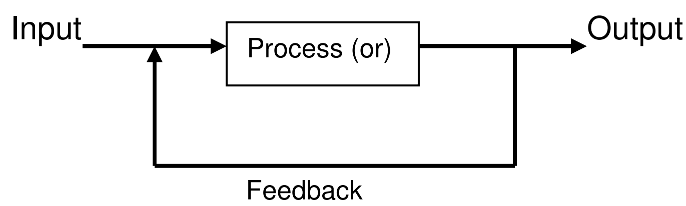

Figure 3.2: The basic system with feedback loop (modified from Wilson, 1974)

The systems approach (also called holistic approach) is the most popular problem-solving technique today (Jackson, 2000). It is favoured [for application in waste management issues] over its counterpart, systems analysis, because the latter is useful for revealing *how* a system works while the former exposes *why* a system works the way it does (Watkins, 2000). The applicability of the systems approach can be challenged since waste management systems are composed of subsystems over which no single person has overall control (White *et al,* 1995). The advantages of the systems approach outweigh this challenge and are as follows:

- It provides an overall picture of the waste management process, which is essential for strategic planning.
- Since all waste management systems are parts of the global ecosystem, reductions of certain unwanted parameters of the system (e.g. land pollution) could bring greater impacts elsewhere. Changes in consumption for example can have a reduction in pollution.
- Economically financial incomes from waste management must at least match the expenses. Through this approach, each boundary of operation [sub-system] can be checked for inefficiency and thus the efficiency of the whole system (White *et al*., 1995).

The holistic approach is also connected to a form of synergistic impacts, which comes from a general thesis of wholes: "*the whole is more than the sum of its parts*" (Encyclopaedia of Educational Technology, 2004). White *et al*. (1995) point out that a holistic approach is environmentally and economically sustainable. One can extend this observation to include socially sustainable. They further explain that looking at different related parts individually leads to inefficiency due to duplication of efforts.

According to Athey (1984) and Beck (1973), the systems approach to solving problems is based on [but not restricted to] the following steps:

- Define the problem;
- gather the data describing the problem;
- identify alternative solutions [within the system identified];
- evaluate these alternatives [to meet objectives of the system];
- select the best alternative [based on criteria that prioritise multiple objectives of a system]; and
- follow up to determine if the alternative is working.

The above points are encompassed in this research study. The selections of the best alternatives, as well as the follow-up, fall within the implementation of the research. It is therefore proposed that a systems approach in the developing country context is required as a basis for the development of an appropriate waste optimisation model. The Water Research Commission (1995) identifies a holistic approach for developing countries to constitute of the following:

- Institutional arrangements
- Appropriate systems
- Finance
- Community involvement

The above-mentioned points tally with what Wilson (1974) and Tchobanoglous *et al.* (1977) refer to as elements of a system, to which they add components such as objectives, reporting and accounting, as well as operations. Reporting and accounting can be related to feedback in Figure 3.2, which allows inputs to be controlled in relation to measured output (usually a predetermined standard). All subsystems of HCWM (health care waste management) should be managed to optimise the operations. It is therefore important to implement a model that leads to the adoption of an optimised systems approach. WasteOpt is the proposed model.

In comparison to the systems presentation in Figures 3.1 and 3.2, WasteOpt is illustrated in Figure 3.3 below.

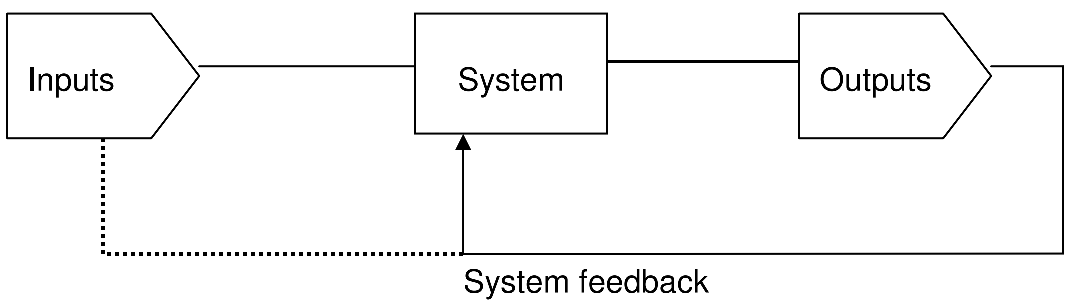

Figure 3.3: WasteOpt presented as a systems approach

WasteOpt's application in this study is not to redesign the system but optimise its functionality by optimising the use of scarce resources. The inputs are to an extent limited to the availability of resources, so the system feedback changes are directed towards the functioning of the system. The functionality of the system adjusts to the inputs and can operate in a sustainable manner with the limited resources.

WasteOpt can be applied to waste management in resource poor countries in two parts, as discussed below.

PART A: The selection of Environmentally Sound Technologies is based on reducing risk using the following activities

The system inputs are:

- A database of available technologies (options), prepared by an expert and a survey of the facilities and equipment subsystem).

- A representative working group of the human resources subsystem which has the role to compare options. It comprises of nurses, environmental health practitioners, waste management control and pollution control practitioners.
- An independent facilitation team that is not part of the system .It includes the participation of waste management experts whose role is to describe the system in terms of tasks and available technologies.

The WasteOpt's outputs to allocate priorities to combinations of available technologies are:

- A ranking of acceptable risk of each unit task, divided into equipment, procedures and manpower.
- The identification of optional activities.

PART B: The preference of Environmentally Sound Technologies (ESTs) is based on cost/finances.

The inputs are:

- Cost analysis for preferred ESTs.

Outputs:

- Ranking of costs for ESTs that are similar or near to similar ranking in safety.

The views of Clark and Augustine (1992) and those of Forrester (1972) are taken to validate the WasteOpt tool's applicability.

- Clark and Augustine are of the opinion that "*to pursue a modelling methodology, we must identify a complete and relevant set of information attributes, assign different dimensions to these attributes and test the performance of the system on these several dimensions*".
- Forrester says, "*the obvious purpose and test of a model of an industrial system is its ability to predict a specific future action*". From this statement Watkins (2000) draws an analogy that the quality of input to a model has a direct bearing on the model's ability to predict future action accurately.

It is therefore the objective of this dissertation to verify that the WasteOpt is applicable to the design of a waste management system in rural health care facilities of Lesotho. The method of verification is the outcome of the model that will direct action towards improved waste management of health care waste. The considerations for a systems approach for HCWM are diagrammatically represented in Figure 3.4. Figure 3.4 is based on an ideal situation, which is what developing countries should strive to achieve.

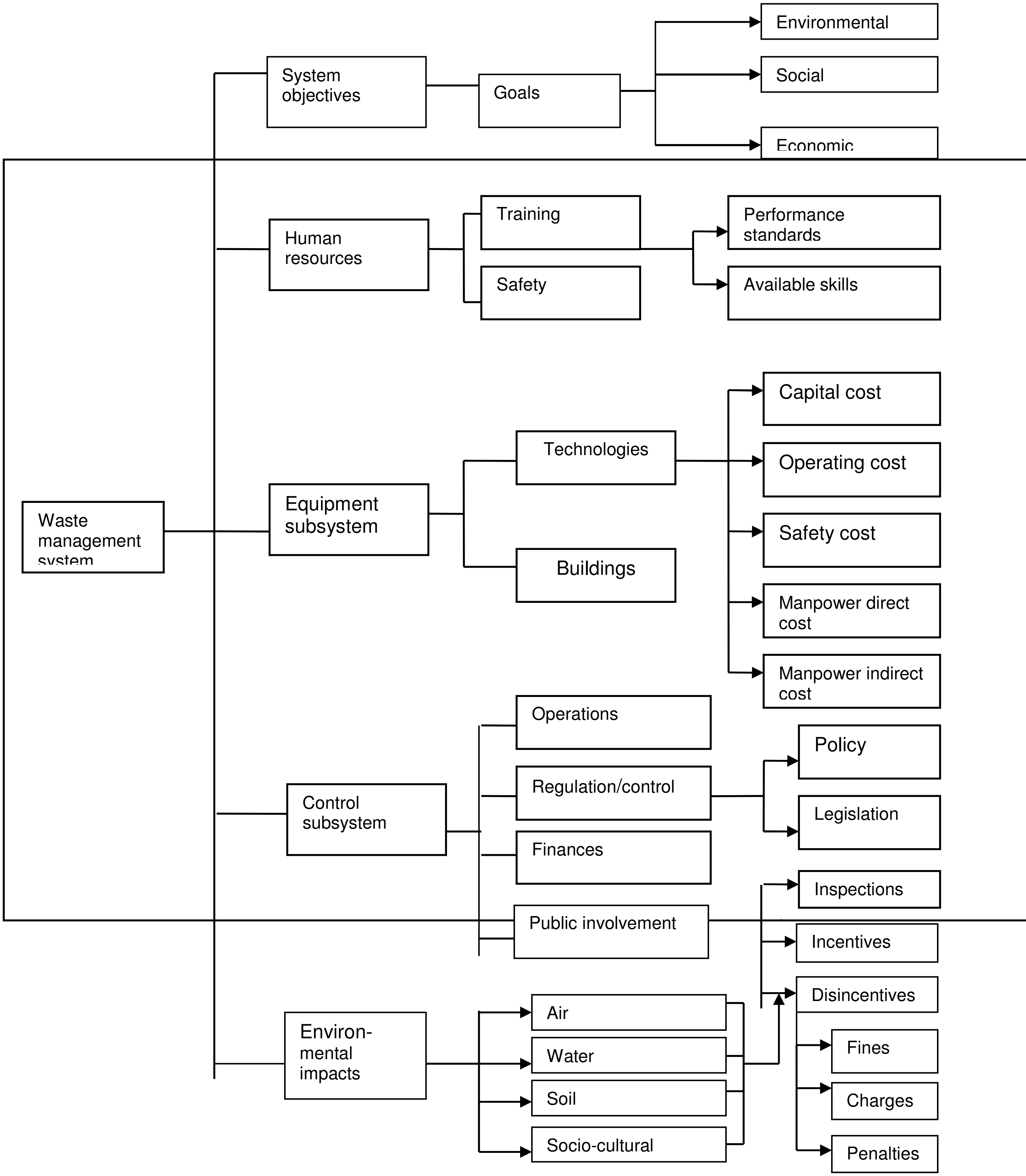

Figure 3.4: The systems approach to waste management

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3.3 THE USE OF AHP AND ENVIRONMENTAL LIFE CYCLE DECISION SUPPORT TOOL

WasteOpt is based on the combination of two well-known decision support tools: the Analytical Hierarchy Process (AHP) to establish priorities and Life Cycle Management (LCM), and specifically Life Cycle Assessment (LCA) and Costing to identify technical options for HCWM. The benefits of both processes are shown in Table 3.1.

Table 3.1: The benefits of LCM and AHP

Life cycle Management	Analytical Hierarchy Process
1. LCM includes all inputs and outputs and procedures of a system, over time and overall space. 2. Quantitative outcomes ensure the exclusion of emotions in decision-making. 3. Encompasses all sustainability issues pertaining to a system	1. Does not insist on consensus but synthesizes a representative outcome from diverse judgements 2. Considers priorities of factors in a system and enables the selection of the best alternative based on goals. 3. Offers a scale for measuring intangibles and a method for establishing priorities. 4. Integrates deductive and systems approaches in solving problems • Reflects the natural tendency of the mind to sort elements of a system into hierarchies while also tracking the logical consistency of judgements used for determining priorities.

WasteOpt combines LCM and AHP in a unique way. The model shifts from AHP to LCM and then to AHP. WasteOpt encourages the construction of multiple hierarchies for each life cycle phase as opposed to a single hierarchy (see 3.4.1 below). This is because the AHP requires attributes at level 1 to be independent of each other. In the case of HCW, the life cycle phases (which are level 1 attributes in the hierarchy) are related. Figure 3.5 below summarises the WasteOpt shifts.

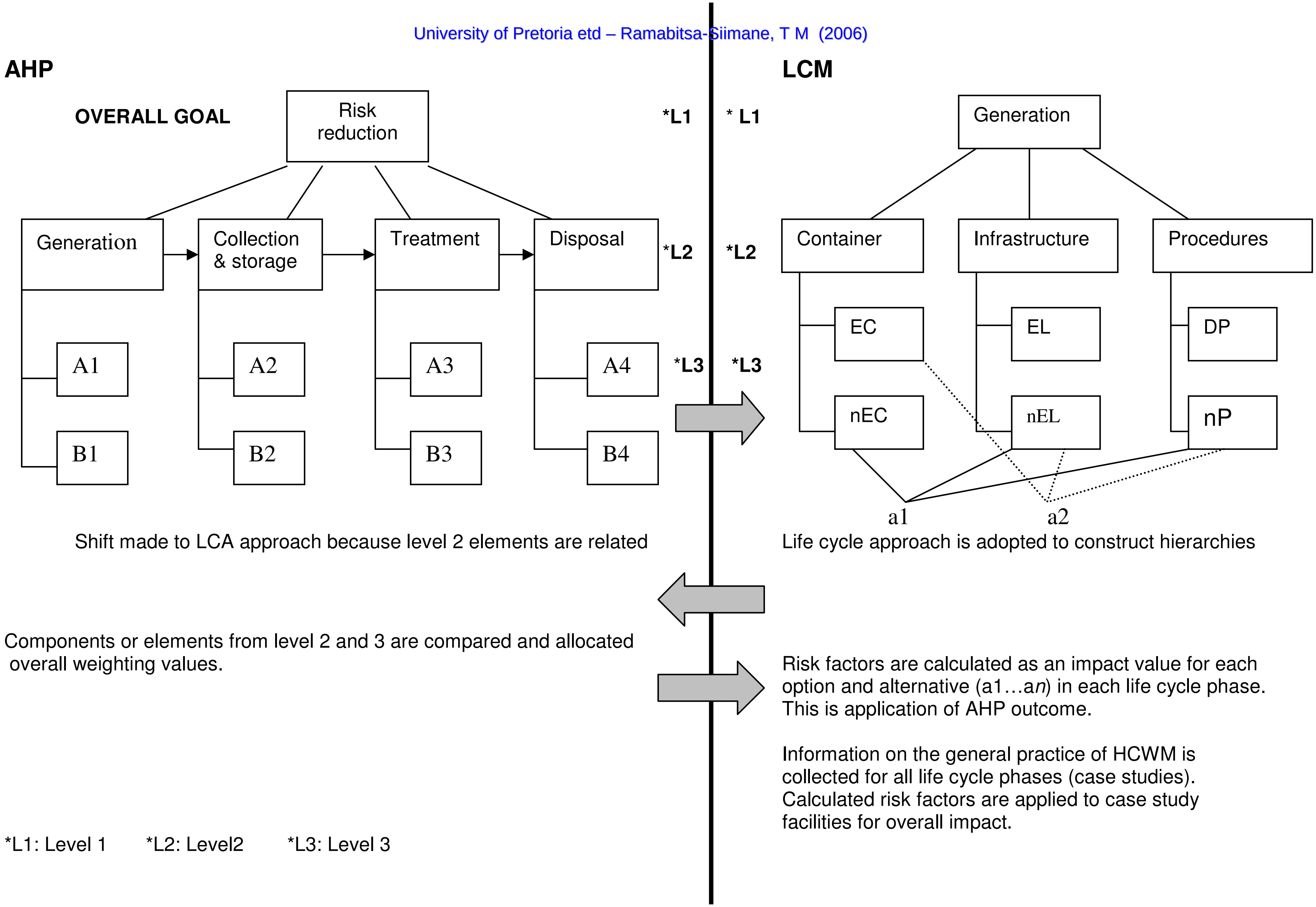

Figure 3.5: The AHP and LCA as combined by WasteOpt (example for the generation life cycle phase)

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3.3.1 The Analytical Hierarchy Process (AHP)

For the application of the AHP all stakeholders (as stipulated in Section 3.3 above) in the system are required to participate. Their role is to define the goal and scope of the system, consider the inventory data (from, for example, the WHO Rapid Assessment Tool), and participate in the impact assessment (setting of priorities to calculate risk scores). It is then up to the decision-makers of the HCWM system to choose the most appropriate life cycle alternatives.

The step-by-step methodology of the AHP as devised by Saaty (1980) is given below.

Step 1: Setting up the hierarchy

The problem is first structured into a hierarchy of three levels or more. The first level is the overall goal of the decision-maker. The second level consists of factors that contribute to the goal, while the third level denotes the alternatives or options available for application. Saaty (1986) explains that the elements in each level should be clustered into homogenous groups so they can be meaningfully related to elements in the next higher level. Any element in one level must be capable of being related to some element in the next higher level. An example of a hierarchy for the generation phase is shown on the LCA side of Figure 3.5. Hierarchies for other life cycle phases can be found in Appendix 4.

Step 2: Setting the priorities

In this step, the priorities for each element are established within each level. Saaty proposes the pair wise comparison to compare the factors, i.e. the factors are compared in pairs against a given criterion. The preferred form for the comparison is a matrix, for example, in Figure 3.5, level 2, elements (container, infrastructure, procedures) are compared for importance in respect of achieving the overall goal. In this study the overall goal is to minimise the risk of infection due to HCW. A judgement of how important each element is compared to another element is made by asking a question such as, *"How much more strongly does this element contribute to, dominate, influence, satisfy or benefit*

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the property than the one to which it is being compared"? (Saaty, 1986). The exact AHP question for the study is shown below.

> *"How much more important is each option compared against the other in terms of minimising infection risk?*

Saaty proposes the use of an ordinal scale of 1 to 9 (-9 to +9) and the results are filled out in a matrix since it uniquely reflects the dual aspects of priorities, i.e. dominating and dominated.

A sample matrix for the tree in Figure 3.5 is presented below.

Table 3.2: Sample matrix for pair wise comparison

	Container	**Infrastructure**	**Procedure**
Container	1	4	3
Infrastructure	1/4	1	1/2
Procedure	1/3	2	1

Step 3: Establishment of the Eigenvector

Comparisons of each element against itself result in unity and the remaining ones are reciprocals of the first judgements. The reciprocals hold true only when the matrix is consistent[1] (Saaty, 1980). From the matrix, the Eigenvector is computed and normalised to yield a vector of priorities. Saaty proposes four methods for calculating this vector. The methods increase in complexity and accuracy from 1 to 4. WasteOpt is based on the third method, but this thesis focuses on the fourth method in an effort to increase accuracy. These methods are briefly described.

[1] Consistency is a statistical measure of the extent to which an individual's decision structure, i.e. set of assessment judgements, is closer to being logically related than randomly chosen. The consistency of judgements reflects the extent to which the decision-maker(s) understands the problem, is knowledgeable of the decision variables involved, understands the assessment process, and is able to make a series of logically related judgements based on uncertain and often incomplete information.

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Method 1: Elements in each row are summed. To normalise, row sums are then added to get a single figure. The single figure then divides each row sum such that the resultant figures add up to unity.

Method 2: Elements in a column are added and then converted into reciprocals. Normalisation is achieved by dividing each by the sum of reciprocals.

Method 3: Each element in a column is divided by the sum of the column (normalised). The resultant rows are averaged (added and divided by the number of elements in a row).

Method 4: *n* elements in a row are multiplied together and the *n*th root of the product taken. Normalisation is then done.

The normalised columns are shown in Table 3.3.

Table 3.3: Normalised columns

	Container	**Infrastructure**	**Procedure**
Container	0.63	0.57	0.67
Infrastructure	0.16	0.14	0.11
Procedure	0.21	0.29	0.22

The geometric mean of the rows is then computed to give the Eigenvector. Saaty (1986) uses the average, but the geometric mean is used in this study in an effort to reduce the effect of outliers on the result (Aull-Hyde, Erdogan and Duke, 2004). The Eigenvector for this example is **0.625** for container**,** **0.136** infrastructure and **0.240** procedure.

Step 4: Comparison of options

In this step, the decision-maker moves to the next higher level, e.g. level 3 in Figure 3.4, and compares the options in that level in terms of the ones on level 2. The Eigenvector is calculated for these comparisons. With this Eigenvector overall ranking is thus performed to select the favourable alternative. The matrices for level 3 comparisons are shown below:

Container	EC	nEC	Eigenvector
EC	1	7	**0.875**
nEC	1/3	1	**0.125**

Procedure	DP	nP	Eigenvector
DP	1	6	**0.857**
nP	1/6	1	**0.143**

Infrastructure	EL	nEL	Eigenvector
EL	1	8	**0.889**
nEL	1/4	1	**0.111**

Figure 3.6: Matrices for level 3 comparisons

Step 5: Establishment of overall weighting values

The overall weighting values for the options are calculated by multiplying the determined weighted values (Eigenvectors) of level 3 by the Eigenvector of the level 2 component to which the option belongs. Figure 3.7 illustrates the Eigenvectors (weighting values) for elements in all levels.

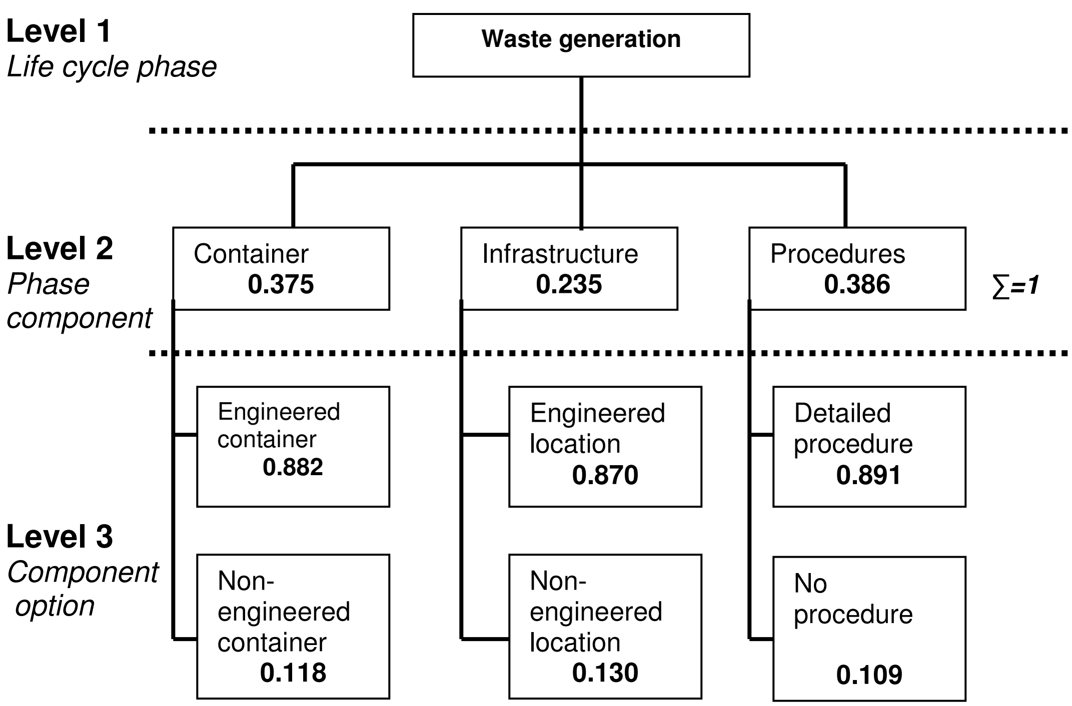

Figure 3.7: Hierarchical tree of available options for waste life cycle generation

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For the engineered container component option the weighted value is:
(0.63) (0.875) = 0.551.

Application of the AHP outcome

Step 6: Computation of options risk factors

Weighting values for options belonging to one phase component are calculated and normalised by assigning to the largest weighting value, a base risk value of 1.0. Equation 3.1 below is then applied to the remaining options. For ease of comparison of the options' risk factors, the reciprocal is taken.

$$R_{ap} = (W_i / N_w)^{-1} \qquad \text{.........equation 3.1}$$

Where: R_{aP} = Risk factor for an alternative in a life cycle phase in relation to the risk factor of 1 for alternative with the least risk for the phase

W_i = Overall weight value for a specific option in a phase component

N_w = Normalization value, i.e. the maximum combined weighting value for the choice of options

Step 7: Computation of alternatives' risk factors

At primary health care clinics HCW is managed by using different combinations of options (scenarios or alternatives). All possible combinations of component options in a life cycle phase are compiled as possible alternatives. A combination has one option belonging to each of the phase components in level 2, e.g. Engineered Container (EC) + Engineered Location (EL)+ Detailed Procedures (DP) for the generation phase. The risk posed by each alternative is related to the alternative with the least risk by adding the weighted values of the options and normalising the result. The reciprocal is again applied to get a risk factor.

Saaty has been criticised for the use of the Eigenvector by Baba e Costa and Vansnick (2001) using the principal eigenvector because they state that it does not always meet all required mathematical condition. Laininen and Hämäläinen (2002) critisize the eigenvector for its lack of practical statistical theory. Although the AHP has been criticised before by Watson and Freeling (1982 and 1983), Belton and Gear (1983 and 1985), French (1988), Holder (1990), Dyer (1990a and b), Barlizai and Golany (1994) and Salo and Hämäläinen (1997), the AHP methodology has not been changed. Harker and Vargas (1987) have discussed these major criticisms and proved with theory and examples that they are not valid. They proved the AHP to be a viable and useful decision-making tool and it has been applied in real life cases as reported by Zahedi (1986), Golden *et al.* (1989), Shim (1989) and Vargas (1990). Laslib and Jinesh (2001) have applied the AHP to environmental management systems while HajShirmohammadi and Wedley (2004) applied the AHP to centralisation/decentralisation strategies.

Correlating AHP and life cycle management terminology

Due to the different terminologies used in the AHP and life cycle management fields, it is necessary to correlate the two terminologies for application in WasteOpt. The use of AHP terms depends on the type of hierarchical tree and its application. Table 3.4 summarises the AHP terminology as used in WasteOpt.

Table 3.4: Correlation of AHP and LCM terminology

Classified hierarchy levels	Conventional AHP terminology	WasteOpt terminology
Level 1	Overall objective or focus.	Essential life cycle phase.
Level 2	Criteria, property, factor, or influence.	Essential life cycle phase components.
Level 3	Alternatives, possibilities, or outcomes.	Life cycle phase component options.

3.3.2 Life Cycle Management

Life Cycle Assessment (LCA) is a tool used to predict the environmental impacts of a product or service (in this case waste) from cradle to grave (SABS ISO 14040). Extensive data of inputs and outputs is required and these are converted into their effects on the environment. LCA has four distinct phases, which are described below (White *et al.*, 1995):

Goal definition: defines options to be compared, the intended use of the results, the functional unit and the system boundaries.

Inventory analysis: accounts for all material and energy inputs and outputs.

Impact analysis: converts the inventory into environmental effects.

Interpretation: balances the importance of different effects.

Due to the reduced availability of data experiences in developing countries situations and the data intensiveness of LCA's, the Streamlined Life Cycle Assessment Approach (SLCA) is proposed, which is life cycle management. It still includes the four stages of the conventional LCA, but with reduced quantitation. The approach uses qualitative rather than quantitative data and the impact analysis procedures are simplified (Rogers *et al.*, 2002). Based on the AHP and the SLCA approach, WasteOpt is developed as described below.

3.4 THE DEVELOPMENT OF WASTEOPT

3.4.1 Goal and scope development

1. Functional unit

The functional unit of WasteOpt is defined as *the amount of health care waste generated in an average rural primary health care facility in one day.* It can be represented as a table and the user can modify the quantity and composition of the HCW in the functional unit.

2. Boundaries of the development work

The setting of the boundary relies on the assumptions made for the system in question. The assumptions used for WasteOpt are as follows:

- HCW is segregated from general waste.
- HCW begins its cycle when medical supplies have served their purpose to become classified as waste (corresponding to the "cradle"). The cycle

ends at final disposal that corresponds to the "grave". Emissions to air, water and soil correspond to the final boundary.

- In terms of temporal dimensions, the system is bounded by the time at which the HCW has caused a predetermined percentage of its impacts (5 %).
- The individual life cycles of the various unit processes are taken into account if they fall within a certain cut-off criteria, e.g. the conventional relative mass energy economic (RMEE) system boundary selection.

3. Allocation assumptions

It may not be realistic to assume that Healthcare Risk Waste (HCRW) is always segregated from Healthcare General Waste (HCGW). If the two types of waste are collected, handled, stored, treated and/or disposed together, the resultant impacts should be allocated to the two types separately. For the purpose of this tool, however, the risks associated with HCGW when contaminated with HCRW are regarded as considerable and thus all impacts are allocated to the HCW in general (HCRW + HCGW =HCW).

3.4.2 Development of an Inventory Analysis Database

WasteOpt allows the population of an inventory using data that is available. The requirement of qualitative or quantitative data depends on the ultimate use of the results of the study: if the aim is for strategic decisions, less data or qualitative data is required. The more the use of results shifts towards design or redesign of systems, then the more quantitative data is required. WasteOpt includes the use of the WHO RAT for collection of data on the current practices of HCWM throughout the life cycle of HCW.

3.4.3 Development of an Impact Analysis Procedure

Potential and actual impacts associated with the inputs and outputs at each stage, are identified. These impacts are classified as follows:

- Quantitative: impacts that are directly measurable and an estimate of its uncertainty can be made, e.g. the cost associated with a certain unit process in the life cycle.
- Qualitative: non-quantitative impacts that can be assigned a risk based on expert assessment.
- Direct: a direct impact on a receptor, e.g. a needle prick on a health worker, which can result in an infection.
- Indirect: an indirect impact on the environment, e.g. dioxin formation by a poorly-operated incinerator.

An impact rating system is availed which uses a linear scale from 1 (lowest risk) to 10 (highest risk). These risk factors are based on calculations from acquired data. They may also be assigned by expert assessment by evaluating the compliance of a practice or equipment to set standards, e.g. SABS code of practice for handling waste from health care facilities.

3.4.4 Development of an Interpretation Procedure

WasteOpt calculates the overall impact of the unit processes in the life cycle of HCW and tallies them into a single score. The lower the final score, the lower the overall risk of that specific option. The different HCWM options in an area are compared and the results are presented graphically according to the following criteria:

Overall risk due to direct exposure of health care workers and the public.

Overall risk due to indirect exposure of health care workers and the public.

Overall costs for implementing and operating the HCWM system.

The overall model process for WasteOpt is diagrammatically presented in Figure 3.8. Figure 3.9 summarises the overall flow of the research process.

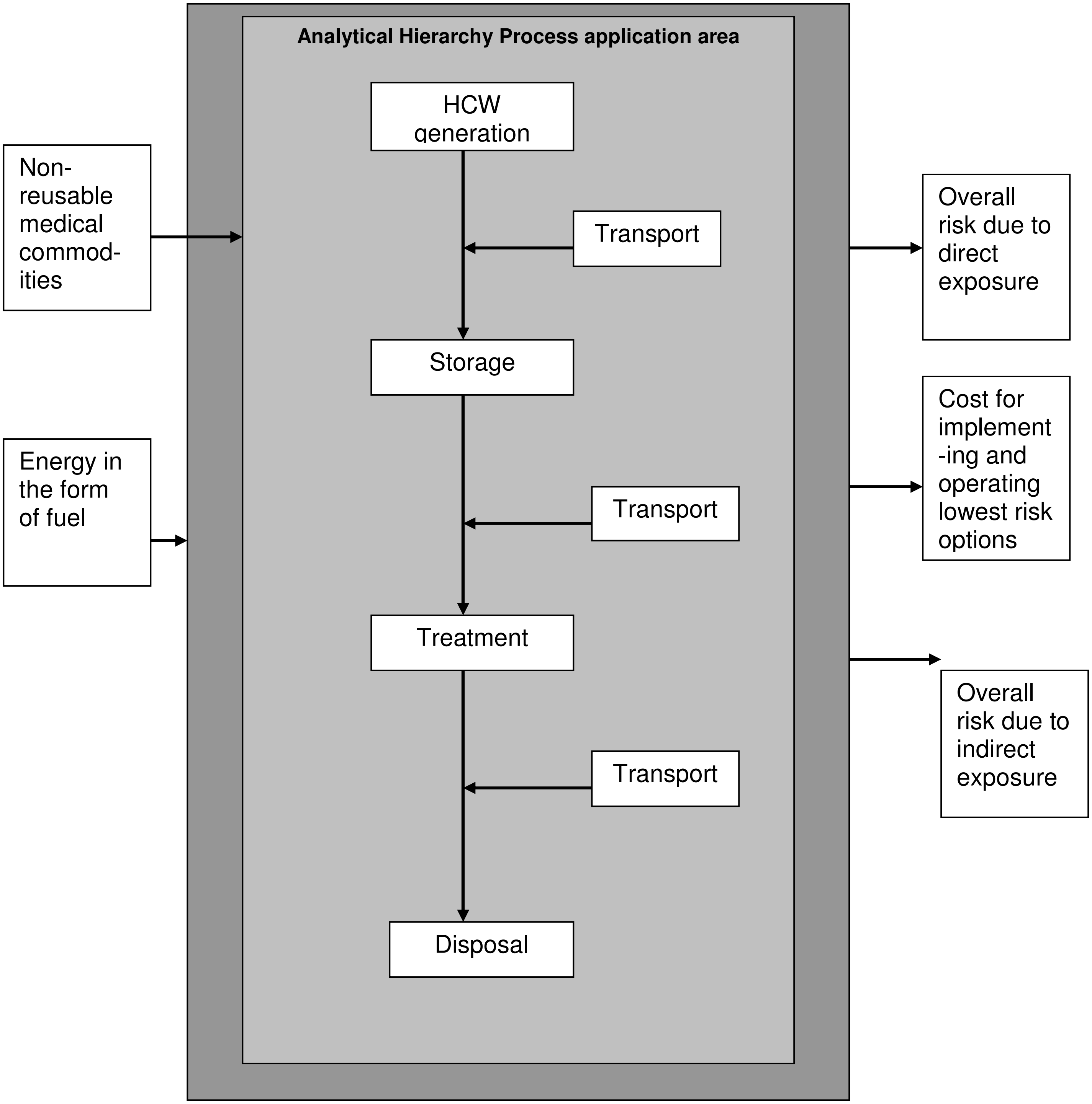


Figure 3.8: The WasteOpt Model summarised

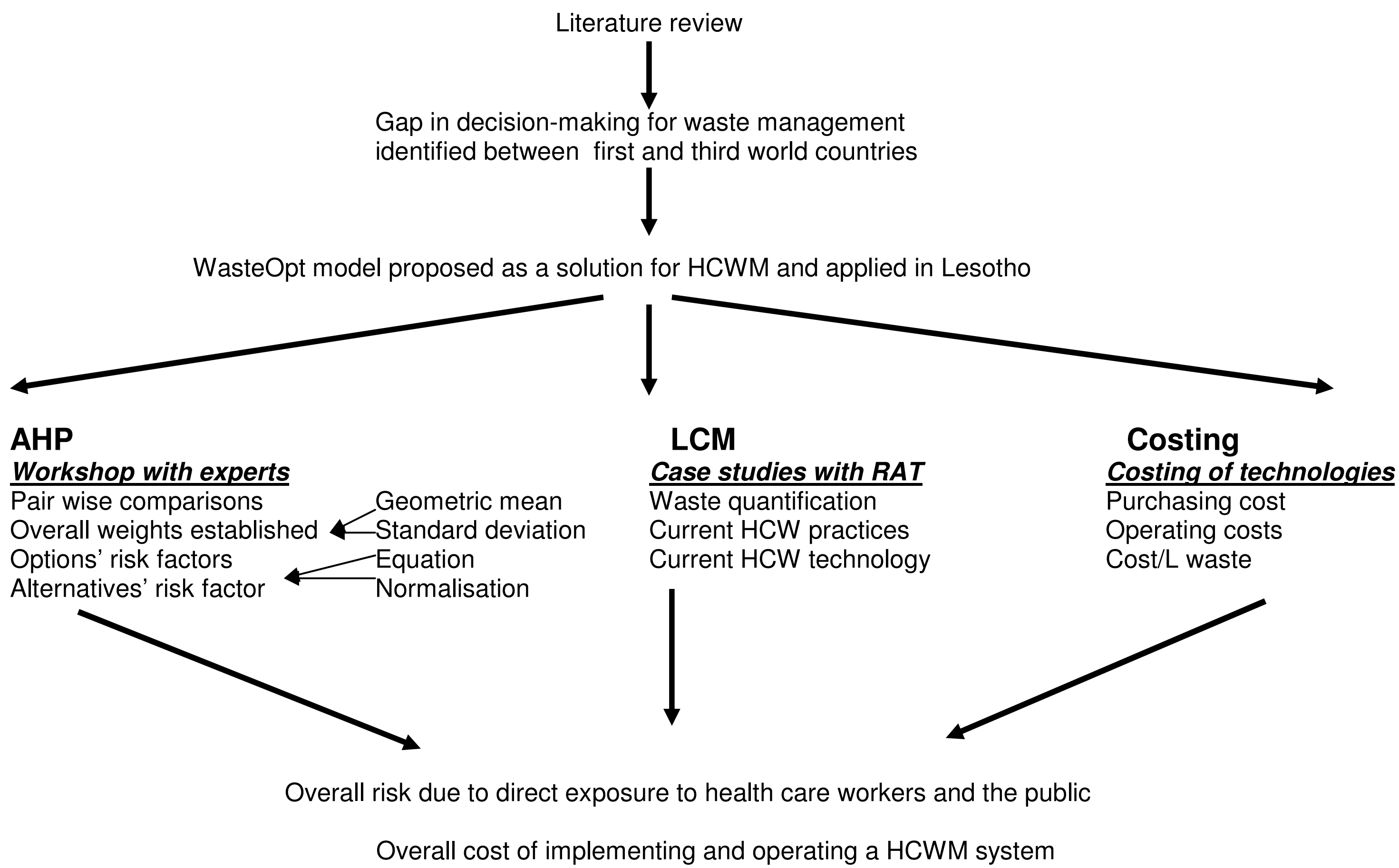


Figure 3.9: The WasteOpt process flow (with AHP, LCM and Costing integration)

CHAPTER 4

Research methodology

1. INTRODUCTION

This research project is directed towards resource-poor decision-makers. It aims to provide them with a practical tool to identify and prioritise options that reduce impacts on the public and health care workers resulting from the management of hazardous waste generated at health care facilities. To achieve this, both qualitative and quantitative primary data was acquired. The data was focussed on the current practices of managing waste from “cradle to grave” in rural health care facilities. It also focussed on weighing available options that can improve the situation.

The research objectives were thus met by completing the following phases:

- Literature review.
- Supervisory waste management pilot study of a rural South African health care facility.
- Case studies of ten (10) rural primary health care facilities in Lesotho.
- Holding a workshop with health care waste experts in Lesotho.
- Risk factors computation and identification of options and alternatives that minimise infection.
- Data analysis and interpretation.
- Conclusion and recommendations.

2. LITERATURE REVIEW

A literature review was conducted in order to find out what research had been done on health care waste, risk assessment and other related aspects. This shed light on what had not been done that could be used to define the scope of the research. The comparison of waste management in developing and developed countries shed light on what gaps need to be filled in developing countries. The studies that have been conducted to this point in Lesotho did not encompass the risk of waste handling and the costs of efficiently managing health care waste. This is what the research aims to address.

The literature was taken from various sources, including official letters from the government of Lesotho to the Council for Scientific and Industrial Research (CSIR) South Africa, books, journals, government documents (Lesotho and South Africa), the World Wide Web and similar studies performed in other countries, among others.

3. PILOT CASE STUDY IN SOUTH AFRICA

A pilot case study was conducted towards the end of 2004. The aim of the supervisory study was to ensure that the researcher would be autonomous in the subsequent case study undertakings in Lesotho and determined the suitability of the WHO RAT (World Health Organisation Rapid Assessment Tool) in achieving the objectives of the research.

Mmametlhake hospital (Nkangala district) was the targeted facility. The main reasons it was specifically chosen were that:

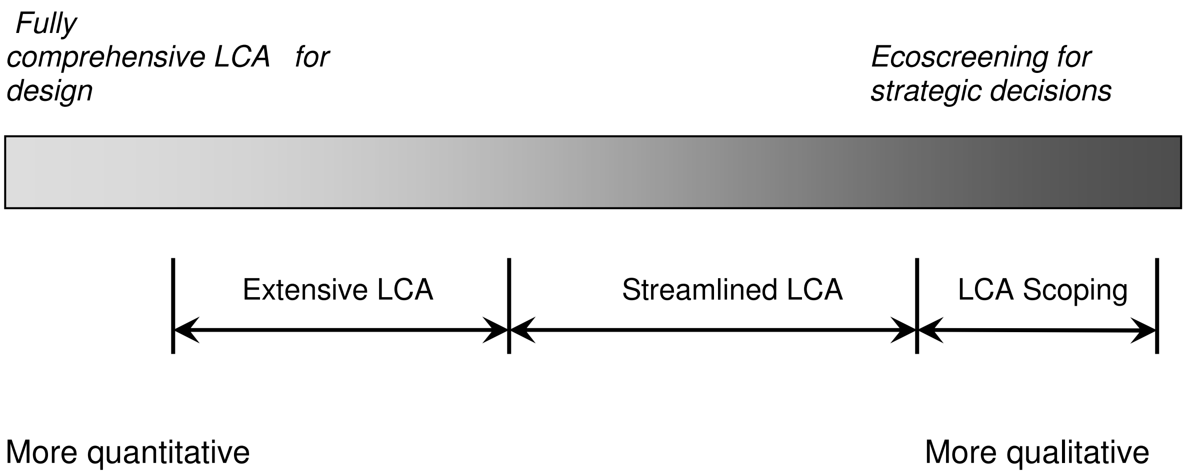
a) Mmametlhake was used as a pilot project for a new specification for a small-scale incinerator designed by specialists at the CSIR. The specific model would be included in options for treatment of HCW in Lesotho. It was worthwhile to consider this incinerator model for rural health care facilities due to its low maintenance and high efficiency.
b) The hospital was geographically convenient (Yin, 1989).
c) The facility was slightly different (in terms of services offered) and was bigger than the real case study facilities. It therefore prepared the researcher for handling large amounts of data.

The RAT was used in its original form to interview relevant staff. A report was compiled afterwards, which was, however, not in the format of the findings presented in this thesis. The report is attached in Appendix 4.

4. DATA COLLECTION

Figure 4.1 below depicts that both qualitative and quantitative data were required since a streamlined life cycle assessment (SLCA) approach was used.

Figure 4.1: The LCA/SLCA continuum



Adopted from Graedel, T (1998) and Rogers et al., (2002)

According to Kibwage (2002) qualitative or descriptive methods tend to be strong in validity but weak in reliability, while quantitative methods are strong in reliability and weak in validity. Flick (1998) views the use of these forms of data as triangulation. He asserts that using both qualitative and quantitative data in one study is a complementary compensation of each method's weaknesses. The use of the two methods thus strikes a balance between the strengths and weaknesses.

The following methods were used to collect the required data:

4.1 Case Studies

The case study approach was adopted as a means of acquiring qualitative data regarding HCW practices in rural clinics. The findings from the cases were used to verify the applicability of the options in WasteOpt in the Lesotho context, as well as to evaluate the potential risk at the different clinics by allocating calculated risk factors to the current HCWM scenarios observed. As Yin (1989) asserts, "*the case study is preferred in examining contemporary events..*." and adding direct observations and systematic interviewing makes case studies more relevant than other strategies like history reporting. Reige (2003) recommends that maximisation of the four tests for establishing quality in qualitative studies, is important. These tests are listed below, together with techniques that were used to maximise them.

1. Construct validity:
    a) The use of verbatim interview transcripts and notes of observations made during the field trips.
    b) Letting key informants review interview scripts after the interviews. As will be discussed in the following section, key informants of a workshop were also given a report during the writing of the research to alter unclear aspects (Yin, 1989).
2. External validation was maximised by defining the scope and boundary of the study during the study design, to achieve generalisation [over the study area] (Reige, 2003).
3. Reliability:
    a) The recording of data mechanically using a camera (photographs).
    b) Recording of data in as concrete a manner as possible by:
        - Recording relevant information even if it was not asked.
        - Recording the exact words of interviewee.
4. Internal validity:
    a) The display of diagrams and illustrations in the data analysis phase helped to build explanations in the data analysis phase.

4.1.1 The Choice of Case Studies

Rural clinics were targeted and the following were chosen using a stratified random sampling. This sampling method was chosen to reduce bias. The stratified random sampling method was coupled with "sampling with replacement". This meant that all the elements were eligible for selection at any stage of the selection process (Tryfos, 1996). It was discovered after the initial identifying of samples that some of the selected clinics were closed, while others had been incorrectly assigned to a stratum, which required that replacements were chosen.

Clinics falling within the Lesotho Flying Doctors Services (LFDS) were excluded from the sample population due to the inaccessibility of the clinics by car. Also clinics situated in urban areas did not form part of the population.

The sample size was chosen such that it represented proprietorship of clinics in the representative ratio of 49 % Christian Health Association of Lesotho (CHAL), 50 % government and 1 % private. Of the ten clinics studied, five (5) were public owned, four (4) were church owned (and therefore coordinated by CHAL), while one (1) was private (belonging to the Red Cross Society) as shown in Table 4.1.

Table 4.1: Clinics selected for case studies

Public Health Centres	CHAL Health Centres	Private Health Centres
Likalaneng	St Leonard	Kolojane
Linots'ing	Matukeng	
Sekameng	St Barnabas	
Matsieng	Holy Cross	
Malealea		

4.1.2 Sources Of Evidence

Questionnaire/interviews: The WHO RAT was used as the questionnaire/interview tool at the ten (10) rural clinics in Lesotho. It comprises both open and close-ended questions. The tool has been tested and used widely in many countries. It was however modified to include more financial management questions for the following reasons:

- The RAT was developed in a developed country (for use in 2nd and 3rd world countries) where financing of HCWM is not a constraint. For a developing country financial evaluation is vital due to lack of funds.
- Some clinics belong to non-profit organisations (NPO's) that are not motivated to earn profit. They must however acquire, manage and allocate funds so that the main mission of the organisation can be realised (Bryce, 1987).
- In any organisation, strategic management and financial function is intricately tied and thus bad or uninformed financial decisions can lead to mission failure.

Health care institutions are tasked with the responsibility for managing their health care waste. This is a completion of the cycle of health care that is not given the attention it deserves, partly due to financial constraints.

- The health care services of Lesotho are delivered by a partnership of government, CHAL and other NPO's. Since health care waste management will be compared by proprietorship, government clinics are at a financial advantage because they can exist forever under the taxing power of the state, despite the strength of their financial management status. Since other NPO's have no such powers, they may lack funds to implement waste management targets, go bankrupt and close (Bryce 1987).

The RAT touches on financial issues and as such does not cover all the important factors of good financial management. These important factors include, among others, budgeting, sustainability of funding and the cost for implementing and operating appropriate health care waste management systems. By the evaluation of such questions personnel can understand the cause for their deficit in allocations for health care waste management in their plans. It also helps them to recognise that appropriate HCWM is part of health care provision. The

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decisions of the planner should also focus on the protection of health workers and the public through environmentally sound practices.

The modified questionnaire also enables the capturing of qualitative data (current practices and infrastructure) and quantitative data in the form of amounts of waste generated by the clinics. The modified questionnaire is included in the thesis in Appendix 3.

Direct observations: These were done in the field visits to the clinics. These were recorded exactly as observed. Photographs of the main observations were also taken.

Records: The following data were acquired from records.

a) Budgets (as organisational records).

b) Patients served per day and injections given over a certain period (as service records) (Yin, 1989).

4.2 The Workshop

A two-day workshop was conducted for experts in waste management in Lesotho. The objectives of the workshop were:

a) to establish weighting values for the waste management options at primary health care facilities in Lesotho;

b) to establish the objectives and the roles of each participant in the waste management system of Lesotho;

c) to reach a consensus regarding the definitions of HCW and a Primary Health Care (PHC) facility; and

d) to identify the gaps within the HCWM system of Lesotho and devise a way forward for filling the gaps.

4.2.1 Selection of the Panel of Experts

Noble (2003) is of the opinion that the size of an assessment panel depends on the objectives of the assessment, resources and time available. As few as 10

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people are sufficient. This panel should comprise of stakeholders, facilitators and experts. The workshop had a maximum of 18 participants. Due to time constraints, two stakeholders from the private sector could not attend. There were 15 participants from the Ministry of Health and Social Welfare (national and district levels), Ministry of Tourism, Environment and Culture, CHAL, Department of Environmental Affairs and Tourism (SA), as well as three facilitators from the University of Pretoria and the CSIR. The criteria for selecting the panel and the number who participated per category are shown in Table 4.2(a) (Noble, 2003). It is based on the recent involvement of participants in waste management.

Table 4.2(a): Selection by recent participation in health care waste management

Selection criteria	Number of participants
Experience in two or more fields	5
Current or previous leadership	8
Experience in affected field	2
Experience in education and profession	5
Experience in similar assessments	5
Professional publications	2
Participation in professional meetings	18
Membership to HCWM panels	18
Interest in the HCWM	1

Saaty (1986) and Noble (2003) advise the engagement of a small group of participants to attain a sharp focus. The panel of experts was representative in number but deficient in public-private significance since only one participant represented non-governmental organisations (CHAL). Saaty (1980) also states that the level of expertise need not be equal as long as all participants are familiar with the problem.

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Table 4.2 (b) represents the classification that was used to cluster the participants within the workshop to analyse and classify the Analytical Hierarchy Process consistency of the participants.

Table 4.2(b): Grouping by function in organisation

Focus area	Group	Level of operation	Number of participants
Health inspectors	HI	Implementation	6
Occupational health	OH	Strategic planning	1
Environment officers	EO	Strategic planning	2
Infection control	IC	Planning	2
Technical officer	TO	Strategy and implementation	2
Senior health inspectors	SHI	Strategic planning	2

The information above is based on representation of waste managers (especially health care waste) from one private and two public organisations in Lesotho. The criteria for grouping were the level of operation of participants in their respective organisations and the major focus areas.

4.2.2 Sources of Information

Presentations: This activity was done both by participants and facilitators of the workshop. The facilitators used presentations to inform the panel of the research, its objectives and expected outcomes. The panel was also introduced to the AHP. Participants gave presentations on their roles in HCWM in a separate session described below.

Colour coded cards: Participants were asked to write down the roles they play within the following categories: Policy, Action Plan, Standards, Monitoring, Capacity-building and Tenders. The participants were given colour-coded cards to write on.

Pink: Name and position

Green: The role that he/she plays in waste management

Yellow: The challenges that he/she faces in his/ her position

The outcome of this exercise is tabulated in the findings.

Open discussions: Throughout the workshop, participants were advised to ask questions, which were answered by both the facilitators and the panel. This encouraged openness and transparency in the current situation of HCWM. The questions, answers and comments emanating from the different sessions of the workshop are presented in the findings.

Consensus: Definitions for the issues mentioned below were reached by consensus. The nominal group technique was engaged for these sessions to reach a common understanding for thee whole group.

a) Statement of the HCWM problem.
b) Solutions to the identified problem.
c) The objectives of Lesotho's waste management system.
d) The definition of HCW in the Lesotho context.
e) The definition of a rural primary health care facility.

Although Coxon (1982) argues that "*aggregating assessment data without examining individual differences may lead to a false sense of group consensus*", Noble (2003) argues that the aggregate of a group will provide results that are superior to those of an individual.

AHP questionnaire: The hierarchical trees were constructed prior to the workshop. The trees were presented on flip charts when doing the comparisons for each life cycle phase. Saaty (1986) recommends that two session leaders and an assistant are used, and this procedure was followed.

The questionnaires for the South African case (with options relevant and/or available in South Africa) were evaluated by the panel and modified so that the options suited the Lesotho context. The changes are discussed in Chapter 5. A

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computer terminal was also set up to consolidate the results as they were generated. It also helped the facilitators to spot inconsistency in the comparisons. The facilitators were able to highlight the consistencies of the weighting factors during the workshop, and this was useful to improve individual consistency.

Planning: The group proposed the way forward by specifying how they wanted to improve HCWM and what they needed to make it happen. The planning session was completed after allowing each individual to raise goals and activities that they believed needed to be performed in order to reach the goals. All these were combined into a report of the workshop (Appendix 2).

4.3 Expert Consultations

Expert e-mail consultation sessions were held with the senior technical officer of CHAL. The expert provided costing information on approximations of infrastructure construction in Lesotho. The approximations included the purchase of materials and labour, but excluded transportation cost.

4.4 Technology Costing

4.4.1 Quotations

The following companies were contacted and provided quotations for the listed technologies (details of contacts in appendix 8):

Reco: refrigerated storage room

Saubtech: Multi- and single-chamber incinerators

Wastegroup: waste containers

The cost of transportation options were obtained from the following sources:

Vehicles: Ministry of Health and Social Welfare, National Healthcare Waste Management Plans (draft).

Trolleys: www.nwims.co.za. The listed costs were inflated by a 10 % contingency for each year following the “last updated” date on the website.

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5. DATA ANALYSIS

5.1 Quantitative Data

Quantitative data resulted from the application of the AHP (analytical hierarchy process) by participants and from waste generation rates in the case studies.

- These comparison (weighting) values from the AHP were populated into Excel spreadsheets to determine their consistency, using Saaty's fourth method (Saaty, 1980) of matrix regression. The comparison values were used for calculations of risk factors per option and alternatives. The results of the calculations were normalised (divided by the largest value element) to yield meaningful comparisons among the elements. The reciprocal was taken to enhance comparability of the risk factor with the common understanding of risk, i.e. risk increases as preference reduces.
- Standard deviation was used because it is the most important measure of variance (Steyn *et al.*, 1994). The geometric mean method of aggregation was used to dampen the influence of outliers (Aull-Hyde *et al.*, 2004). Variability would also assist in judging our reliability on the mean (central location) as a representative of the data.
- The resultant risk factors were classified into three categories, namely lower risk (1.0-1.9), medium risk (2.0-4.9) and high risk (5.0 and higher).
- Some qualitative information was converted to quantitative. Percentages were used to depict the findings at case studies. The percentages were for:
  - Types of containers used
  - Clinics that practice waste segregation
  - Trained waste handlers

5.2 Qualitative Data

To verify the quantitative outputs of the AHP, the following methods were used to analyse the data.

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- Analysis of the prevailing situation at the time of the visits was performed per phase. The major findings were classified into procedures, technology, containers, infrastructure and transportation methods.
- The risks posed to health care workers in the clinics visited, were also determined by applying the relevant calculated alternatives' risk.

6. LIMITATIONS TO THE METHODOLOGY

6.1 Analytical Hierarchy Process Limitations

The main limitations observed in the AHP application are:

a) There was a lack of understanding of the ranking procedure.

b) There was lack of full information on HCWM systems at the workshop.

6.2 Case Study Limitations

a) According to Yin (1989): "*A...common concern about case studies is that they provide very little basis for scientific generalization*." Ten cases were studied out of a total of 172. Whether generalisation is applicable will be discerned in the discussion of the results.

b) Bias may have prevailed for certain sections of the case studies since the researcher went to the field with prior knowledge of what to expect in rural clinics of a developing country. Methods of reliability and validity testing were discussed earlier that eliminate the bias.

c) The sample size for case studies was limited as a way of reducing the time it would take to study the statistically required sample size.

7. PROBLEMS ENCOUNTERED

7.1 Case Studies

a) Some clinics did not have a balance to weigh the waste generated. The waste generation was therefore estimated in litres throughout the field survey for standardisation.

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b) Some clinics did not segregate their waste such that sharps and soft waste were mixed in an unlined bin. The risk of transferring such waste to a container of known capacity was high and had to be avoided. In order to estimate the waste generated, the waste was estimated in the holding container.

c) In some clinics, due to understaffing and large numbers of patients seen, the time allocated for the case was unsatisfactory.

d) No clinic was able to give information of what it had cost to erect current waste management technologies or how much was spent to operate these technologies per unit of waste.

7.2 Workshop

a) One participant attended the workshop for only half of the first day, while another one attended for one day only. Two other participants attended only for the second day. Their sets of results were therefore incomplete and could not be used.

b) In preparation for the workshop, not all HCWM technology options were identified and included in the ranking. Some that were identified were excluded by consensus since they have never been used in Lesotho.

c) Some of the participants could not understand the meaning of inconsistency and could not be urged to alter their results to an acceptable level.

d) There were differing levels of participation in the workshop (managers and implementers). The implementers (district level) were ready to acquire new knowledge on management systems while the national managers debated new knowledge at a higher level since they had existing knowledge on waste management systems.

e) The implementers were found to be "black and white" thinkers while the national waste management experts perceived "grey" areas.

f) The application of the AHP was taken as a judgement call to many, whereas it is a ranking methodology to assist judgement. Therefore, most participants executed only horizontal and not both vertical and horizontal ranking (See AHP questionnaire, appendix 8). Some participants from the MoTEC saw two discrete sets of values in a criterion.

g) Some of the participants performed the ranking with pre-conceived ideas, which clouded their ranking abilities. It was their perception that direct weighting was easier and more relevant than pair-wise comparisons.
h) While some members thought the scale was too small (1 up to 9) and disabled them to allocate numbers properly, other participants were confused by the scale such that they mixed the left and the right hand sides of the scale when allocating.
i) Imprecision: Comparisons could not be guaranteed to have high precision.
j) There was a temptation to conclude prematurely from small amounts of data available (AHP results) whereas qualitative data was also required.

The limitations and problems encountered compromised the quality of this study to an extent. The goals of the study were realised despite these setbacks due to the sturdiness of the tools applied in the study. The results are stipulated in the following chapter.