APPLICATION OF AHP FOR THE DEVELOPMENT OF WASTE MANAGEMENT SYSTEMS THAT MINIMIZE INFECTION RISKS IN DEVELOPING COUNTRIES: CASE STUDIES LESOTHO AND SOUTH AFRICA

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ABSTRACT

This paper focuses on the establishment of waste management systems that minimize infection risks in the context of sustainable development in the developing country situations. The Analytical Hierarchy Process (AHP), a known multi-criteria decision-analysis approach, has been incorporated with international Life Cycle Management best practice to subsequently develop a decision support tool (WasteOpt) to optimise developing country rural Health Care Waste Management (HCWM) systems to address a main objective of HCWM systems, i.e. to minimize infection of patients and workers, and the public within the system. The tool was applied to two case studies: the sub-Saharan African countries of Lesotho and South Africa. Quantitative weightings from the AHP are used to identify alternative systems that have similar outcomes in meeting the systems objective, but may have different cost structures and infection risks. The two case studies illustrate how the WasteOpt tool can be used (with strengths and weaknesses) in waste management decision support.

KEYWORDS

Rural regions, waste management, health care, sustainable development, Analytical Hierarchy Process, multi-criteria decision-analysis, Life Cycle Management, Lesotho, South Africa.

INTRODUCTION

The Analytical Hierarchy Process (AHP) (Saaty, 1980) is a known multi-attribute weighting method for decision support. As such, the AHP has been used for solving complex decision-making problems in various disciplines, e.g. public policy, strategic planning, viability determination, forecasting, and project management (Kamal, 2001). The AHP, which follows an approach of pair-wise comparison, provides a way for calibrating a numerical scale, particularly in new areas where measurements and quantitative comparisons do not exist. The process is summarised in figure 1.

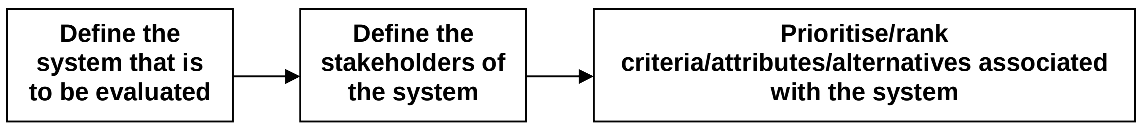

Figure 1: A schematic diagram of the AHP process.

The concept of sustainability and sustainable development can be understood intuitively, but it remains difficult to express it in concrete, operational terms (Briassoulis, 2001). Consensus on the general objectives and basic principles of sustainable development may be obtained in theory. But consensus on the details of how to achieve sustainable development or maintain sustainability is difficult to obtain in practice. This difficulty can be attributed to the variety of perceptions on specific socio-cultural and political contexts that change over time (Brent et al, 2005; Briassoulis, 2001). For example, very high inconsistencies in the judgements of panels with regards to strategic sustainability assessments have been documented (Noble, 2004). This is most probably an inherent weakness of the AHP when it is applied without support data in the context of sustainable development. This weakness is highlighted in developing countries by the difficulties to establish operable systems and to obtain support data that can be measured against sustainable development criteria such as the principles proposed in Agenda 21. Regardless, the AHP has been used before for the purposes of assessing and weighting criteria and indicators for sustainable development in specific applications (Mulder and Brent, 2006; Brent et al, 2005; Mendoza and Prabhu, 2003; Mendoza and Prabhu, 2000).

Sustainable development and Health Care Waste Management (HCWM) systems

Health care is a basic need for current and future generations, and is therefore one of the objectives of sustainable development systems. In developing countries the main symptom of poor health is the high mortality rate due to infectious diseases with the accompanying reduced life expectancy. For example, in Lesotho the life expectancy for women is 40 and for men 35 (WHO, 2005). The main objective identified of Health Care Waste Management (HCWM) systems in South Africa and Lesotho is to prevent the spread of infections from the health care waste to the workers and the community. This compares with the first objective of health care systems in general: “first do no harm” (WHO, 2002; Johannessen et al, 2000). Although data on spread of infections due to waste handling is limited, experts accept that 5% of all HIV infections in Africa are due to unsafe injections (Crabb, 2003), of which unsafe waste disposal is a component (WHO, 1999).

The HCWM system can be seen as a sub-system of the health care system. Therefore, optimizing efficiency of the waste management system, although not a guarantee for improvement in health care systems, is a component of sustainable development in such systems. The balancing of tradeoffs between the three dimensions of sustainable development, i.e. environment, economy, and society, may not be so difficult when a systems approach is taken to HCWM. Therefore, it can be argued that “strong sustainability” criteria can be identified for waste management systems, i.e. a direct relationship between action and sustainability response.

Health care systems can be described quantitatively using standardized systems tools, such as the Life Cycle Assessment tool (ISO, 1997), which is incorporated in the ISO 14000 family of standards and is based on inventories of materials and quantification of adverse impacts. Such tools allow the use of a number of quantitative approaches, e.g. mass flow analysis (Brunner and Rechberger, 2004), and Life Cycle Costing (Rebitzer and Hunkeler, 2003). Thereby, assessments can be made to identify how to develop more sustainable systems providing that the information is available. These assessments are difficult to perform in the developed world and there is, as yet, no consensus on a consistent methodology to measure these causes or effects. In the developing world there is often not enough quantitative information to follow these types of formalised methodologies (Brent, 2004).

In the developing country context, the availability of technology can also be seen to be a major limitation to introducing safe HCWM systems. Developing countries often do not have support systems to install, maintain, and operate developed world environmental technologies. The sustainable approach is to accommodate the use of more Environmentally Sound Technologies (ESTs) in the design of the waste management system. These ESTs are safer than the technologies they replace and more suited to the economic, social, and environmental conditions of the developing country, which can be contextually unique (Tanner, 2005).

In the absence of quantitative data on impacts and descriptions of systems capability to use ESTs in developing countries, a process is required by which the priorities can be set to establish safer systems.

Application of the AHP as decision support for the sustainable development of Health Care Waste Management (HCWM) systems

The complexities of Health Care Waste Management (HCWM) systems result from the many possible combinations of options, or alternatives, apart from singular technologies. However, when Multi Criteria Decision Analysis (MCDA) models, such as the AHP, are used to consider waste management options, the models identified in the literature only take into account waste once generated (Morrissey and Browne, 2004). Waste prevention, waste minimisation, or product design for the environment, which would eliminate the production of materials which cannot be reused, recycled, or naturally biodegraded are generally not considered (Morrissey and Browne, 2004). With respect to the sustainability of HCWM systems, the problems with accidental infection of health care personnel and patients have been recognized and safer technical alternatives are being researched (Dziekan et al, 2003) with the support of developing countries. In contrast to non-hazardous waste management approaches to sustainability, little can be achieved to prevent or minimise infectious waste, for which reuse, recycling, or natural biodegradation are not recommended due to safety and cost considerations (Rogers, 2004). In the developing country context, especially, the focus is currently on the management of generated waste in terms of technical aspects, costs, and risks (Brent et al, in press).

This paper concentrates on the infection risks related to the generated waste in HCWM systems, and specifically the waste generated at primary health care facilities in rural areas of developing countries, in order to address the main research question (Brent et al, in press): can the AHP be applied meaningfully in the context of sustainable development in order to establish HCWM systems that minimise infection risks in developing countries?

Objectives of the research study

The primary objectives of the research study were therefore (Ramabitsa-Siimane, 2006):

- To propose a model, which integrates the AHP with other systems approaches in order to establish primary HCWM systems that minimise infection risks in developing countries; and
- To identify the key barriers to apply the AHP within such a model, which must be addressed when applying the model.

RESEARCH METHODOLOGY

A case study research methodology was followed to evaluate the application of the AHP to HCWM systems. The case studies consisted of two workshops in South Africa and Lesotho, with participants from the respective HCWM systems, where the AHP was applied.

The representation of the AHP workshops of Southern African HCWM systems

The two workshops stretched over one and two days, for South Africa and Lesotho respectively. It has been stated that the size of an assessment panel depends on the objectives of the assessment, resources, and time available. As little as 10 participants are sufficient (Noble, 2004). This panel should comprise stakeholders, facilitators, and experts, although the level of expertise need not be the same as long as all participants are familiar with the problem (Saaty, 1980). Furthermore, to focus the AHP process it has been advised to engage a small group of participants (Noble, 2004; Saaty, 1986).

In the case of the South African and Lesotho workshops, 11 individuals participated over the full duration of the workshops that represent different operational levels in the respective HCWM systems:

- Strategic planning, e.g. occupational health, environment, and technical government officials and public-private specialists;
- Implementation planning, e.g. infection control, and technical government officials and public-private specialists; and
- Implementation, e.g. health inspectors, and waste management technical specialists.

INTEGRATING LIFE CYCLE THINKING TO CONSTRUCT APPROPRIATE HIERARCHY TREES

A model was developed for primary HCWM systems, termed WasteOpt (Brent et al, in press), which is based on the combination of the Life Cycle Management (LCM) approach (Hunkeler et al, 2004), and specifically the standardised Life Cycle Assessment (LCA) (ISO, 1997) and Life Cycle Costing (LCC) (Rebitzer and Hunkeler, 2003) tools, and the Analytical Hierarchy Process (AHP). It therefore inherits the benefits of both processes (see table 1). AHP is often applied as part of the LCA tool to evaluate environmental performances of system alternatives (Pineda-Henson et al, 2002).

Table 1: The benefits of LCM and AHP.

Life cycle Management	Analytical Hierarchy Process
1. LCM includes procedures for all inputs and outputs of a system, over time and space, although social aspects are limited at present. 2. Quantitative outcomes mitigate the use 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 5. 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.

Waste Life Cycle Management at primary health care facilities

A generalised life cycle system of health care waste has been introduced before in the context of primary health care facilities in rural areas in developing countries (Rogers et al, 2002). The life cycle system consists of four distinct main phases, each with a number of components, which are generic to any HCWM system (see figure 2). The reference of the life cycle system is a unit of waste generated at a typical primary health care facility. The assumptions concerning the spatial boundaries and inventories of the life cycle system, as well as the typical options available for the different life cycle phases, are summarised elsewhere (Brent et al, in press).

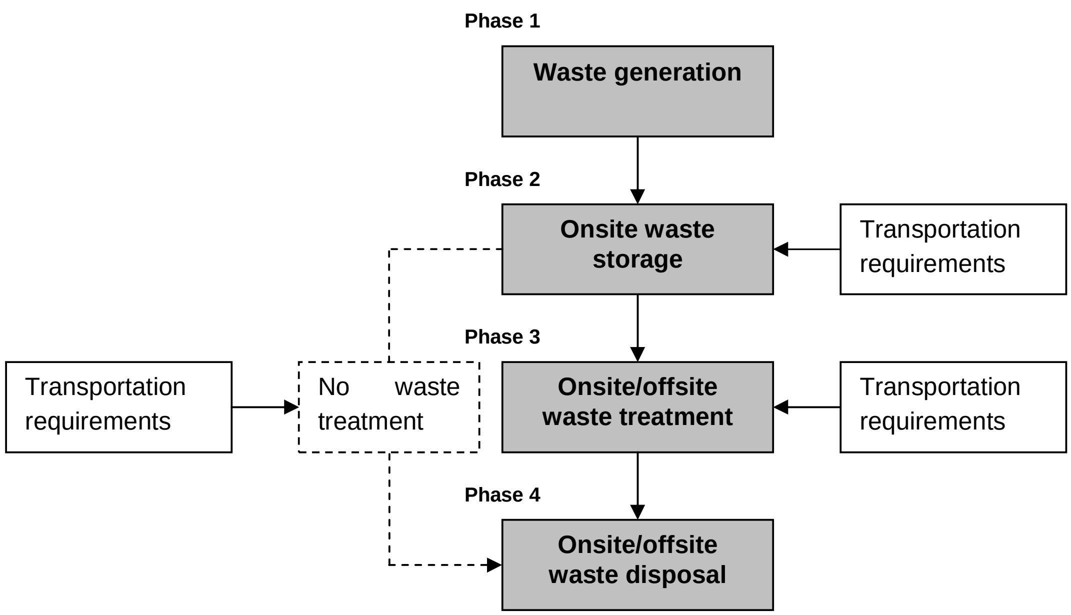

Figure 2: A schematic diagram of the AHP process.

The approach followed here was to use expert opinion to place weights (in terms of infection risks, which are seen as the highest potential impact) on options in the developing country context. These weights were used to compare alternatives for the four life cycle phases and to identify the alternative(s) with the minimum perceived infection risk. Ranking of the alternatives assists decision-makers to select the best available combination of options for the components of an entire HCWM system in a specific region.

Correlating AHP and waste Life Cycle Management terminology

From the above it is necessary to correlate the different terminologies of the two decision support tools, if AHP is to be used to establish the (perceived) health risks associated with each option available for a life cycle phase component at rural primary health care facilities. The use of the AHP terms depends on the type of hierarchical tree and its application. Table 2 defines the terms of AHP when applied as part of the WasteOpt model.

Again, in the context of waste LCM, the overall objectives are to minimise the risk of infection at a clinic for a specific life cycle phase (see figure 2), and an alternative is therefore a combination of component options for each of the four main life cycle phases that can be chosen to minimise the overall risk of a HCWM system.

Table 2: Correlation of AHP and waste LCM terminology.

Classified hierarchy levels	Conventional AHP terminology	WasteOpt terminology
Level 1	Overall objective or focus.	Minimise infections risks for each essential life cycle phase.
Level 2	Criteria, property, factor, or influence.	Essential life cycle phase components, and associated options.
Level 3	Alternatives, possibilities, or outcomes.	Combination of life cycle phase component options.

Structuring of hierarchical trees of options for the life cycle phases

The conventional AHP protocol (Saaty, 1980) requires that the elements be clustered into homogenous groups so they can meaningfully be compared with other elements in the level. It is also required that any element in one level must be capable of being related to some element in the next higher level. In a typical AHP 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 available for application. Due to the fact that the factors in second level relate to a specific life cycle phase, individual hierarchies were constructed for each phase separately, as opposed to a single hierarchy for the entire system. Through the hierarchies, decision-makers are thereby enabled to select the preferred alternative for each life cycle phase. Options were identified for the life cycle components (of the phases) of waste systems at typical primary health care clinics in rural areas (see figure 2), and structured into the appropriate levels (see table 2). These hierarchy trees are published elsewhere (Ramabitsa-Siimane, 2006; Brent et al, in press).

RESULTS AND DISCUSSION

The allocated time for the facilitation and coordination of the workshop process as a key issue in developing countries

The number of individual judgement inconsistencies when comparing the results of the two workshops (Brent et al, in press) highlights the importance of the workshop process.

The length of time allocated to an AHP-dedicated workshop is of major importance. Because of the difficulty in keeping groups of people together, only one or two days for decision analysing are considered achievable. For example, in the Lesotho workshop additional people arrived on the second day and some left after the first day.

The one day that was allowed for the South African workshop, compared to the two days allocated to the Lesotho workshop, influenced the:

- Time available for group discussions and subsequent consensus within sub-groups and the whole group in some cases; and
- The number of iterations; where inconsistencies were detected during the Lesotho workshop, subsequent iterations could be undertaken after further discussion, which has been shown to dramatically improve the CRs (Noble, 2004).

In another study where sustainable development aspects had to be weighted (Mulder and Brent, 2006), up to five days were required to reach good consistency within a panel of experts in a developing country context. This points to other limitations when applying the AHP.

The problem of diverse decision-makers in HCWM systems

There were diverse participants in the two workshops, i.e. managers and implementers. The implementers at district level participated to acquire specific knowledge while the national managers argued at a higher level since they have more knowledge of the HCWM systems in general. The implementers were found to be “black or white” thinkers while the national experts perceived “grey” areas. The implementers subsequently formed sub-groups and could reach consensus amongst them, while the national planners differed in opinions and tended not to reach consensus in groups.

The ranking within the AHP by some national planners was taken as a separate judgement call for each comparison, instead of a judgement ranking within a set of comparisons. Therefore this level of participants tended to see discrete sets of options within an attribute option set. It was found to be very difficult to communicate this aspect of the AHP to the group at large. In these cases discussions between the workshop facilitators and individuals were required to inform participants of inconsistencies and how these come about, which, again, required additional time.

Some of the participants performed the ranking with pre-conceived ideas, which also negatively influenced consistencies within sets of comparisons. It is subsequently believed that direct weighing is easier and more relevant than pair-wise comparisons for these types of participants.

Some participants thought the conventional AHP scale of 1 to 9 was too small and did not allow them to allocate numbers properly. In contrast the scale confused other participants such that they mixed the left and the right hand sides of the scale when confronted by the comparison question, e.g. which option is more important, and by how much, to minimise infection risks. Furthermore, precision errors with the conventional AHP scale and eigenvector approach have been noted in literature (Laininen and Hämäläinen, 2002), and the precision level of each of the comparisons cannot be guaranteed.

For these reasons the spread of priority weights is rather large for some of the hierarchical tree attributes, which has been shown to be characteristic of the application of AHP to sustainable development (Noble, 2004). Considering the standard deviation and mean values in the results (Ramabitsa-Siimane, 2006; Brent et al, in press) large spreads are more pronounced for the life cycle phase components than the associated specific options of components. This highlights the difficulty for the multiple decision-making panels to achieve consistent ranking of items on the upper levels of the hierarchical trees.

Applying the priority weights to rank alternatives and assign risk factors

The overall weights for alternatives, i.e. the combination of option choices for the essential life cycle phase components, were obtained with the conventional AHP by multiplication of the priority weight of each component option by the priority weight of the associated life cycle phase component. The consequent priority rankings were translated into impact indicators of the risk of each alternative for a life cycle phase (Ramabitsa-Siimane, 2006; Brent et al, in press).

An analysis of the risk factors (Ramabitsa-Siimane, 2006; Brent et al, in press) shows a definite trend towards higher risk with less engineered technology and this is consistent with the approach used in the development of standards in the developed world (Grimmond et al, 2003). The largest risk reduction is associated with the introduction of an engineered safety box. This risk reduction is consistent with the safety box policy of the World Health Organization (WHO) (Prüss et al, 1999). In the rural developing country situation, where training and working conditions are least controllable, the WHO intention is to ensure that at least there is a an engineered safety box in the generation life cycle phase.

The challenge of following this approach in the WasteOpt tool is the communication of the outcomes, i.e. the risk factors are not necessarily a true reflection of how much more risk is associated with one set of alternatives compared to another; it is only based on the combined perceptions of the selected panel.

CONCLUSIONS AND WAY FORWARD

A model is introduced that incorporates the standardised Life Cycle Management (LCM) approach with the Analytical Hierarchy Process (AHP), whereby Health Care Waste Management (HCWM) systems can be optimised in developing countries. The AHP has been used to assign priorities to the alternatives in the life cycle of waste according to the infection risks associated with the life cycle component options that are available to decision-makers in the life cycle of waste. Thereby, alternatives, or combinations of options for essential components of a HCWM system have been ranked according to the respective combined risks in relation to best practices for that developing country context. Also, allocations of resources for the implementation of these priorities can be assigned in short and medium terms based on availabilities of resources and largest benefit (Ramabitsa-Siimane, 2006). Therefore waste management systems can be optimized within the sustainability requirements of stakeholder acceptance, national safety requirements, and available system resources.

Two case studies were used to apply the AHP as part of the model. The case studies consisted of workshops that were held with stakeholders of the HCWM systems in South Africa and Lesotho. The case studies highlighted a number of barriers to the application of the AHP in developing countries, which must be addressed when applying the introduced WasteOpt tool:

- The available time for a workshop: At least two days with two workshop facilitators and one assistant are required.
- Group size: A workshop should comprise of no more than 15 participants that represent the different stakeholder groups of the HCWM systems.
- Diversity of educational level and background of participants: Facilitators of workshops must take cognisance of the fact that the stakeholders of HCWM systems in developing countries represent different levels in public and private sectors, with varying educational backgrounds. Therefore separate discussions in subgroups may be necessary to reach consensus and thereby improve consistencies.
- AHP scale and set of comparisons: Much time is required to explain the AHP scale, the set of pair-wise comparisons, and the importance of consistency in order to achieve buy-in to the process.
- Individual judgements: The problem of judgements, and possible outliers, has been noted (Laininen and Hämäläinen, 2002), which can be addressed with mathematical manipulation of the AHP matrices such as regression. At the very least it is important to report the intervals of priority weights (Mustajoki et al, 2005).

The choice of WasteOpt as a decision-making tool for developing country situations is based on its appropriateness to HCWM at all levels of administration and implementation in healthcare. Use of the hierarchy of waste management alone will not necessarily lead to economically and otherwise sustainable systems because it does not attempt to measure the impacts of the individual options available (White et al, 1995). The further development of the WasteOpt model would provide the benefits of ranking of options with little available information or data.

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