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Application of ANP and DEMATEL to evaluate the decision-making of municipal solid waste management in Metro Manila

Ming-Lang Tseng

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Abstract A municipal solid waste management (MSW) expert group was consulted in order to mirror how government officials might reach an effective solution regarding municipal solid waste management in Metro Manila. A critical issue regarding this is how the expert group can better evaluate and select a favorable MSW management solution using a series of criteria. MSW management solution selection is a multiple criteria decision-making (MCDM) problem, which requires the consideration of a large number of complex criteria. A robust MCDM method should consider the interactions among these criteria. The analytic network process (ANP) is a relatively new MCDM method which can deal with all kinds of interactions systematically. The Decision Making Trial and Evaluation Laboratory (DEMATEL) not only can convert the relations between cause and effect of criteria into a structural model, but also can be used as a way to handle the inner dependences within a set of criteria. Hence, this paper applies an effective solution based on a combined ANP and DEMATEL method to assist the expert group evaluating different MSW management solutions. According to the results, the best solution is for each city to have its own type of thermal process technology and resource recovery facility before landfill rather than entering a joint venture with enterprises or going into build-operate-transfer projects in order to be able to construct thermal process technologies and resource recovery facilities.

Keywords Municipal solid waste (MSW) · Municipal solid waste management (MSWM) · Analytical network process · DEMATEL

Introduction

Metro Manila is considered the Philippines' gateway to the world. It serves as the country's major commercial, financial and educational center and the heart of the country's national government where the major administrative offices are located. Metro Manila is geographically defined by fourteen (14) cities and three (3) municipalities. These are the cities of Manila, Quezon, Caloocan, Makati, Marikina, Mandaluyong, Las Piñas, Pasig, Muntinlupa, Malabon, Valenzuela, Pasay, Taguig and Parañaque and the municipalities of Navotas, Pateros and San Juan.

Metro Manila, while being the heart of the Philippine economy, is also considered one of the

M.-L. Tseng (✉)
Department of Business Administration,
Ming-Dao University, 369 Wenhua Rd.,
Pitou Township, Chunghwa county, Taiwan
e-mail: ml.tseng@msa.hinet.net

most polluted areas in the Asia Pacific region. As in most developing countries which have harvested the success of economic growth, the consumption and production behavior of its millions of residents greatly threatens the quality of its environment and the integrity of its natural resources. The region is now facing a huge problem of pollution. Aside from the conventional air and water pollution threats, the solid waste issue has also been a perennial problem. Unsegregated MSW forms a strong barrier to the resource recovery strategy and the lack of sanitary landfills generates challenge to the limited disposal options in a scenario wherein an incinerator ban policy was introduced in the Philippines (Chiu 2006). An Asian Development Bank (2003) study showed that Metro Manila generates 6,720 metric tons of MSW on a daily basis. It is said that this amount will grow by 40 percent by 2010. This alarming rate of waste generation leaves the region with an overwhelming problem of MSW management. Much needed improvements on resource recovery strategy and disposal methods are thus becoming more critical issues as garbage production in the region increases.

Two alternatives are currently used as solutions to MSW management in Metro Manila: different thermal process technologies and resource recovery facilities. The latter involves sorting solid waste at a barangay level into three categories: those that can be reused recycled, and which are sent to landfills. Composting also occurs at these facilities. On the other hand, different examples of thermal process technologies include cement kiln technology, byproduct utilization, refuse-derived fuel (RDF) combustion, and pyrolysis.

Improper, MSWM also has an impact on air, soil, and water pollution. Indiscriminate dumping of wastes contaminates surface and ground water supplies. In urban areas, solid waste clogs drains, creating stagnant water for insect breeding and floods during rainy seasons. Uncontrolled burning of wastes and improper incineration contributes significantly to urban air pollution. Greenhouse gases are generated from the decomposition of organic wastes in dumpsites, and untreated leachate pollutes surrounding soil and water bodies (IBRD-WB 1999).

Effective solid waste management largely begins with proper MSW management. Hence, in order to implement MSW management successfully, better evaluation and selection of a favorable MSW management solution is critical. MSW management solution evaluation usually involves subjective and qualitative judgment. In particular, selection of MSW management options is a strategic issue (Vego et al. 2007; Khan and Faisal 2008), which is restricted by resource needs, realistic support, time requirements, conformity with expected outcomes, etc. In this sense, the process of selecting an MSW management solution requires the handling of several complex decision factors in a sensible and logical manner. Therefore, MSW management selection is a multiple criteria decision-making (MCDM) problem, and requires MCDM methods to solve it appropriately.

Traditional MCDM methods are based on the additive concept along with the independence assumption, but individual criterion is not always completely independent (Shee et al. 2003). For solving the interactions among elements, the analytic network process (ANP) as a relatively new MCDM method was proposed by Saaty (1996). The ANP is a mathematical theory that can deal with all kinds of dependence systematically. The ANP has been successfully applied in many fields (Chung et al. 2005; Tesfamariam and Lindberg 2005; Tseng et al. 2008). ANP has a systematic approach to set priorities and trade-offs among goals and criteria, and also can measure all tangible and intangible criteria in the model. However, the treatments of inner dependences in those ANP works were not complete and perfect. To address this, the Decision Making Trial and Evaluation Laboratory (DEMATEL), a mathematical computation method, not only can convert the relations between cause and effect of criteria into a visual structural model (Hori and Shimizu 1999; Wu 2008), but also can be utilized as a wise way to handle the inner dependences within a set of criteria. As the ANP and the DEMATEL both have their respective advantages, this paper applies an effective solution based on a combined ANP and DEMATEL approach to assist the expert group that will mirror the selection of a favorable MSW management solution. Also, it illustrates the application for the expert group decision making. The rest of this paper is organized as follows. In Literature review, an evaluation framework is proposed. In Research method, literatures relevant to the topic are reviewed. In Metro Manila case study, evaluation methods are presented. In Discussion, a study is illustrated. Finally, according to the findings of this research, conclusions and suggestions are presented in Conclusions.

Literature review

The section aims to identify the theoretical composition that will be considered in this study's objectives. Researchers have described MSW management as a strategic, decision making perspective in order to improve present performance. Their researches covered criteria identification in order to describe such a decision-making process and criteria in enhancing such.

After the 1990s, as MSW policies became more complicated, the factors to be considered also increased; hence, several MSWM models with deeper analysis emerged. Hokkanen and Salminen (1997) applied the decision making method ELECTRE to select a MSW management system in Finland, with eight criteria; namely: cost per ton, technical reliability, global effects, local and regional health effects, acidic releases, surface water dispersed releases, number of employees, and amount of recovered waste. Twenty-two alternatives under either decentralized or centralized management systems were examined, with various treatment methods such as composting, RDF combustion, and landfill.

The factors considered in MSW management models tend to be mainly economic (e.g., system cost and system benefit), environmental (air emission, water pollution) and technological (the maturity of the technology). Wilson et al. (2001), who interviewed eleven different leading edge European MSW programs in nine countries, proposed that "including different public groups in the process from the very beginning can help avoid the high levels of controversy and public opposition that have surrounded many MSW projects". Morrissey and Browne (2004) proposed that a sustainable MSW management model should not be only environmentally effective and economically affordable but also socially acceptable. Karagiannidis and Moussiopoulos (1998) proposed a set of multiple criteria, which cover social, environmental, financial, and technical aspects, for dealing with optimization of regional solid waste management. Su et al. (2007) studied many modern decision making support systems which already partially consider social factor analysis in addition to expenses and benefits, environmental effects, technical issues, and management aspects. A study in Taiwan's major MSW policies in the past 10 years discovered that there is still a great deal of uncertainty associated with policy implementation, even when the effects of factors related to environmental, economic, social, technological, and management aspects have been considered. Hung et al. (2007) reviewed several models developed to support decision making in MSW management. Their concepts underlying sustainable MSW management models can be divided into two categories; this same clustering was also supported by various researchers. The first category incorporates social factors into decision making methods (Chung and Lo 2003; Cavallaro and Ciraolo 2005; Hernandez and Martin-Cejas 2005), whereas the other model incorporates public participation into the decision making process (Ananda and Herath 2003; Skordilis 2004).

This study uses objective factors that cover all the major key elements; namely: social, economic, technological, political and administrative dimensions These factors were used extensively in Chiu (2006), Cheng et al. (2002), Chung and Lo (2003), Hernandez and Martin-Cejas (2005), Skordilis (2004), Cavallaro and Ciraolo (2005), Su et al. (2007) and Hung et al. (2007). In addition, this study applied an effective solution based on a combined ANP and DEMATEL approach to assist the expert group that needs to select a favorable MSW management solution. Also, Metro Manila case study presents the application of expert group decision making.

Research method

The research method can be justified using precise values in complex evaluation systems. A complex evaluation environment can be divided into subsystems to more easily judge differences and measurement scores. A DEMATEL is used to construct interrelations between criteria. The criteria weights are then obtained through ANP, measuring dependence and feedback.

The DEMATEL method

The DEMATEL method originated from the Geneva Research Centre of the Battelle Memorial Institute (Gabus and Fontela 1973; Fontela and Gabus 1976). It is especially practical and useful for visualizing the structure of complicated causal relationships with matrices or digraphs. The matrices or digraphs portray a contextual relation between the elements of the system, in which a numeral represents the strength of influence. Hence, the DEMATEL method can convert the relationship between the causes and effects of criteria into an intelligible structural model of the system. The DEMATEL method has been successfully applied in many fields (Hori and Shimizu 1999; Sankar and Prabhu 2001; Chiu et al. 2006; Seyed-Hosseini et al. 2006). The essentials of the DEMATEL method suppose that a system contains a set of criteria $C = \{C_1, C_2, \ldots, C_n\}$, and the particular pairwise relations are determined for modeling with respect to a mathematical relation. The solving steps are as follows:

Step 1: *Generating the direct relation matrix.* Measuring the relationship between criteria requires that the comparison scale be designed as four levels: 0(no influence), 1(low influence), 2(high influence), 3(very high influence). Experts make sets of the pairwise comparisons in terms of influence and direction between criteria, the initial data can be obtained as the direct-relation matrix that is a $n\ x\ n$ matrix A, in which a_{ij} is denoted as the degree to which the criteria$i$ affects the criteria j.

Step 2: *Normalizing the direct relation matrix.* On the base of the direct – relation matrix A, the normalized direct-relation matrix X can be obtained through the following formulas:

$$X = k \times A \tag{1}$$

$$k = \frac{1}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}}, \quad i, j = 1, 2, \ldots\ldots.., n \tag{2}$$

Step 3: *Attaining the total relation matrix.* Once the normalized direct-relation matrix **X** is obtained, the total relation matrix **T** can be acquired by using formula (3), in which **I** is denoted as the identity matrix:

$$T = \mathbf{X}\,(\mathbf{I} - \mathbf{X})^{-1} \tag{3}$$

Step 4: *Producing a causal diagram.* The sum of rows and the sum of columns are separately denotes as vectors ***D*** and vector ***R*** through formula (4)–(6). The horizontal axis vector (***D***+***R***) named “Prominence” is made by adding ***D*** to ***R***, which reveals how much importance the criterion has. Similarly, the vertical axis (***D***–***R***) named “Relation” is made by substracting ***D*** from ***R***, which may group criteria into a cause group. Or, if the (***D***–***R***) is negative, the criterion is grouped into the effect group. Therefore, the causal diagram can be acquired by mapping the dataset of the (***D*** + ***R***,***D*** - ***R***), providing valuable insight for making decisions.

$$\mathbf{T} = \left[t_{ij}\right]_{n \times n}, \quad i, j = 1, 2, \ldots\ldots\ldots\ldots., n \tag{4}$$

$$\boldsymbol{D} = \left[\sum_{i=1}^{n} t_{ij}\right]_{n \times 1} = [t_i]_{n \times 1} \tag{5}$$

$$\boldsymbol{R} = \left[\sum_{j=1}^{n} t_{ij}\right]_{1xn} = \left[t_j\right]_{nx1} \tag{6}$$

In these equations, vector ***D*** and vector ***R*** denote the sum of rows and the sum of columns from total-relation matrix $\mathbf{T} = \left[t_{ij}\right]_{n \times n}$, respectively,

Step 5: *Obtaining the inner dependence matrix*. In this step, the sum of each column in total-relation matrix is equal to 1 by the normalization method, and then the inner dependence matrix can be acquired.

The ANP method

MSW management is a MCDM problem, but the chosen solution must consider the interdependences among elements. In order to deal with these, the ANP as a new MCDM method was proposed by Saaty (1996).

Saaty (1999) demonstrated several types of ANP models, such as the Hamburger Model, the Car Purchase BCR model, and the National Missile Defense model. This kind of model can effectively capture the complex effects of interplay in human society, especially when risk and uncertainty are involved Saaty (2003). However, it is usually hard to obviate the possibility of interactions within the criteria cluster. Thus, this paper suggests a modified feedback system model (Fig. 1) that allows inner dependences within the criteria cluster, in which the looped arc signifies the inner dependences.

This study involves numbers of pairwise comparisons for deriving the priorities of different alternative evaluation. Synthesizing experts' opinions is in compliance with the geometric mean method Buckley (1985). The valuation scales used in the study are those recommended by Saaty (1980, 1996), where 1 is equal importance, 3 is moderate importance, 5 is strong importance, 7 is very strong or demonstrated importance, and 9 is extreme importance. Even numbered values will fall in between importance levels. Reciprocal values (e.g. 1/3, 1/5, etc.) mean less importance, even less importance, etc.

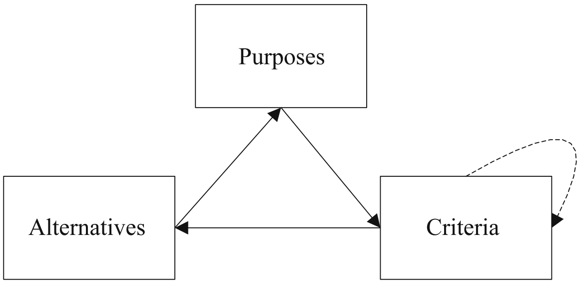


Fig. 1 Study feedback system model

Saaty (1980) proved that for consistent reciprocal matrix, the $\lambda_{\max}$ value is equal to the number of comparisons, or $\lambda_{\max} = n$. A measure of consistency was given, called Consistency Index as deviation or degree of consistency using the following formula. If the value of C.I. Ratio C.I. = $(\lambda_{\max} - n)/(n{-}1)$ is smaller or equal to 10%, the inconsistency is acceptable. If the C.I. ratio is greater than 10%, the subjective judgment needs to be revised.

n in the formula denotes the number of elements that have been compared. When $\lambda_{\max} = 0$, the complete consistency exists within judgment procedures and then $\lambda_{\max} = n$. The consistency ratio (C.R.) of C.I. to the mean random consistency index (R.I.) is expressed as C.R. (C.R. = C.I./ R.I.) less than 0.1. Saaty randomly generated reciprocal matrix using scale 1/9, 1/8, 1/7, ...1,...., 8, 9 (similar to the idea of Bootstrap) and took the random C.I. to see if it was about 10% or less.

After eigen-vector decomposed, the priority weights in the same hierarchy are computed through normalization. The normalized weight vectors are $W = (x_1, x_2, \ldots\ldots x_n)$. The outcome of the process above is able to compose an unweighted supermatrix. Its columns contain the priorities derived from the pairwise comparisons of the elements. In an unweighted supermatrix, its columns may not be column stochastic. To obtain a stochastic matrix, i.e., each column sums to one, the blocks of the unweighted supermatrix should be multiplied by the corresponding cluster priority. The supermatrix should then be raised to a large power to capture first, second, and third degree influences. When the differences between corresponding elements of a column are less than a very small number, for successive powers of the supermatrix, the process has converged. To derive the overall priorities of elements, this method involves multiplying submatrices numerous times in turn, until the columns stabilize and become identical in each block of submatrices. The research model requires adjusting of the unweighted supermatrix to keep it column stochastic because it involves inner dependences and interdependency in the element clusters, The weighted supermatrix (the adjusted unweighted supermatrix) can then be raised to limiting powers to calculate the overall priority weights. The ANP employs the limiting process method $\lim_{k\to\infty} W^k$ of the powers of the supermatrix (Saaty 1996; Meade and Sarkis 1998; Sekitani and Takahashi 2001; Tseng et al. 2008). For synthesizing overall priorities for the alternatives, the unweighted supermatrix requires adjusting in order to keep it column stochastic (Sarkis 1999).

The weighted supermatrix (the adjusted unweighted supermatrix) can be raised to limiting powers to calculate the overall priorities. However, before forming the unweighted supermatrix, the treatment of inner dependences needs to employ the DEMATEL. The treatment of inner dependences can theoretically use the ANP, but DEMATEL might be a better option as it can produce more valuable information for making decisions.

Metro Manila case study

This section aims to operationalize evaluation methodology of the different MSW management criteria so to select an optimal alternative for Metro Manila. The expert opinions are obtained from the expert group composed of two professors and six technologists with extensive experience consulting in government projects.

MSW management in Metro Manila

Inefficient and ineffective MSW management practices are said to be the center of the country's garbage problem. Mismanagement of MSW can also cause different serious problems with linkages to ground and surface water contamination, obstruction of drainage causing flooding and breeding grounds for disease carrying organisms, air pollution with exposure to harmful dioxins if MSW were improperly incinerated, and other ill effects. The effects of the MSW problem can be substantially evident even to the casual observer given its environmental, health, and aesthetic impacts.

In lieu of that past practices which were insufficient to handle the holistic issues of MSW, Republic Act 9003, also known as the Ecological Solid Waste Management Act of 2001, was enacted. This Act provides a broad-based and comprehensive approach for MSW management in the country by essentially covering the social, economic, technological, political and administrative dimensions of MSW management (NSWMC 2005). The social dimension of MSW management involved the participation of the community in their consumption and disposal attitude towards minimizing MSW generation. The economic dimension dealt with resource recovery. The technological dimension discussed state-of-the-art appropriate, effective and acceptable practices of waste disposal. Cutting across these three dimensions were political and administrative dimensions of waste minimization, recovery and disposal.

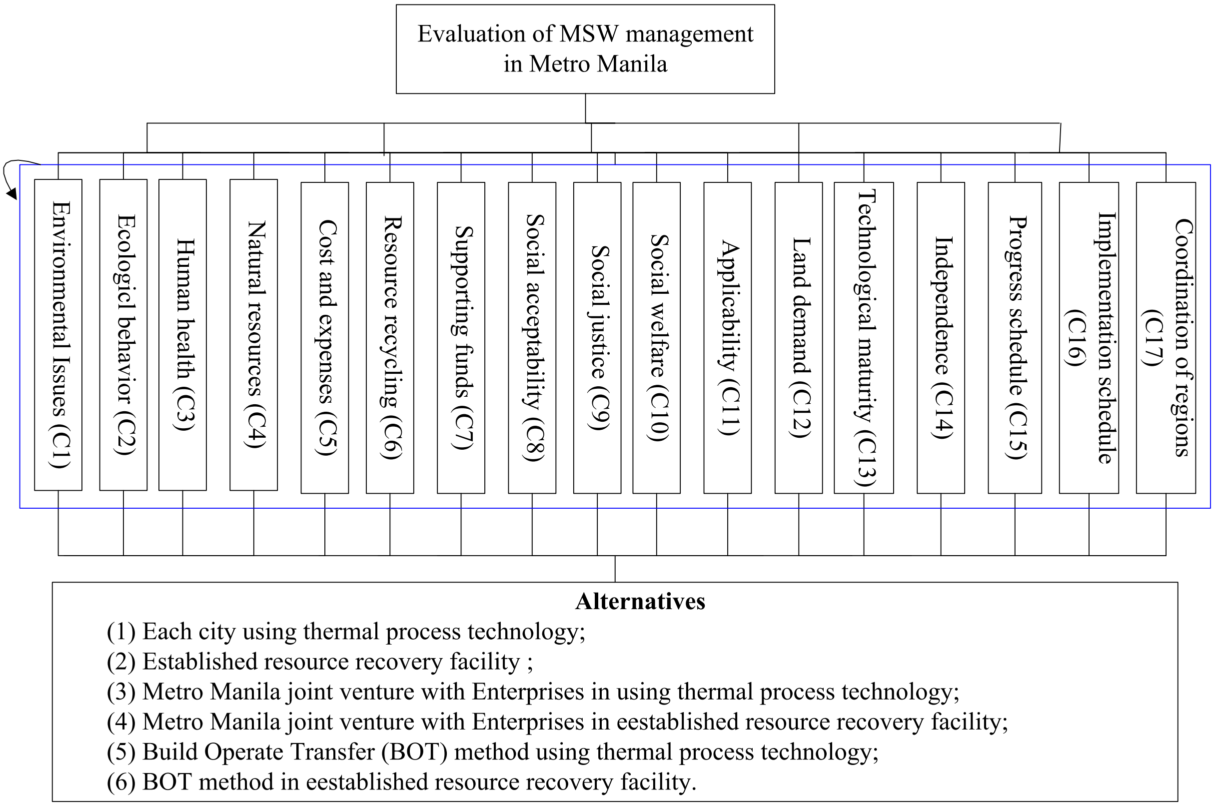
The trends in MSWM in the metropolis are studied in order to provide substantial research information on how the expert group responded to the growing concerns on MSWM. This study focuses on how stakeholders and other involved factors influence the decision-making in MSWM in the urban areas of Metro Manila. There are also invaluable lessons that could be extracted from the existing practices on waste generation pattern, management options, resource recovery, key influence factors, and other factors that could contribute to the new Ecological Solid Waste Management Act with integral approaches.

Problem description

The expert group strived to recommend the MSWM system and expected it to remain long-term in Metro Manila. The expert group reviewed the MSWM because environmental protection is one of the most prioritized issues of the present government. The expert group has the same need to find a solution regarding MSW management. It intends to evaluate and select a proper solution of MSW management, and made this MSWM selection more logical and persuasive as there is a growing need for an analytical and systematic way of solution selection in government decision procedures. For better handling of this MCDM problem, the eight-member expert group, should adopt possible solutions and criteria of MSW management which essentially cover the social, economic, technological, political and administrative dimensions. This study would provide policy recommendations, and would be useful in the efficient and effective implementation of MSW management in Metro Manila.

Recovery problem

A small portion of the solid waste is currently successfully recovered, recycled, or composted, despite the existence of a relatively large market for compost and used products made from recycled plastics, glass bottles, scrap paper, and scrap metals (WB 2001). Although many improvements are being achieved by the recycling sector, there is still plenty of room for further improvement. In fact, recycling rates in Metro Manila are increasing at a very fast pace. In 1997, the recycling rate of Metro Manila based on reports by junkshop dealers was only 6%. This grew to 13% in 2000 and to 25% in 2003 due to efforts made by the MMDA and NGOs to promote segregation at source, composting, and recycling. A proper way of recycling of resources which fits 17 essential criteria needs to be identified These criteria are based on the consideration of administrative and technological dimensions along with the triple bottom line, which takes into account the importance of environment, economic, and social impacts in decision-making. They are, namely; environmental issues, ecological, behavior, human health, natural resources, cost and expenses, resource recycling, supporting funds, social welfare, applicability, land demand, technological maturity, independence, progress schedule, implementation schedule, and coordination of resources.



(1) Each city using thermal process technology;
(2) Established resource recovery facility ;
(3) Metro Manila joint venture with Enterprises in using thermal process technology;
(4) Metro Manila joint venture with Enterprises in eestablished resource recovery facility;
(5) Build Operate Transfer (BOT) method using thermal process technology;
(6) BOT method in eestablished resource recovery facility.

Fig. 2 Operational decision framework

Table 1 The direct-relation matrix

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17
A1	3.000	2.000	1.000	1.000	1.000	3.000	2.000	0.000	1.000	2.000	3.000	1.000	1.000	1.000	1.000	1.000	3.000
A2	3.000	1.750	1.000	1.000	1.125	1.875	2.000	0.000	1.125	1.500	3.000	1.125	1.000	1.000	2.000	1.000	2.000
A3	3.000	2.000	0.000	1.250	1.000	2.375	1.375	1.000	1.250	1.750	2.625	2.000	1.125	2.000	1.000	0.000	4.625
A4	0.250	0.000	0.000	0.000	1.000	2.125	1.125	2.000	2.000	1.500	2.250	1.000	1.125	1.000	0.000	1.000	2.875
A5	3.000	2.000	1.000	0.000	2.000	1.375	2.000	2.625	1.000	1.125	1.875	0.000	0.250	1.000	0.000	1.000	2.375
A6	3.000	1.875	0.000	1.125	1.000	2.000	1.000	2.000	1.000	1.750	1.625	0.250	1.000	1.125	1.125	0.000	2.000
A7	2.500	0.000	1.000	1.125	1.125	1.750	1.500	2.000	2.000	2.000	1.875	1.125	1.000	1.125	0.000	1.000	2.625
A8	2.875	2.000	0.000	1.375	1.000	0.625	1.250	2.000	2.000	0.625	1.125	1.125	0.000	0.000	1.125	0.000	0.000
A9	0.000	0.000	0.000	0.000	2.000	1.500	1.750	1.000	1.000	1.750	2.000	1.125	1.125	1.000	0.000	1.000	2.875
A10	2.750	2.000	1.000	1.000	0.000	1.750	1.750	1.750	2.000	1.625	2.625	1.000	0.000	1.125	0.125	1.000	2.000
A11	0.000	2.000	1.000	0.000	1.000	1.500	2.000	1.000	1.000	1.500	1.500	0.000	1.000	0.000	0.000	1.000	3.000
A12	2.750	0.000	0.000	1.125	2.000	1.750	1.625	0.000	2.000	1.500	2.250	1.000	0.000	1.000	1.125	0.000	0.000
A13	0.250	0.000	1.000	0.000	1.000	1.875	1.875	0.000	1.000	1.750	1.500	0.000	1.000	1.000	0.125	1.000	3.000
A14	0.250	2.000	0.000	1.000	1.000	2.375	2.000	3.000	1.125	1.625	2.000	0.000	1.125	1.250	0.250	2.250	0.000
A15	0.000	0.000	0.000	0.000	0.000	2.250	0.875	3.000	2.000	1.500	1.875	1.000	0.000	2.000	1.000	2.000	3.000
A16	3.000	2.000	1.000	1.000	1.000	1.875	2.000	2.000	1.000	1.750	3.000	1.000	0.000	2.000	1.000	1.000	0.000
A17	3.000	2.000	1.000	0.000	1.000	2.000	1.000	1.750	2.000	1.750	2.000	1.000	0,000	1.000	1.000	1.000	3.000

Table 2 The inner dependence matrix

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17
C1	0.079	0.079	0.084	0.078	0.070	0.080	0.075	0.056	0.067	0.075	0.077	0.074	0.080	0.071	0.079	0.074	0.078
C2	0.074	0.071	0.079	0.074	0.067	0.068	0.071	0.053	0.064	0.067	0.073	0.073	0.076	0.067	0.096	0.072	0.068
C3	0.080	0.080	0.061	0.084	0.072	0.077	0.071	0.067	0.071	0.074	0.076	0.092	0.083	0.084	0.081	0.060	0.088
C4	0.041	0.040	0.040	0.038	0.052	0.053	0.048	0.058	0.058	0.051	0.052	0.054	0.061	0.050	0.038	0.054	0.056
C5	0.071	0.071	0.075	0.050	0.074	0.059	0.066	0.073	0.058	0.058	0.061	0.049	0.054	0.060	0.051	0.064	0.064
C6	0.066	0.065	0.047	0.069	0.057	0.060	0.054	0.064	0.055	0.060	0.056	0.049	0.067	0.059	0.070	0.046	0.059
C7	0.067	0.051	0.073	0.073	0.064	0.062	0.062	0.067	0.068	0.066	0.061	0.069	0.070	0.063	0.048	0.065	0.066
C8	0.054	0.054	0.035	0.064	0.049	0.040	0.046	0.052	0.054	0.040	0.043	0.056	0.036	0.034	0.060	0.036	0.036
C9	0.038	0.038	0.040	0.036	0.063	0.047	0.052	0.047	0.047	0.052	0.049	0.055	0.059	0.049	0.035	0.053	0.054
C10	0.069	0.070	0.073	0.071	0.050	0.062	0.064	0.064	0.068	0.064	0.067	0.068	0.051	0.063	0.053	0.065	0.062
C11	0.039	0.058	0.063	0.037	0.050	0.048	0.054	0.046	0.047	0.050	0.047	0.038	0.058	0.037	0.039	0.053	0.057
C12	0.055	0.037	0.038	0.059	0.063	0.050	0.051	0.038	0.056	0.050	0.052	0.053	0.039	0.050	0.058	0.038	0.038
C13	0.037	0.036	0.060	0.034	0.047	0.048	0.050	0.036	0.044	0.050	0.044	0.034	0.056	0.048	0.036	0.051	0.054
C14	0.043	0.061	0.041	0.063	0.053	0.057	0.058	0.069	0.051	0.054	0.053	0.040	0.065	0.056	0.046	0.060	0.039
C15	0.041	0.043	0.040	0.042	0.041	0.056	0.048	0.071	0.060	0.053	0.052	0.058	0.039	0.067	0.063	0.073	0.057
C16	0.072	0.072	0.075	0.074	0.064	0.065	0.069	0.070	0.060	0.066	0.071	0.068	0.053	0.077	0.073	0.068	0.051
C17	0.074	0.074	0.077	0.053	0.065	0.067	0.061	0.067	0.071	0.067	0.066	0.070	0.052	0.065	0.076	0.068	0.071

Table 3 The unweighted supermatrix

	G1	G2	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	A1	A2	A3	A4	A5	A6
G1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.568	0.470	0.430	0.370	0.440	0.570
G2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.432	0.530	0.570	0.630	0.560	0.430
C1	0.068	0.080	0.079	0.079	0.084	0.078	0.070	0.080	0.075	0.056	0.067	0.075	0.077	0.074	0.080	0.071	0.079	0.074	0.078	0.000	0.000	0.000	0.000	0.000	0.000
C2	0.070	0.065	0.074	0.071	0.079	0.074	0.067	0.068	0.071	0.053	0.064	0.067	0.073	0.073	0.076	0.067	0.096	0.072	0.068	0.000	0.000	0.000	0.000	0.000	0.000
C3	0.079	0.084	0.080	0.080	0.061	0.084	0.072	0.077	0.071	0.067	0.071	0.074	0.076	0.092	0.083	0.084	0.081	0.060	0.088	0.000	0.000	0.000	0.000	0.000	0.000
C4	0.055	0.043	0.041	0.040	0.040	0.038	0.052	0.053	0.048	0.058	0.058	0.051	0.052	0.054	0.061	0.050	0.038	0.054	0.056	0.000	0.000	0.000	0.000	0.000	0.000
C5	0.066	0.036	0.071	0.071	0.075	0.050	0.074	0.059	0.066	0.073	0.058	0.058	0.061	0.049	0.054	0.060	0.051	0.064	0.064	0.000	0.000	0.000	0.000	0.000	0.000
C6	0.053	0.083	0.066	0.065	0.047	0.069	0.057	0.060	0.054	0.064	0.055	0.060	0.056	0.049	0.067	0.059	0.070	0.046	0.059	0.000	0.000	0.000	0.000	0.000	0.000
C7	0.059	0.059	0.067	0.051	0.073	0.073	0.064	0.062	0.062	0.067	0.068	0.066	0.061	0.069	0.070	0.063	0.048	0.065	0.066	0.000	0.000	0.000	0.000	0.000	0.000
C8	0.037	0.021	0.054	0.054	0.035	0.064	0.049	0.040	0.046	0.052	0.054	0.040	0.043	0.056	0.036	0.034	0.060	0.036	0.036	0.000	0.000	0.000	0.000	0.000	0.000
C9	0.046	0.052	0.038	0.038	0.040	0.036	0.063	0.047	0.052	0.047	0.047	0.052	0.049	0.055	0.059	0.049	0.035	0.053	0.054	0.000	0.000	0.000	0.000	0.000	0.000
C10	0.062	0.072	0.069	0.070	0.073	0.071	0.050	0.062	0.064	0.064	0.068	0.064	0.067	0.068	0.051	0.063	0.053	0.065	0.062	0.000	0.000	0.000	0.000	0.000	0.000
C11	0.039	0.039	0.039	0.058	0.063	0.037	0.050	0.048	0.054	0.046	0.047	0.050	0.047	0.038	0.058	0.037	0.039	0.053	0.057	0.000	0.000	0.000	0.000	0.000	0.000
C12	0.053	0.053	0.055	0.037	0.038	0.059	0.063	0.050	0.051	0.038	0.056	0.050	0.052	0.053	0.039	0.050	0.058	0.038	0.038	0.000	0.000	0.000	0.000	0.000	0.000
C13	0.042	0.042	0.037	0.036	0.060	0.034	0.047	0.048	0.050	0.036	0.044	0.050	0.044	0.034	0.056	0.048	0.036	0.051	0.054	0.000	0.000	0.000	0.000	0.000	0.000
C14	0.062	0.052	0.043	0.061	0.041	0.063	0.053	0.057	0.058	0.069	0.051	0.054	0.053	0.040	0.065	0.056	0.046	0.060	0.039	0.000	0.000	0.000	0.000	0.000	0.000
C15	0.067	0.077	0.041	0.043	0.040	0.042	0.041	0.056	0.048	0.071	0.060	0.053	0.052	0.058	0.039	0.067	0.063	0.073	0.057	0.000	0.000	0.000	0.000	0.000	0.000
C16	0.080	0.059	0.072	0.072	0.075	0.074	0.064	0.065	0.069	0.070	0.060	0.066	0.071	0.068	0.053	0.077	0.073	0.068	0.051	0.000	0.000	0.000	0.000	0.000	0.000
C17	0.062	0.083	0.074	0.074	0.077	0.053	0.065	0.067	0.061	0.067	0.071	0.067	0.066	0.070	0.052	0.065	0.076	0.068	0.071	0.000	0.000	0.000	0.000	0.000	0.000
A1	0.000	0.000	0.242	0.190	0.131	0.290	0.180	0.134	0.113	0.113	0.151	0.137	0.326	0.152	0.234	0.185	0.130	0.162	0.247	0.000	0.000	0.000	0.000	0.000	0.000
A2	0.000	0.000	0.131	0.098	0.424	0.126	0.121	0.135	0.286	0.201	0.141	0.083	0.106	0.250	0.120	0.174	0.163	0.250	0.190	0.000	0.000	0.000	0.000	0.000	0.000
A3	0.000	0.000	0.126	0.195	0.128	0.212	0.201	0.077	0.096	0.155	0.268	0.113	0.120	0.190	0.139	0.201	0.138	0.130	0.140	0.000	0.000	0.000	0.000	0.000	0.000
A4	0.000	0.000	0.217	0.147	0.120	0.065	0.131	0.260	0.201	0.217	0.116	0.210	0.200	0.105	0.203	0.132	0.164	0.217	0.119	0.000	0.000	0.000	0.000	0.000	0.000
A5	0.000	0.000	0.131	0.130	0.124	0.189	0.207	0.238	0.177	0.174	0.117	0.123	0.137	0.201	0.191	0.152	0.186	0.140	0.168	0.000	0.000	0.000	0.000	0.000	0.000
A6	0.000	0.000	0.153	0.240	0.074	0.118	0.161	0.156	0.127	0.141	0.207	0.154	0.110	0.102	0.113	0.155	0.220	0.101	0.136	0.000	0.000	0.000	0.000	0.000	0.000

Landfilling problem

Solid waste disposal site availability continues to be a pressing problem in Metro Manila. With the closure of two disposal sites in Carmona and San Mateo in 1998 and 2000 respectively, Local Government Units in Metro Manila are searching for available disposal sites for their garbage. Presently, all collected wastes in Metro Manila are disposed in controlled dumpsites. As resource recovery, e.g. composting; and final disposal, e.g. landfill are the recognized feasible options for the outbound process of the Metro Manila solid waste, landfill availability would be a priority issue. . However, similar to most developing countries in Asia, household solid waste reaching open dumpsites in the Philippines is high in moisture and organic content, and low in calorific value. These conditions are not favorable to simple landfilling nor energy recovery.

In summary, this study is composed of two research problems; namely: resource recovery and the inadequacy of landfills as a MSW solution; and six solution alternatives, which involve the use of either thermal process technology or resource recovery facilities. The government can opt to construct either of these in three different ways: as self-owned facilities, in a joint venture with a private company, or using a build-operate-transfer process.

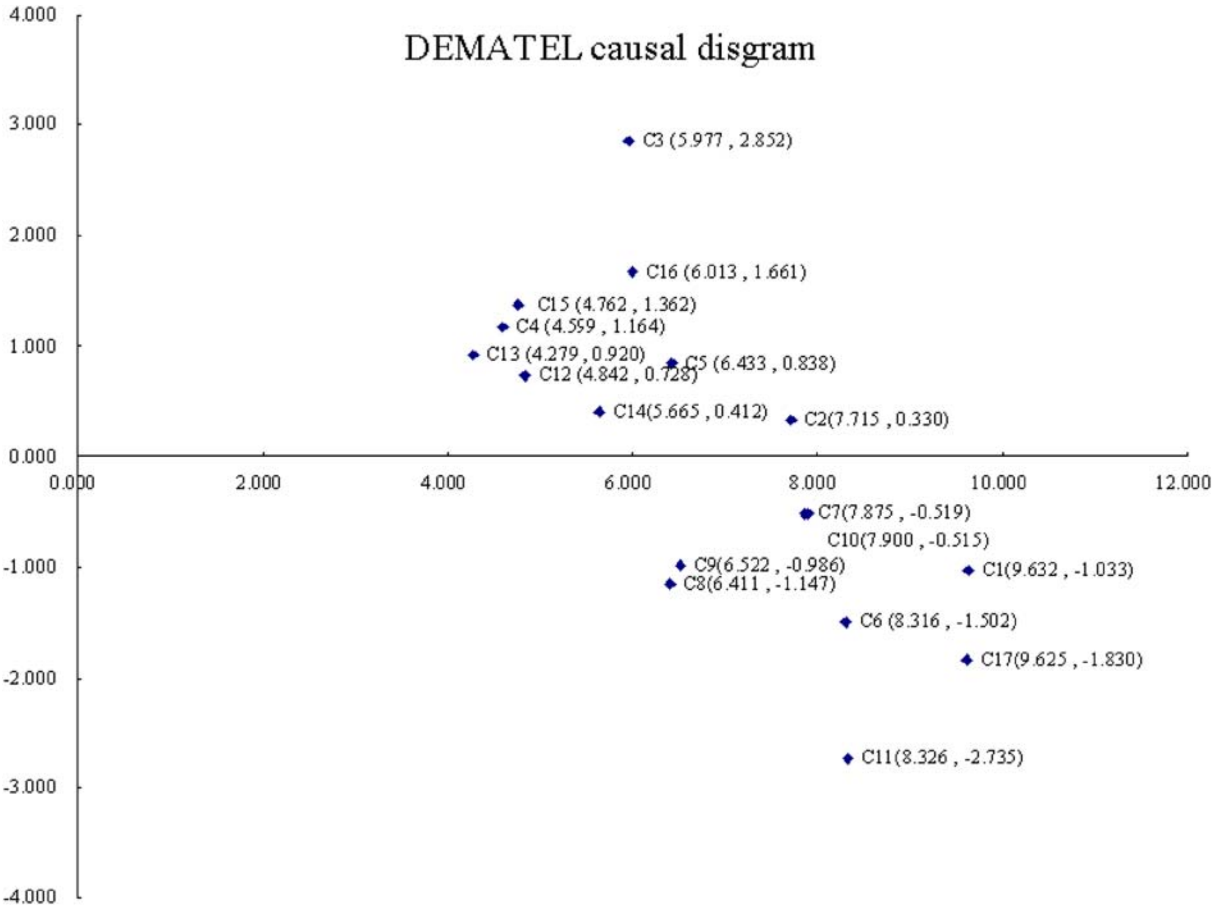


Fig. 3 DEMATEL causal diagram

Table 4 The normalized unweighted supermatrix

	G1	G2	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	A1	A2	A3	A4	A5	A6
G1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.568	0.470	0.430	0.370	0.440	0.570
G2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.432	0.530	0.570	0.630	0.560	0.430
C1	0.068	0.080	0.039	0.039	0.042	0.039	0.035	0.040	0.037	0.028	0.033	0.038	0.039	0.037	0.040	0.035	0.040	0.037	0.039	0.000	0.000	0.000	0.000	0.000	0.000
C2	0.070	0.065	0.037	0.036	0.040	0.037	0.034	0.034	0.035	0.027	0.032	0.034	0.037	0.036	0.038	0.034	0.048	0.036	0.034	0.000	0.000	0.000	0.000	0.000	0.000
C3	0.079	0.084	0.040	0.040	0.031	0.042	0.036	0.038	0.035	0.034	0.036	0.037	0.038	0.046	0.041	0.042	0.041	0.030	0.044	0.000	0.000	0.000	0.000	0.000	0.000
C4	0.055	0.043	0.020	0.020	0.020	0.019	0.026	0.026	0.024	0.029	0.029	0.026	0.026	0.027	0.031	0.025	0.019	0.027	0.028	0.000	0.000	0.000	0.000	0.000	0.000
C5	0.066	0.036	0.036	0.036	0.037	0.025	0.037	0.029	0.033	0.036	0.029	0.029	0.030	0.025	0.027	0.030	0.025	0.032	0.032	0.000	0.000	0.000	0.000	0.000	0.000
C6	0.053	0.083	0.033	0.033	0.024	0.034	0.029	0.030	0.027	0.032	0.028	0.030	0.028	0.025	0.034	0.030	0.035	0.023	0.029	0.000	0.000	0.000	0.000	0.000	0.000
C7	0.059	0.059	0.033	0.025	0.036	0.036	0.032	0.031	0.031	0.034	0.034	0.033	0.031	0.034	0.035	0.031	0.024	0.032	0.033	0.000	0.000	0.000	0.000	0.000	0.000
C8	0.037	0.021	0.027	0.027	0.018	0.032	0.024	0.020	0.023	0.026	0.027	0.020	0.021	0.028	0.018	0.017	0.030	0.018	0.018	0.000	0.000	0.000	0.000	0.000	0.000
C9	0.046	0.052	0.019	0.019	0.020	0.018	0.031	0.024	0.026	0.024	0.023	0.026	0.025	0.027	0.030	0.025	0.018	0.027	0.027	0.000	0.000	0.000	0.000	0.000	0.000
C10	0.062	0.072	0.034	0.035	0.037	0.036	0.025	0.031	0.032	0.032	0.034	0.032	0.033	0.034	0.026	0.032	0.027	0.033	0.031	0.000	0.000	0.000	0.000	0.000	0.000
C11	0.039	0.039	0.020	0.029	0.032	0.019	0.025	0.024	0.027	0.023	0.024	0.025	0.024	0.019	0.029	0.018	0.019	0.027	0.029	0.000	0.000	0.000	0.000	0.000	0.000
C12	0.053	0.053	0.027	0.019	0.019	0.030	0.032	0.025	0.026	0.019	0.028	0.025	0.026	0.026	0.019	0.025	0.029	0.019	0.019	0.000	0.000	0.000	0.000	0.000	0.000
C13	0.042	0.042	0.019	0.018	0.030	0.017	0.024	0.024	0.025	0.018	0.022	0.025	0.022	0.017	0.028	0.024	0.018	0.026	0.027	0.000	0.000	0.000	0.000	0.000	0.000
C14	0.062	0.052	0.021	0.030	0.021	0.032	0.027	0.028	0.029	0.035	0.026	0.027	0.026	0.020	0.033	0.028	0.023	0.030	0.020	0.000	0.000	0.000	0.000	0.000	0.000
C15	0.067	0.077	0.021	0.021	0.020	0.021	0.020	0.028	0.024	0.036	0.030	0.027	0.026	0.029	0.019	0.033	0.031	0.036	0.029	0.000	0.000	0.000	0.000	0.000	0.000
C16	0.080	0.059	0.036	0.036	0.037	0.037	0.032	0.033	0.034	0.035	0.030	0.033	0.035	0.034	0.027	0.038	0.036	0.034	0.026	0.000	0.000	0.000	0.000	0.000	0.000
C17	0.062	0.083	0.037	0.037	0.038	0.027	0.032	0.033	0.030	0.034	0.035	0.034	0.033	0.035	0.026	0.032	0.038	0.034	0.036	0.000	0.000	0.000	0.000	0.000	0.000
A1	0.000	0.000	0.121	0.095	0.065	0.145	0.090	0.067	0.056	0.057	0.076	0.159	0.163	0.076	0.117	0.093	0.065	0.081	0.124	0.000	0.000	0.000	0.000	0.000	0.000
A2	0.000	0.000	0.066	0.049	0.212	0.063	0.061	0.068	0.143	0.100	0.071	0.042	0.053	0.125	0.060	0.087	0.081	0.125	0.095	0.000	0.000	0.000	0.000	0.000	0.000
A3	0.000	0.000	0.063	0.097	0.064	0.106	0.100	0.039	0.048	0.077	0.134	0.056	0.060	0.095	0.070	0.101	0.069	0.065	0.070	0.000	0.000	0.000	0.000	0.000	0.000
A4	0.000	0.000	0.108	0.074	0.060	0.033	0.065	0.130	0.101	0.109	0.058	0.105	0.100	0.053	0.101	0.066	0.082	0.109	0.060	0.000	0.000	0.000	0.000	0.000	0.000
A5	0.000	0.000	0.066	0.065	0.062	0.094	0.104	0.119	0.089	0.087	0.058	0.062	0.069	0.101	0.096	0.076	0.093	0.070	0.084	0.000	0.000	0.000	0.000	0.000	0.000
A6	0.000	0.000	0.077	0.120	0.037	0.059	0.080	0.078	0.063	0.070	0.103	0.077	0.055	0.051	0.056	0.078	0.110	0.050	0.068	0.000	0.000	0.000	0.000	0.000	0.000

Table 5 The limited weighted supermatrix

	G1	G2	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	A1	A2	A3	A4	A5	A6
G1	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119
G2	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131	0.131
C1	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038
C2	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
C3	0.039	0.039	0.039	0.040	0.039	0.040	0.040	0.039	0.040	0.040	0.039	0.040	0.039	0.039	0.040	0.039	0.040	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
C4	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
C5	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
C6	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032
C7	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031
C8	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
C9	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024
C10	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
C11	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022
C12	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
C13	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022
C14	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027	0.027
C15	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031
C16	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
C17	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
A1	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048
A2	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
A3	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038
A4	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042
A5	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
A6	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036

The following section shows how the expert group used the application solution to evaluate and select its MSW management option.

Application of study method

In this section, an empirical study is presented to illustrate the application of the solution for evaluating and selecting a favorable MSW management solution. This study attempts to apply the ANP to the MSW management along with government-favored alternatives. The study objective is to demonstrate how ANP and DEMATEL can be used to determine the best MSW management solution in the Metro Manila.

The expert group followed the application solution with the four-phase procedure (see Fig. 2). First, they defined the decision purposes for selecting a favorable MSW management. In phase 2, after conducting the literature review and a discussion, three evaluation clusters were used to select a favorable MSW management solution. Specifically, the "Purposes" cluster involved two purposes of MSW: MSW management using thermal process technology (G1) and in an established resource recovery facility (G2). The "Criteria" cluster contained the seventeen criteria enumerated in Recovery problem, which were denoted as C1–C17, respectively. The "Alternatives" cluster was comprised of six MSW management solutions: (1) Each city having its own established thermal process technology; (2) Establishing a resource recovery facility; (3) Metro Manila joint venture with enterprises in the established thermal process technology; (4) Metro Manila joint venture with enterprises in established resource recovery facilities; (5) BOT method-established thermal process technology and (6) BOT method-established resource recovery facilities before landfill.

In phase 3, the feedback system model was used (Fig. 1) and then the decision structure (Fig. 2) was shaped for evaluating MSW management, in which looped arcs indicate that inner dependences are to be handled by the DEMATEL.

In phase 4, for obtaining the relative influence between elements, the members of committee were asked to respond through a series of pairwise comparisons. In order to aggregate their assessments, the geometric mean method was used for the ANP, while the arithmetic mean method was used for the DEMATEL. After the aggregation, the direct-relation matrix (Table 1) was obtained, hereby the inner dependence matrix (Table 2) was acquired by using the DEMATEL, and the unweighted supermatrix was formed as shown in Table 3. Additionally, based on the direct-relation matrix (Table 1), the causal diagram in terms of the "Criteria" cluster can be acquired as shown in Fig. 3. By mapping a dataset of (D+R, D-R), it is clear that evaluation factors are visually divided into the cause group, including C1, C2, C3, C4, C5, C12, C13, C14, C15, C16 while the effect group is composed of such factors as C1, C6, C7, C8, C9, C10, C11, C17.

The calculations of the supermatrix can be solved by using Microsoft Excel. The normalization process must first be done, as shown in Table 4, before obtaining the overall weights from the limit supermatrix (see Table 5): WG = (G1,G2) = (0.119, 0.131),WC = (C1,C2,C3,C4,C5,C6,C7,C8, C9,C10,C11,C12C13,C14,C15,C16,C17) = (0.038, 0.035, 0.039, 0.024, 0.028, 0.032, 0.031, 0.019, 0.024, 0.033, 0.022, 0.025, 0.022, 0.027, 0.031, 0.034, 0.035), WA = (A1,A2,A3, A4,A5,A6) = (0.048, 0.045, 0.038, 0.042, 0.040, 0.036). Therefore, the most considered purpose was G2 (MSW management solution using established resource recovery facilities) due to the highest priority of 0.131; the most important criterion was C3 (Human health) due to the highest priority of 0.039; and the desired alternative is Solution A2 (established thermal process technology for each city) due to the highest priority of 0.048.

Discussion

An MSW management solution needs to be unique and based on capitalizing strengths and mitigating weaknesses. It cannot be said for certain what type of MSW management solution is the best, since the selection of a certain solution depends on the differences of purposes, the condition of resources and capabilities, and the existing organizational cultures. In this sense, selecting a MSW management solution is a MCDM problem. Although there is no standard answer to what

MSW management solution is right, this study can make the solution selection process more systematic.

Many works related to MSW provided valuable advice, including essential factors for a successful MSW management (Su et al. 2007; Vego et al. 2007; Khan and Faisal 2008). However, few works provided methods which can empirically evaluate and model the MSW management involved with several complex criteria systematically for Metro Manila. Hence, this paper proposes an effective solution that can resolve the problem of MSW management selection in an analytical manner. As a test case, the expert group used the proposed solution in the selection process and obtained a unique MSW management alternative. In order to assess the selected MSW management tool and the effectiveness of the proposed solution, this paper conducted a post-survey discussion with the MSW expert group. The discussion results are summarized as follows.

First, it is a common understanding that MSW purposes often emphasize the expectation of improving performance. However, the expert group chose thermal process technology (G1) to be the most considered purpose rather than the established resource recovery facility before landfill (G2). This is because accomplishing thermal process technology is easier to achieve because it involves many other complicated factors which are not MSW related efforts. This means that thermal process technology or resource recovery facilities may be part of a successful MSW implementation, but still needs other parties' efforts in formulating successful MSW strategies and employing effective management tools and government regulations.

Secondly, the expert group chose C3 (Human health) to be the most important criterion from among a set of criteria. This choice is sensible because human health is important in many kinds of government activities, which should aim primarily to take good care of their citizens.

Thirdly, although many works on MSW suggest that a sound MSW management should be a hybrid one which should integrate thermal process technology and resource recovery facilities, the expert group chose an established thermal process technology for each city (A1) as the ideal form of MSW management rather than a resource recovery facility (A2). According to the expert group, a MSW management which can in practice "utilize a mix of both" will be the most favorable solution due to reasons stated in the Banning Incinerators Act concerning problems in resources recycling, namely toxic flying ash and hazardous technology (Chiu 2006).

Additionally, the expert group remarked on the merits and drawbacks of the proposed solution. Unlike a traditional hierarchical model based on the linear and piecemeal approach, the Modified Feedback System model is novel since it is based on a complex interrelationship and interwining among criteria. Moreover, it is favorable to use the DEMATEL to handle the problem of inner dependences, since it can provide more valuable information for decision-making. For example, from the causal diagram it can be directly and visibly seen that the most important criterion is C3 (human health) and the least important criterion is social acceptability (C8).

Some implications can be derived from this study, one of which is that a more analytical and methodical MCDM method is required in order to make solid decisions regarding MSW management and policies

Conclusions

As knowledge takes on an important strategic role, governments expect that their MSW management be performed effectively in order to enhance its environmental, economical, and social management into national competitive advantages. Successful MSW management starts with a proper MSW management solution that is chosen through a robust evaluation method. This selection process can be classified as an MCDM problem, which requires the consideration of a large number of complex factors as multiple evaluation criteria.

Since it is an MCDM problem, it is better to employ MCDM methods for reaching an effective solution. The ANP is a relatively new MCDM method which can deal with many interactions systematically, unlike traditional MCDM methods which are based on the independence assumption.

Moreover, the DEMATEL can be used not only as a way to handle the inner dependences within a set of criteria, but also as a way of producing more valuable information for decision-making. Hence, this paper proposes a solution based on a combined ANP and the DEMATEL in MCDM are introduced in previous section, future insight of integration about MCDM methods to provide a robust procedure can be described. This approach helps the decision-making team to have a proper solution in MSW management.

The results of this study show that the most desired solution was the establishing of thermal process technology for each city (A1) and a resource recovery facility (A2). Because the proposed solution can handle the effects of dependences, it is relatively useful and makes the evaluation results reasonable. Additionally, this study has contributed to extending practical applications of both ANP and the DEMATEL in the MSW field. Furthermore, it was found that the suggested analytical procedure, can effectively handle problem of selection with multi-faceted factors. However, there are some limitations, such as the non-unification of the assessment scales of the ANP and the DEMATEL. Therefore, in order to promote and deepen continuing research in future, it is worthwhile to investigate more cases and exemplary thermal process technologies or resource recovery facilities in order to uncover invaluable new issues to be studied further. Additionally, the assessment criteria can be improved as different status suffered.

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