Journal of Cleaner Production 135 (2016) 139–147

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Considerations for choosing appropriate healthcare waste management treatment technologies: A case study from an East Midlands NHS Trust, in England

Steve Lee [a], Mentore Vaccari [b], Terry Tudor [a, b, *]

[a] The School of Science and Technology, University of Northampton, Northampton, NN2 7JD, UK
[b] Department of Civil, Environmental, Architectural Engineering and Mathematics, University of Brescia, Brescia, Italy

ARTICLE INFO

Article history:
Received 10 June 2015
Received in revised form
24 May 2016
Accepted 25 May 2016
Available online 17 June 2016

Keywords:
Healthcare waste management
Waste treatment technology
Analytic hierarchy process
National health service
Decision-making

ABSTRACT

Through their decision-making processes, organisations can play a key role in addressing global environmental challenges. However, to be effective, these processes need to be based on evidence. This paper aims to evaluate the 'optimum' healthcare waste treatment technology, using a National Health Service organisation in the East Midlands region of England, as the case study organisation. Using analytic hierarchy process as the research tool, this research determined that the 'optimum' approach was a mix of technologies. However, this result was largely driven by costs considerations. Thus the findings suggest the need for a holistic approach to the decision-making process for the procurement of their healthcare waste management services. The use of analytic hierarchy process generally worked well in informing the decision-making process.

1. Introduction

Globally, there are a number of key environmental challenges, including climate change, resource depletion, pollution, increasing waste quantities, and environmental health concerns, which require urgent attention (IPCC, 2013; UNEP, 2015a, 2015b). Indeed, in April 2016, over 130 global leaders gathered at the United Nations headquarters in New York, to sign the Paris Agreement. In December 2015, all 196 Parties to the United Nations' Framework Convention on Climate Change adopted the Paris Agreement, at COP21, agreeing to work to limit global temperature rise to well below 2 °C (UNEP, 2015a).

By their nature, organisations can play a key role in addressing these challenges and realise significant socio-economic and environmental benefits (Fisher et al., 2012; Caniato et al., 2015; Long and Young, 2016). Specifically for healthcare organisations, mitigation can enhance public and environmental health, and save money (Nguyen, 2013; Pollard et al., 2014; DOH, 2015). However, the effectiveness of the mitigation approaches is dependent on having sound evidence (Garcia et al., 2016; Kishita et al., 2016; Vučijak et al., 2015). Developing a strong evidence-base for such decision-making and the rationales for these decisions is therefore crucial.

Using an National Health Service (NHS) organisation in the East Midlands region of England as the case study, this project sought to inform the decision-making processes within the organisation as regards to an 'optimal' choice for selecting its waste treatment technologies (Saaty, 2008). Deep landfill, incineration and autoclaving were the three technologies examined, as they were the most commonly deployed within the United Kingdom (UK), at the time of the study (DOH, 2014a).

1.1. The case study organisation

The NHS is one of the largest organisations in the UK and due to the nature of its activities it is energy intensive and a high generator of waste (Tudor, 2013; GIB, 2014). It is also a major consumer of resources and emits around 18 $MtCO_{2e}$ (carbon dioxide equivalent), per annum (SDU, 2016). There are a range of legislative and financial drivers in place to help it to become a low carbon, sustainable organisation, while still maintaining patient and staff safety. For example, in line with UK Government targets, it has set

* Corresponding author. University of Northampton. St George's Avenue, Northampton, UK.
E-mail address: terry.tudor@northampton.ac.uk (T. Tudor).

http://dx.doi.org/10.1016/j.jclepro.2016.05.166
0959-6526/

itself a target to reduce CO_2 emissions by 80%, by 2050 (Tudor et al., 2015). However, it is expected that patient numbers, service provision and thus resource consumption levels within the NHS will significantly increase in the coming years, thus further increasing consumption and outputs (DOH, 2015). At the same time, the organisation is facing significant financial constraints, in order to meet an anticipated £30 billion deficit by 2020 (NHS, 2014). Thus it faces a number of competing legislative, compliance and financial challenges, which will become even more stringent in future.

At the time of the study, the case study NHS organisation had over 8800 staff. It provided services in a variety of settings, ranging from the community and mental health, through to acute wards, as well as secure settings, including prisons. These services were delivered over a radius of around 120 miles. Given the organisation's size, number of staff and geographical reach, its service provision therefore had significant environmental and economic impacts.

The framework used by the case study organisation to approach contractual decisions was influenced by the Purchasing Managers' Strategic Framework, which advocates 16 separate factors which may influence a purchasing decision (NHS Supply Chain, 2015). Of these factors, four were applicable to the decision process relating to the selection of appropriate waste treatment technologies, namely:

- Legal and Compliance
- Sector specific guidelines (Guidelines)
- Mandatory reporting requirements (Environment, Sustainability & Carbon Reporting)
- Cost of purchased solution (Economics)

These four factors were therefore used as the basis for examining the selected waste treatment technologies and informing the decision-making processes.

2. Evaluating the treatment technologies

2.1. Decision-making tools

Decision-making tools have been employed in a range of environmental management scenarios to inform decision-making, including for general sustainability (Garcia et al., 2016), air quality (Martenies et al., 2015), Environmental management systems (Guerrero-Baena et al., 2015), and specifically related to this study, waste management (Vučijak et al., 2015). For example, Martenies et al. (2015) used a range of environmental and economic health impact assessments (e.g. the number of cases of adverse outcomes avoided, disability-adjusted life years (DALYs), benefits per tonne of emissions reduced, and cost-benefit ratios), to inform policy and decision-making related to air quality. Guerrero-Baena et al. (2015) employed a novel decision-making approach based on the multi-criteria method of Analytic Network Process (ANP), in order to evaluate and prioritise the implementation of environmental management system alternatives. While Vučijak et al. (2015) utilised multi-criteria tools to select the best municipal solid waste management scenario from six different alternatives. The decision tools have also been utilised more widely, for example, in the area of planning. For example, Rojas-Zerpa and Yusta (2015) combined the application of two multi-criteria decision-making methods, namely, the Analytical Hierarchy Process (AHP) and Compromise Ranking method (VIKOR), to select the best solution for electrical supply of remote rural locations, involving technical, economic, environmental and social criteria.

Thus, multi-criteria decision-making tools are a useful and appropriate approach to finding appropriate solutions for different criteria or in the event of conflicting points of view.

2.2. Multiple criteria decision analyses

Multiple Criteria Decision Analysis (MCDA) is a field of operations management research that has evolved organically alongside disciplines where structured decision making is required (Zeleney, 1982). Increases in computational power, and the requirements for advanced decision-making in poorly constrained numerical environments (e.g. fuzzy), have meant that most models of MCDA are often software based (Masud, 2008; Abassi, 2013).

Various approaches enable criteria selection including: (1) AHP, which focuses on group decision-making and seeks to prescribe and 'optimal' outcome based on available data and inputs where criteria are independent from each other and distinct (Saaty, 2008; Abassi, 2013); (2) ANP, which prescribes a network where inter-dependence between variables is accepted, similarly considered criteria can be enhanced or rejected (if below 3% relevant typically) and inputs can be adjusted (Abassi, 2013); (3) Evidential Reasoning Approach (ERA), is a mechanism of MCDA which allows both qualitative and quantitative inputs to be considered in the form of decision matrices, and allows for statistical variation (randomness) (Bartlett and Ghoshal, 1990); and (4) Potential Pairwise Ranking (PPR) which allows for pairwise comparison of alternatives ranked additively taking into consideration the preferences of the participants undertaking the ranking (Vlasev, 2013). Critics of this approach argue that whilst allowing greater user choice, it can introduce too much 'noise' into results as decisions between criteria become obscure (Barzilai, 2002).

AHP was the most relevant to this study, as inter-dependence between the criteria is minimal, it enables both qualitative and quantitative inputs, and a step-wise process is employed within the context of the overall problem or situation (Saaty, 2008). Researchers have made extensive use of AHP for predicting or prescribing 'optimal' results in complex situations (Armstrong and Kotler, 2011; Rojas-Zerpa and Yusta, 2015; Wijenayake et al., 2016), even in situations involving significant unknowns, or poorly constrained variables (Bartlett and Ghoshal, 1990; Bhushan, 2004).

AHP is not without its criticisms and does suffer from known issues, particularly around the mechanism applied to priorities derivation (Ishizaka and Lusti, 2006), the comparison scale (Barzilai, 2002) and the rank reversal problem (Johnson, 1979; Saaty, 2008). The option selected for priorities derivation is a topic of intense academic debate, polarised between the proponents of eigenvalue method (Harker and Vargas, 1987; Ishizaka and Lusti, 2006; Saaty, 2008) and the geometric mean method (Barzilai, 2002; Bhushan, 2004).

2.3. Waste treatment approaches

2.3.1. Landfill

Landfilling of hazardous (infectious) healthcare waste was outlawed by the EU Landfill Directive (EC, 1999). However, 'deep landfill' (cell separated landfill) of offensive waste (referred to in the European Waste Catalogue (EWC) as 18.01.04) (EC, 2008), is still permitted at landfill sites with the appropriate licences, and makes up a significant volume of segregated healthcare waste (DOH, 2014a). Offensive waste includes items which are not hazardous, but which due to their odour and visual appearance may cause offense (e.g. nappies and feminine hygiene products). However, opponents have highlighted that landfills contribute to greenhouse gases (GHGs) (Nwachukwu and Anonye, 2012), and the significant scrubbing required of landfill gas, further increases its carbon inefficiency (Nock and Walker, 2014). In addition, the EU Landfill Directive requires a reduction to 35% of the 1995 level of