Proceeding Paper

Hierarchy of Waste Management: Option Selection for Managing Johannesburg City's Restaurant Food Waste [†]

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Abstract: Waste management strategies specified in the hierarchy of waste management were evaluated by applying a Multi-Criteria Decision-Making (MCDM) technique called the Analytic Hierarchy Process (AHP) to choose a strategy for managing Johannesburg (JHB) city's food waste. Under the different weighting scenarios for the evaluation criteria considered in this AHP, the recovery strategy scored an average of 41% while other strategies each scored 33%, 29% and 22% for prevention and reduction, treatment and disposal, re-use and recycle, respectively. Optimisation of resource recovery strategies from food waste is recommended for further consideration and investigation by the JHB municipality in its attempt to promote a circular economy and surmount food waste hurdles.

Keywords: food waste management; multi criteria decision method; Johannesburg; valorisation; analytic hierarchy analysis

1. Introduction

The city of Johannesburg generates approximately 12 kg of food waste per person per year and this is predominantly restaurant or kitchen food waste [1]. With an estimated population of five and a half million people, this means the city accrues an unimaginable amount of food waste [2]. Some of this food loss is avoidable through implementation of good practices while the other portion cannot be avoided [3]. Food waste in the city of Johannesburg was previously managed through treatment and disposal in four landfills of which two of these four are closed after being filled to their maximum capacity [4]. The remaining two active landfills currently being used for waste disposal are fast running out of space as waste generation is increasing every day. The Municipality of Johannesburg city has limited land space to develop new landfills and such an exercise would also require huge sums of capital outlay. Globally, managing organic waste through landfilling has lost popularity as new and more sustainable strategies have now advanced to the commercial scale. Some of these strategies include biomethanation, composting and reuse of waste in resource recovery. Practitioners in waste management rank strategies on "The Hierarchy of Waste Management" to reflect the most preferred strategy based on addressing the circularity of the economy. The strategies can be grouped as prevention and reduction, reuse and recycle, recover, and finally treat and dispose, in order of most preferred to least preferred [5]. To select the appropriate waste management strategy or technology for each situation depends on several factors which are derived from the customer's main goal in managing the waste. Several methods are available in the literature for guiding decision making where several criteria, alternatives and factors are involved. Among these methods

and techniques is the Analytic Hierarchy Process (AHP) technique which falls under the Multi-Criteria Decision-Making (MCDM) method [6,7]. Although this technique is widely applied in various industries, there is no literature on this technique's use in selecting the best food waste valorisation route specifically for JHB city. This study seeks to choose the most sustainable food waste management strategy for JHB city's municipality from those stated in the waste management hierarchy.

2. Methodology

Food-waste-related sustainability factors picked from literature were grouped according sustainability pillars of socio-cultural, environmental, technical and economical attributes. Waste management strategies presented on the "hierarchy of waste management" were then evaluated using these pillars as criteria while the factors are the sub-criteria in the AHP technique as described by Yakubu and Zhou (2019) [8]. The AHP structure developed and considered in this study is depicted in Figure 1. The waste management strategy with the highest overall AHP score was chosen and recommended for further investigations towards application in managing JHB food waste.
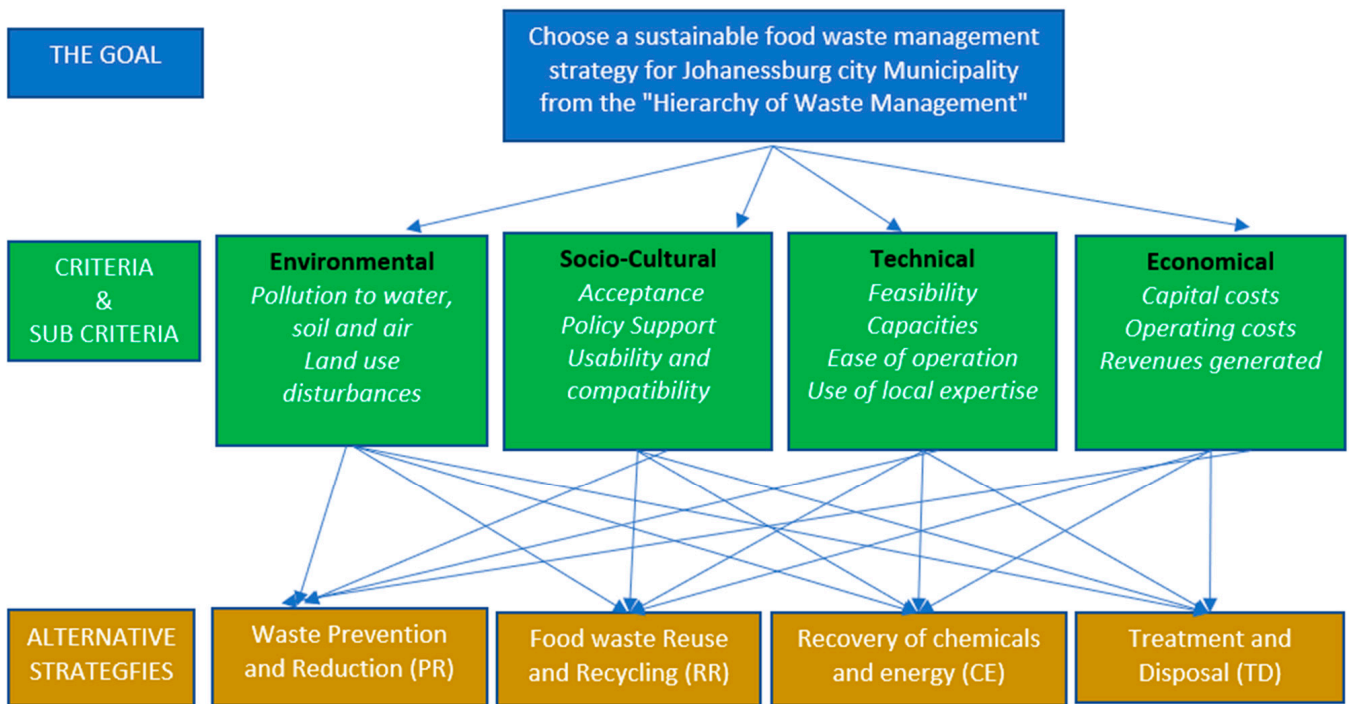

Figure 1. AHP tree structure for JHB's food waste management strategies. Source: *Author's drawing*.

3. Results and Discussion

The AHP results (under the base case and sensitivity analysis cases) are summarised in Figure 2 where waste recovery came out favoured as the most sustainable strategy for JHB city's food waste management. In one of the sensitivity analysis cases, in which weights were biased towards the environmental aspects (Figure 2b), the prevention and reduction strategy scored highest among all strategies. However, too high a bias towards the environment while downplaying other criteria is not a recommended course of action to follow as it has been pinpointed in other studies that sustainable policymaking should incorporate socio-cultural factors for success [9]. Resource recovery from waste is a broad waste management strategy which may involve waste composting to make biofertilisers and converting the waste into value-added chemicals and/or energy carriers. Biological processes such as fermentation to produce value-added chemicals and anaerobic digestion to produce biogas are ranked top among green processes. It is therefore recommended that the city of JHB should consider these options in the recovery strategy. The waste

management hierarchy strategies' suitability in managing JHB food waste are briefly scrutinised in Table 1.
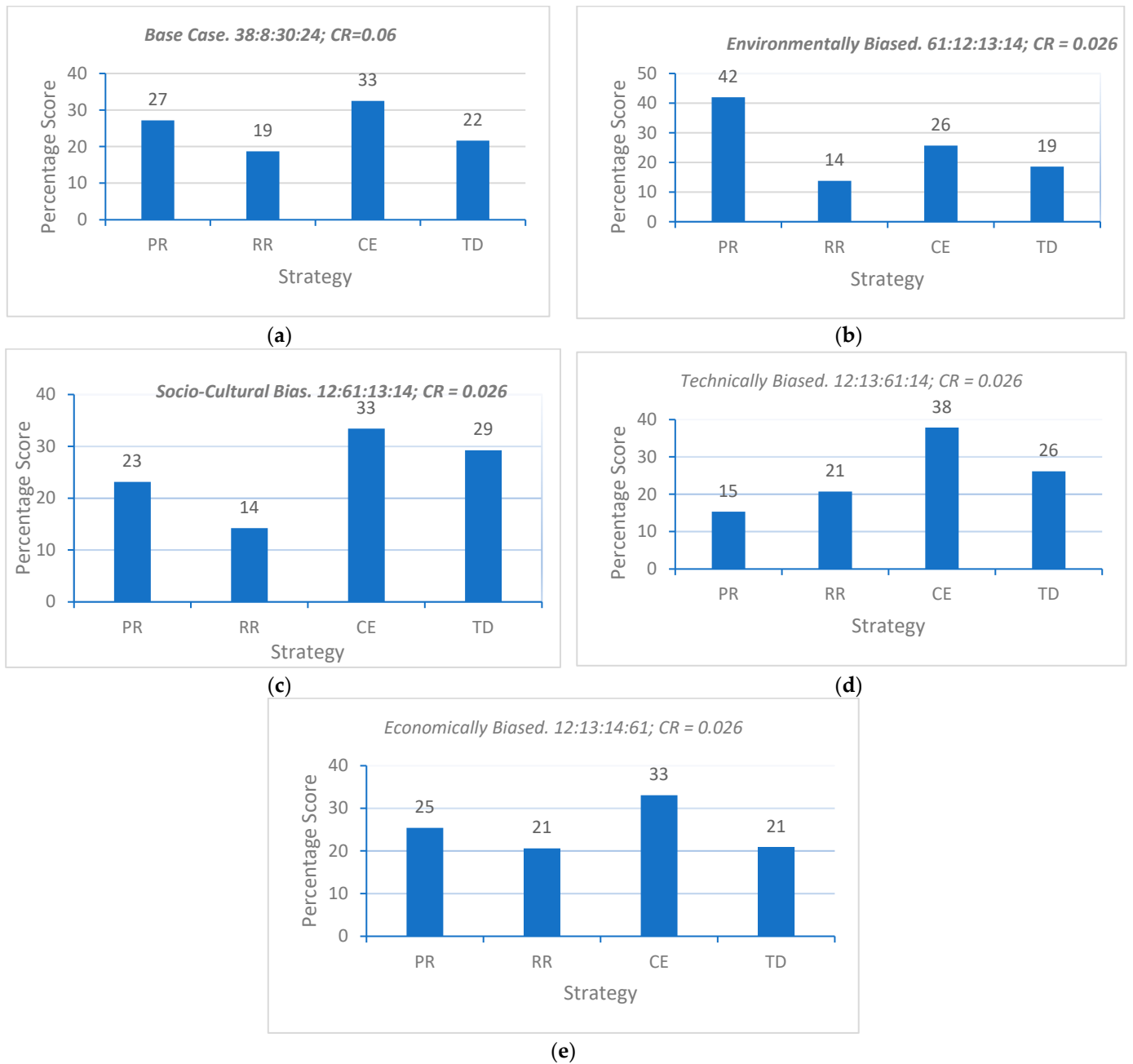

Figure 2. AHP results for different scenarios: (**a**) Base (**b**) environmentally biased (**c**) socio-culturally biased (**d**) technically biased and (**e**) economically biased. (Numbers after each title indicate % weight of each criterion in the case mentioned. The order of weights is Environment; Socio-Cultural; Technical; Economical, then CR is the consistency ratio).

Table 1. Summary of waste management strategies' applicability to JHB city's food waste.

Strategy (Explanation/Example)	Strategy's suitability for managing food waste in Johannesburg
Prevention and Reduction (Reduce surplus food generation)	Measures to reduce losses can be implemented. However, it is practically impossible to accurately predict the ever-fluctuating food demand for a restaurant business. Maintaining accurate quantities of restaurant stock inventory, cooked meals and food orders is almost impossible in order to eliminate losses completely.
Re-Use and Recycle (Reuse by donating extra food to food banks, soup kitchens, etc) (Recycle by scrapping food and use as feedstock for animals)	Contaminated food cannot be repurposed for human consumption. It is practically challenging to avoid contamination during handling and collection of food waste from restaurant guests.
	This is a selective process whereby certain foods cannot be fed to certain animals or certain conditions such as expired or fermented foods may make food unsuitable as feed to specific animals. Sorting waste food may be costly and no such systems exist in South Africa at the moment.
Resource Recovery (Composting for soil amendments as well as processing to recover energy)	Multiple benefits derived from these processes including addressing clean energy needs, cleaning the environment, job creation, improved agricultural yields, providing raw materials for other industries, etc. Most of the applicable technologies have matured and have been applied elsewhere with success so they can be replicated for Johannesburg city.
Treatment and Disposal in landfills (Stabilise and dispose)	This has been practiced traditionally in the whole country (South Africa) but space constraints and other challenges are now exposing this strategy's sustainability shortcomings.

4. Conclusions and Recommendations

Based on South Africa's drive for a circular economy and evaluation of sustainability factors discussed above in the context of the country, resource recovery presents the best strategy for managing JHB city's food waste among the options specified in the hierarchy of waste management. To tap into benefits of best practices recommended in this hierarchy a small portion of the restaurant food waste can be diverted into recycling and reuse while actions aimed at prevention of food loss should continue to be put in place. Future efforts by JHB municipality must be directed towards understanding optimised processing conditions for recovery strategies such as anaerobic digestion for biogas recovery. Biological processes for food waste valorisation have since been proven to be highly sustainable in most situations. They also enjoy ease of scalability to commercial scale and their circularity benefits are undoubtable.

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