Application of Cost- Benefit Analysis and Data Envelopment Analysis to Evaluate the Municipal Solid Waste Management Projects in Metro Manila

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Abstract: - Based on consultations with a municipal solid waste management (MSW) expert group, this study elucidates how governmental officials can solve the problems surrounding municipal solid waste management in Metropolitan-Manila. A crucial related issue is how the expert group can better evaluate MSW solutions and select favorable ones better evaluate and select a favorable MSW solution using a series of criteria. MSW solution selection is a multi-criteria decision-making problem, which requires considering numerous complex criteria. The study applies cost-benefit analysis (CBA) and data envelopment analysis (DEA) to determine the benefits and cost / input and output technical efficiency of alternative projects, which affords financial data information that evaluators can use for economic decision-making regarding MSW projects. Results of this study suggest that the thermal process technology is less efficient than resource recovery using DEA. Nevertheless, the net benefits of resource recovery exceed those of the thermal process technology by CBA.

Keywords: municipal solid waste management, cost-benefit analysis; data envelopment analysis

1. Introduction

Recently industrialized counties in Asia, which are undergoing rapid economic growth are increasing their perceptions of the importance of MSW for mitigating environmental pollution. Metropolitan Manila is considered the gateway of the Philippines' to the world, serving as the major commercial, financial and educational center in the country, as well as the seat of the national government and the location of the major administrative offices. Metropolitan Manila is geographically defined as comprising 14 cities and three municipalities, including 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.

Besides being the heart of the Philippine economy, Manila is also the most polluted region in the Philippines and even one of the most polluted in the world. The success of businesses and industries in Manila, along with the behavior and lifestyle of its millions of residents, significantly threaten the quality of the local environment and the integrity of its natural resources. The region currently faces a huge pollution problem involving MSW. Air quality is dismal and deteriorating. Water resources are being over-exploited with heavy pollution of surface water resources and rapid depletion of underground freshwater sources. MSW has also been a continuous problem, and arises from poor discipline among residents, resulting in the indiscriminate disposal of unsorted waste, and a lack of efficient and sustainable disposal facilities [18].

However, improper solid waste management (SWM) causes various types of pollution, including air, soil and water pollution. Indiscriminate waste dumping contaminates surface and ground water supplies. In urban areas, solid waste clogs drains, creating stagnant water that promotes insect breeding and flooding during rainy season. Uncontrolled burning of waste and improper incineration contributes considerably to urban air pollution. Greenhouse gases are generated by the decomposition of organic waste in landfills, and untreated leach-ate pollutes surrounding soil and water bodies [30]. The lack of a good MSW system causes pollution and environmental damage, which decreasing the quality of food, water and soil and causing numerous diseases [26].

More importantly, effective SWM generally begins with a proper MSW. Consequently, to successfully implement MSW, it is crucial to determine how best to evaluate and select a favorable MSW based on resource recovery facilities before go to landfill and thermal process technologies. However, the MSW evaluation generally involves subjective and qualitative judgments. Particularly, MSW project selection is a strategic issue [16, 27], and is restricted by resource needs, realistic support, time requirements, conformity with expected outcomes and so on. In this sense, the treatment of MSW project selection must handle several complex decision factors in a sensible and logical manner. MSW always neglects to identify cost and benefit analysis to resolve problems related to policy decision-making. Lack of appropriate economic valuation of alternative projects is dangerous, and leads to incorrect decisions regarding SWM options.

To solve this problem, the measurement of the monetary value of benefits and costs can be translated into the total net benefit or net present value (NPV) of a project. If the CBA results exhibited a positive NPV, the work displays a proper result of decision-making. This paper compares MSW project with NPV and choices the higher one. CBA has turned out to be a useful economic tool since it is applicable in a wide range of circumstances and can be compared to different MSW project in the same measurement units. CBA can be also used for both project and policy valuation. CBA stresses the economic value of environmental protection, and the associated opportunity cost. CBA sounds similar to the discounted cash flow (DCF) or NPV, and values the relevant impact factors based on costs and benefits. Numerous experts argue that CBA should never be the sole guide in decision-making, but rather than serve as one input in decision-making**.** Hanely and Spash [9] agued that CBA represents a useful contribution to the decision-making process rather than a sufficient stand-alone criterion. Besides the CBA method, this study also uses DEA to analyze MSW projects, which estimate input- or output-oriented technical efficiency.

The strength of DEA is the frontier technology consisting of MSW input and output sets enveloping the data points with linear facets for calculating performation efficiencies in different projects. The main advantages of DEA that make it suitable for measuring the efficiency of alternative projects include: (1) it enables analysis of multiple outputs inputs simultaneously. (2) efficiency is calculated relative to the highest observed performance rather than average. (3) it does not require price information and requires minimal data. The DEA method is the first method used to measure MSW projects. Since CBA and DEA possess these advantages, this study applies an effective solution based on these two approaches to assist Metropolitan Manila to select a favorable MSW project. Additionally, this study illustrates the application both CBA and DEA for decision-making by a group of experts. The remainder of this work is organized as follows. Section 2 presents a literature review. Section 3 presents evaluation methods. Section 4 then illustrates a relevant study. Finally, Section 5 presents conclusions and suggests future research directions.

2. Literature review

The section identifies the theoretical composition of MSW considered in this study. The term MSW is used to explain the technology and the criteria of waste management. Researchers have described MSW from a strategic, decision-making perspective in an effort to improve performance. In addition, to analyze MSW projects from a costs and benefits perspective, and measure input and output data for economic efficiency.

After the 1990s, as MSW policies became more complicated, the factors requiring consideration also increased, and thus, several MSW models that conducted deeper analysis emerged. Hokkanen and Salminen [11] applied the decision making method ELECTRE to the problem of choosing an MSW system in Finland, based on consideration of eight criteria: cost per ton, technical reliability, global effects, local and regional health effects, acidic emissions, surface water dispersed releases pollution, number of employees, and amount of recovered waste. Twenty-two alternatives are examined under either decentralized or centralized management systems, with various treatment methods, including composting, RDF-combustion, and landfill.

Recently, MSW models have emphasized

‘‘sustainability,’’ and comprise two categories. One model category addresses social factors involved in the decision making methods [3, 5, 10], whereas the other incorporates public participation into decision making [2, 24]. The factors considered in the MSW model are mainly economic (such as, system cost and system benefit), environmental (air emissions, water pollution) and technological (technology maturity). Wilson et al. [29], who interviewed 11 different leading edge European MSW programs in nine countries, proposed that “including different public groups from 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 [17] proposed that a sustainable MSW model should be not only environmentally effective and economically affordable but also socially acceptable. Karagiannidis and Moussiopoulos [15] proposed a set of multiple criteria, including social, environmental, financial, and technical aspects, for optimizing regional SWM. Su, et al. [25] examined numerous modern decision making support systems that already partially consider social factor analysis besides expenses and benefits, environmental effects, technical issues, and management aspects, in a study of the main MSW policies of Taiwan during the past 10 years and found considerable uncertainty associated with policy implementation, even after considering the effects of factors related to environmental, economic, social, technological, and management dimensions. Hung, et al. [5] reviewed several models for supporting decision making in MSW. The concepts underlying sustainable MSW models comprise two categories: the first category incorporates social factors into decision-making methods, while the other category incorporates public participation in decision-making. The impacts of economics or finance including expenses and benefits for alternative project should be considered in each MSW program. Solid wastes comprise consumption and production residuals and are driven by price and income economic variables, meaning SWM is an important economic problem. The economic system for achieving of a cost-effective balance requires a careful use of market and price mechanisms to obtain waste management objectives, and all production and consumption decisions are crucially involved in SWM policy [8].

Kalbermattern et al. [14] demonstrated that CBA should be used to rank alternatives and quantify individual options in terms of monetary units. CBA is becoming increasing popular for valuing policy and investment in the UK [21]. Tin et al. [26] use CBA as a basis for comparing different options related to MSW projects, and employed an economic costing procedure to identify the least costly option. A careful quantitative estimation of the SWM problem becomes relatively more important to decision makers than qualitative valuation, and the empirical results of CBA can afford a breadth in detail [8].

DEA is the non-parameter mathematical programming approach to frontier estimation. Since Charnes et al. [4] applied it to measure the efficiency of individual decision-making units, numerous studies have extended and applied the DEA methodology. Furthermore, Fare et al.[7] specified an out-based Malmquist productivity change index for measuring productivity change, and decomposing into technical change and technical efficiency change. Odeck [19] employed the Malmquist productivity change index to analyze efficiency and productivity growth for Norwegian Motor Vehicle Inspection Agencies, and found that total productivity had progress during 1989-1991, but that individual productivity had reduced during 1990-1991. These figures indicated that decision makers should be able to identify possible reasons for inefficiency and reduced productivity just within one unit. Sena [23] also employed Malmquist productivity change index computed with DEA to measure total productivity and spillover effects for the Italian chemical industry. Malmquist index and DEA have not been used in MSW.

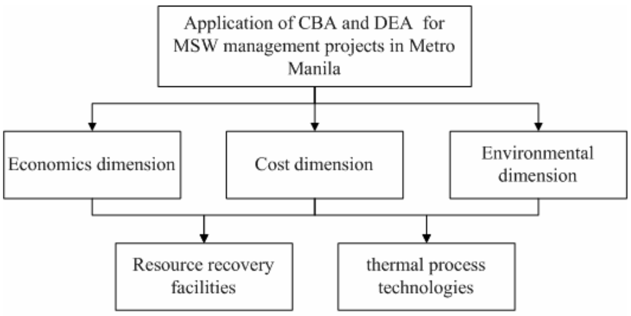

Figure 1. Operational decision framework

The preliminary literature reviewed illustrates the fact that economic, social and environmental dimensions are critical to successful MSW. This study tries to identify the trends in productivity index and CBA for the Philippines. However, the literature lacks evaluation measurements that combine CBA and DEA. MSW contains no studies presenting such measurements. Accordingly, this study extrapolates prior results from MSW studies in the new context of Metropolitan Manila to conduct measurements of resource recovery facilities or thermal process technologies, as shown in the operational framework in Fig. 1

3. Research method

The research method including CBA and DEA will be introduced into complex evaluation systems. A complex evaluation environment can be divided into subsystems to facilitate the assessment of differences and the determination of measurement scores (Fig. 1). Currently, two proposals exist regarding the use of thermal process technologies and resource recovery facilities before landfill process in the country. Valuing costs and benefits of the MSW projects include thermal process technologies and resource recovery facilities in the Philippines are necessary. The efficiency measurement is also critically important. The following paragraphs detail the methods applied in this study.

3.1 The CBA method

The essential theoretical foundations of CBA are: benefits and costs. The benefit is defined as increases in human wellbeing (utility) while cost is defined as reductions in human well-being [20]. CBA is conducted by accounting for the benefits and costs of both alternatives and comparing them to determine which have the greatest net benefit. In this case, the decision maker will have a better basis for final alternative selection.

The CBA methodology involves identifying total benefits and costs. The net benefit, which indicates the improvement, is measured by subtracting total costs from total benefits. In comparing two options, the net benefits are compared to determine which is better. The net benefits are compared between thermal process technologies and resource recovery facilities before landfill process, which evaluate for economic feasibility. From the literature review, the CBA evaluation items are identified as comprising three dimensions, economic, social, and environmental. The total benefits represent the advantages of resource recovery facilities before landfill and thermal process technology, which include the direct and indirect benefits. The total benefits and costs can be expressed in Eqs. (1) and (2) as follows:

$$TB = B_{economic} + B_{social} + B_{environmental} \quad (1)$$

$$TC = C_{economic} + C_{social} + C_{environmental} \quad (2)$$

Where the TB denotes the total project benefits, $B_{economic}$ resprents economic benefits, B_{social} is social benefits and $B_{environmental}$ denotes environmental benefits. TC represents the total cost of using resource recovery facilities before landfill and incineration technology, $C_{economic}$ is economic costs, C_{social} denotes social costs and $C_{environmental}$ represents environmental costs. Net benefit can be expressed by Eq. (3)

$$NB = TB - TC \quad (3)$$

The net benefit can be expressed as net present value, calculated as the current value of future cost and income streams. The NPV test discounts future project CBA as follows:

$$NPV = \sum TB_t (1+i)^{-t} - \sum TC_t (1+i)^{-t} \quad (4)$$

3.2 The DEA method

This study analyzed productivity growth from costs and benefits efficiency of resource recovery facilities before landfill and thermal process technologies, which is measured using Malmquist indices, expressed in distance functions. The productivity change can be decomposed into technical change and technical efficiency change. This study uses the DEA method to estimate Farrell input-oriented technical efficiency. The frontier technology takes benefits as inputs and costs as output sets that envelop the data points with linear facets. For treating multiple inputs and outputs, the problem can be solved using DEA-like linear programs (LP). The input saving can be solved by the following LP problem for each attribute:

$$\underset{i,j,k}{Min} \quad S_k \quad (5)$$

s.t.

$$y_{rk} \le \sum_{j=1}^{n} \lambda_{kj} y_{rj}, \quad r = 1,....,s \quad (6)$$

$$S_k x_{ik} \ge \sum_{j=1}^{n} \lambda_{kj} x_{ij}, \quad i = 1,....,m \quad (7)$$

where $\sum_{j=1}^{n} \lambda_{kj} = 1$, $\lambda_{kj} \ge 0$, $j = 1,....,n$, S_k denotes the input benefit efficiency measure for unit *k* among *n* units, y_{rk} represents the output of unit *r* for unit *k*, x_{ik} is the input of unit *i* for unit *k*, λ_{kj} denotes the weight of the outputs and inputs of unit *j* that define the reference point of unit *k*, and λ_k is a vector including the non negative weights, λ_{kj} resolves the reference point.

A project involves a production possibility set and the transformation of input x^t into output y^t, which does not always operate on the best frontier, but can be located in the production possibility set. The productivity comprises two parts. One movement of the frontier is results from changes in the technological capabilities of the project, while other movements result from reducing internal inefficiency. Productivity change is measured via Malmquist index, which is expressed as follows [23].

$$M = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t}(x^{t}, y^{t})} \times \left[\frac{D_o^{t}(x^{t+1}, y^{t+1})}{D_o^{t+1}(x^{t+1}, y^{t+1})} \frac{D_o^{t}(x^{t}, y^{t})}{D_o^{t+1}(x^{t}, y^{t})} \right]^{1/2} \quad (8)$$

where $D_0^t(x^t, y^t)$, $D_0^{t+1}(x^{t+1}, y^{t+1})$ are output distance functions at time *t* and *t*+1. $D_0^t(x^{t+1}, y^{t+1})$ is the output function measuring the maximum proportional change and make the pair observed (x^{t+1}, y^{t+1}) at time *t*+1, feasible the technology of period *t*. $D_0^{t+1}(x^t, y^t)$ is the output function measuring the maximum proportional change observed input-output pair observed (x^t, y^t) at time *t*, feasible the technology of period *t*+1. If Malmquist index exceeding 1 denotes a trend increase in productivity. This study attempts to examine the productivity of different benefits and costs, and identifies trends in productivity growth. The project can make improvement in technical efficiency by providing productivity information.

4. Metropolitan Manila Study Results

The Philippines, through the Clean Air Act of 1999 [6], banned the use of incinerators for waste disposal with the aim of preventing health and environmental damage. The costly and ineffective management of MSW in the Philippines, which is based purely on traditional solutions (landfill), is a significant source of pollutant emissions. Effective MSW management has potential to both generate employment and reduce pollution. Presently, SWM is a serious problem in Metropolitan Manila. This study aims to estimate MSW option resource recovery facilities before making landfill and thermal process technologies into the evaluation of different criteria of CBA and DEA for optimization of MSW projects in Metropolitan Manila. This study measures the benefits and costs of MSW projects during the period 2000 to 2005.

The population growth of Metropolitan Manila over the past three decades is generally declining compared to the country as a whole. This phenomenon is said to result from the lower number of individuals per household among MSW projects in the region, given that urban women have fewer children than their rural counterparts. Owing to the migration of families in Metropolitan Manila and the adjacent regions housing price is low in the suburbs, results a congestion in the metropolitan area. The occurrence of this migration is evident in increased in population and economic activities in regions adjacent to Metropolitan Manila that produces more solid waste by volume than any other region of the Philippines, and account for 23% of national waste generation. Total population was estimated for a trend of 10% growth, which is reported by MMDA (Metropolitan Manila Development Authority) [1], representing additional daytime population within Metropolitan Manila. Waste generation was estimated at 0.56 kg/capita/day by the Metropolitan Manila MSW Master plan [13]. Table 1 list the population and waste generation of Metropolitan Manila.

4.1 Research problem

A small portion of 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 [30]. Although the recycling sector is achieving numerous improvements, considerable room exists for further improvement. In fact, recycling rates in Metro Manila are increasing rapidly. In 1997, the recycling rate for Metropolitan Manila based on reports from junkshop dealers was just 6%, growing 13% in 2000 and 25% in 2003 due to the efforts of the Metropolitan Manila Development Authority (MMDA) and NGOs to promote segregation at source, composting, and recycling. An appropriate method of resource recycling, which fits CBA and productivity efficiency must be identified in terms of environmental, economic, and social influence on decision-making.

To summarize, this study is focuses on two research problems, including resource recovery facilities and the inadequacy of landfills (Recommended by the group of experts: Thermal process technology due to Clean Air Act 1999 banned on Incinerator) as MSW solutions that involve either thermal process technology or resource recovery facilities. The following section demonstrates how the expert group used application solution for evaluating and selecting MSW management options.

4.2 Waste recycling

This study examined the actual practice in SWM used for Metropolitan Manila. The analysis comprises the traditional dumpsites used to accommodate the 6,795 to 6,472 tons of wastes generated daily from 2000 to 2005. The initial and capital costs are the costs incurred in establishing a resource recovery facility before implementing the landfill and thermal process technologies, including calculating the necessary permits and fees, as detailed in this section. According to Walker et al. [28], landfill capital and operating costs are estimated at US$ 48.6 million for waste generation of 2.757 tons daily. Additionally, in Metropolitan Manila, the recycling stream has a significant role in many communities. Market support for recyclable goods is strong and growing. Owing to the increasing amount of recyclable wastes being disposed of the improving economy and the lifestyle patterns of Metropolitan Manila residents. The Metropolitan Manila Linis-Ganda Network, the most successful recycling and composting initiative in Metropolitan Manila, reports that their activities are continuously increasing. The recycling factories were able to collect 101,850 metric tons of recyclable waste with a value of US$2,524,390 in 2000, increasing to 220,529.7 metric tons with a value of US$5,349,434 in 2005. For the post-strategy scenario, formula used to calculate the capital, operational cost and waste recycle value is shown in Table 2. The bottom row of Table 2 lists the total NPV that discounted by using Philippine average bank lending rate of 10 % in 2005.

Table 1 Population, Waste Generation of Metro Manila

Year	Population	Estimated Population	Waste Generation (Kg)
2000	11,030,486	12,133,535	6,794,779
2001	10,923,490	12,015,840	6,728,870
2002	10,817,533	11,899,286	6,663,600
2003	10,712,603	11,783,868	6,598,963
2004	10,608,690	11,669,559	6,534,953
2005	10,505,786	11,556,365	6,471,564

Table 2 Capital, operational costs and waste recycle value of resource recovery facilities

Year	Capital and operational costs (US$)	Recycle collected (Metric tons)	Waste recycle value (US$)
2000	116,697,487	101,850	1,567,394

	(187,948,924)		(2,524,390)
2001	127,123,941	120,162	2,044,944
	(186,125,829)		(2,994,061)
2002	138,479,924	182.051	3,314,478
	(184,320,410)		(4,411,657)
2003	150,844,858	209,770	4,213,869
	(182,532,500)		(5,099,067)
2004	164,330,673	224,745	4,941,800
	(180,761,933)		(5,435,926)
2005	179,008,543	220,530	5,349,434
	(179,008,543)		(5,349,434)
Total NP	876,485,426		21,431,919

Table 3 The NPV of thermal process technology costs

Year	Economic costs			Social cost	Environmental cost
	Capital cost	Maintenance cost	Insurance and sundries	Human health damage	Emission cost
2000	861,424	172,285	60,300	5,091,069	87,272
	(1,387,380)	(277,476)	(97,117)	(8,199,488)	(140,557)
2001		189,516	66,330	5,545,936	95,069
		(277,476)	(97,117)	(8,119,965)	(139,193)
2002		208,468	72,964	6,041,354	103,569
		(277,476)	(97,117)	(8,041,201)	(137,843)
2003		229,306	80,257	6,580,790	112,809
		(277,476)	(97,117)	(7,963,201)	(136,506)
2004		252,253	88,289	7,169,125	122894
		(277,476)	(97,117)	(7,885,958)	(135,182)
2005		277,476	97,117	7,809,465	133,871
		(277,476)	(97,117)	(7,809,465)	(133,871)
Total NP	861,424	1,329,304	368,140	37,517,739	655,476

*The number in parenthesis is original before calculated to net present value.

4.3 Thermal process technology

The post-strategy scenario used in this study is a hypothetical thermal process technology. Rufo [22] compared two thermal process technologies in terms of their CBA. This study revealed that Modular Starved-Air thermal process technologies have the lowest cost and greatest benefits in terms of reducing negative health impacts. The total costs and benefits are divided into economic, social and environmental dimensions. Tables 3 and Table 4 list NPV, calculate based on the discount rate from using the 10% average Philippine bank lending rate during 2005.

4.3.1 Economic costs

The capital cost for the Modular Starved-Air thermal process technologies was around US$ 1,387,380 in 2000. Moreover, the operating costs of thermal process technologies include vehicle maintenance cost, totaling 20% of the purchase price annually, insurance and sundries cost 7% of the purchase price per year. Since this study finds that both options create the same number of jobs, they cancel the cost of lost jobs arising from selecting the alternative option. Consequently, the costs and benefits in terms of labor are not considered.

4.3.2 Social costs

Human health damage is the social cost in terms of negative human health impacts arising from the inhalation of dioxin emissions from thermal process technologies. Rufo [22] valued health damage using an air dispersion model to determine the number of people at risk exposure to airborne dioxin. Dioxins can result from various formation mechanisms, depending on design, combustion conditions, solid waste feed characteristics (namely the way solid waste is introduced to the burning chamber – by gravity or ram), and the type and operation of air pollution control device (APCD) equipment [22]. The total health damage amounted to US$ 6.45 million for daily waste generation of 5,345 tons.

4.3.3 Environmental costs

The environmental cost of thermal process technology includes total carbon dioxide emissions from the combustor of the thermal process technology plant. These carbon dioxide emissions are converted into monetary values based on the estimates used by Walker et al. [28]. Thermal process technologies comprise a significant source of carbon dioxide, producing approximately 1 ton of CO_2 per ton of municipal waste handled, and where each tons of CO_2 is valued at cost of US$20.686.

4.3.4 Economic benefits

Total benefits are also calculated based on three sub-groups, economic, social and environmental. The economic benefits included in the CBA contain energy savings from the use of recycled materials and the additional tourism potential during the planning up to the commissioning of the thermal process technologies. During the commissioning and training for the incineration plant that expected to attract foreign visitors. The use of recycled materials from pre-thermal process technology activities such as waste sorting generates considerable energy savings. The energy savings from use of recycled materials, which computed by using 28.4% recyclables [1], typical energy value of 3,100 Btu/lb for MM municipal waste and 292.65 kWh/MMBtu of power for the conversion, for an electricity rate of approximately P5/kWh, [22].

Additional tourism benefits is valued based on assumptions of the average number of foreign visitors expected during the commissioning of the incineration plant (CPI Atlantic) and associated training namely 200, for average price of PhP12 and 636 tourists daily. An average business trip of four days was used based on the estimates of GPI Atlantic. Tourism impacts include transportation, accommodations, restaurants, shopping, and entertainment. The economic benefit can be transformed into US$ using the average exchange rate applying during the year in question.

4.3.5 Social benefit

Social benefits include the avoidance of liability costs associated with establishing resource recovery facilities for landfill. The construction of a resource recovery facility site creates a nuisance and hazard for nearby communities. The risks of groundwater contamination not only affect the environment but also the community. In the case of groundwater contamination, the developer of the resource recovery facility site should compensate nearby households for the associated nuisance, including loss of water supply and other issues. Following Walker et al. [28] an approximate cost of US$4/ton is used for avoided liability cost.

The location cost for a resource recovery facility depends on many factors, including real estate values, environmental assessment costs, and government costs related to public consultation. Additionally, the process is frequently time-consuming, labor intensive, and politically explosive. Residents typically vigorously oppose landfill developments close to their own community fears of contamination, odors, and reduced property values [28], which generate the landfill location benefits at price of US$0.55 per ton annually.

4.3.6 Environmental benefit

Recycling also has limitations. There will always be some materials entering the waste stream that cannot be recycled, simply because these have lost all usefulness and they cannot be converted back to raw materials. Furthermore, certain materials should not be recycled, particularly toxic and hazardous waste (THW). Moreover, recycling activities also have significant financial implications and may cause pollution. For example, paper recycling factories may discharge effluent that can harm rivers and waterways if not properly operated or monitored. These economic and technological limitations comprise a continuing challenge for the development of the recycling industry. However, it is important to consider that programs should always maximize the potential of recycling. Limitations only occur once the sector has been fully established and is efficiently operating. Thermal process technology can reduce emissions of CO2 and enhance environmental sustainability.

The environmental benefits of reduced GHG (Greenhouse Gas) emissions are incorporated into the calculation of environmental benefits, which can be traced from the avoidance methane emissions in the resource recovery facility sites. GHG emissions reduction calculates methane emissions from landfill sites as being 105.79 giga-grams of CH_4, and transformed the methane into carbon multiplied 21 times. Finally, a value of US$20.686 per ton was assigned to CO2.

Table 4 The benefits and total NPV of thermal process technologies

Year	Economic benefits		Social benefit		Environmental benefit
	Energy savings	Tourism benefit	Avoided liability cost	Avoided location cost	GHG emission reduction
2000	27,057	142,029	16,876	2,320	28,534

	(43,576)	(228,746)	(27,179)	(3,737)	(45,956)
2001	25,543	135,398	18,383	2,528	31,388
	(37,399)	(198,241)	(26,915)	(3,701)	(45,956)
2002	27,495	147,173	20,025	2,753	34,527
	(36,597)	(195,892)	(26,654)	(3,665)	(45,956)
2003	28,514	154,121	21,814	2,999	37,978
	(34,504)	(186,498)	(26,396)	(3,629)	(45,956)
2004	30,045	163,988	23,764	3,268	41,779
	(33,050)	(180,385)	(26,140)	(3,594)	(45,956)
2005	33,296	183,513	25,886	3,559	45,956
	(33,296)	(183,513)	(25,886)	(3,559)	(45,956)
Total NP	171,951	926,224	126,748	17,428	220,161

*The number in parenthesis is original before calculated to net present value.

4.4 CBA results

The Clean Air Act was passed in 1999, banning the use of thermal process technologies in waste management with aim of preventing health and environmental damage. However, solid waste management appears to be a serious local problem in Metropolitan Manila. This study investigates the costs and benefits data to test the alternative projects of MSW problems in Metropolitan Manila from 2000 to 2005. CBA is performed to assess the benefits and costs of alternative projects, and to perform comparisons. In this case, decision makers can select the optimum alternative based on detailed analytical information.

Table 2 lists the NPV of resource recovery facility benefits and costs, which were US$21,431,919, and US$876,485,426, respectively. Moreover, the net benefit calculated from Eq. (3) is -855,053,507. Both the costs and benefits associated with the NPV of thermal process technology contain economic, social, and environmental three dimensions. The costs of net present value list in Table 3 illustrate that economic costs include capital costs of US$ 861,424, maintenance costs of US$1,329,304, and insurance and sundries of US$368,140, with the total economic costs being US$2,558,868, the total social costs being US$37,517,739, and the total environmental costs being US$655,476, representing overall total costs of US$40,732,083. The economic benefits include energy savings of US$171,951, tourism benefit US$926,224, and economic benefits of US □ 1,098,175, additionally, total social benefits were US$144,176, containing avoided liability costs of US$126,748, avoided location costs of US$17,428, and environmental benefits of US$220,161, the total benefits thus were US$1,462,512. The net benefit calculated from Eq. (3) is -39,269,571. The results of CBA for the waste management options of a landfill site and a thermal process technology site in Metropolitan Manila demonstrate that both projects had negative net benefits in terms of NPV, as listed in Table 5. The thermal process technology option achieves savings of US$815,783,936 compared with resource recovery.

However, based on the use of thermal process technology, there is a net savings of almost US$81.6 million. Owing to the incineration ban, it is necessary to enhance the current practice of MSW program. This study thus recommends further development of an enhanced resource recovery facility program capable of translating recyclable wastes into monetary values and the streamlining of the SWM system for providing as additional benefits for the current SWM scenario in Metropolitan Manila. Additionally, this study ignores the intangible values of environmental externalities, including the use value of environmental amenities, and the option value of the expected value for future use; non-use value of bequest value indicates where users and non-users may derive utility from the expected enjoyment of environmental resources by future generations, and existence value is the value people receive from knowing that a particular environmental resource exists. For omitting the environmental intangible value, the project benefits will be underestimated.

To adapt the analytical context to the demand for sustainability, the CBA can be developing new tools for the valuation use value and non-use value of environmental externalities. The non-market good valuation method can be divided into two categories, namely the revealed and stated preference approaches. Revealed preference methods based on market behaviors include calculations based on market price or consumer surplus, travel cost and hedonic price analysis. Stated preference methods include contingent valuation and choice experiment. The CBA includes an intangible non-market effect that captures the total economic value of environmental resource, increasing the precision of total benefits estimates regarding alternative projects.

Table 5 presents the net benefits of thermal process technologies and resource recovery facilities

Costs and benefits	Thermal process technologies	Resource recovery facilities
Economics costs	2,558,868	
Social costs	37,517,739	
Environmental costs	655,476	
Total Costs	40,732,083	876,485,426
Economics benefits	1,098,175	
Social benefits	144,176	
Environmental benefits	220,161	
Total benefits	1,462,512	21,431,919
Net benefit	-39,269,571	-855,053,507

4.5 DEA results

Traditional CBA analysis lacks sufficient data on benefits and costs at total economic value concept, which are crucial criterions for decision-making. This study adopts DEA to overcome this problem and provide more information to management agencies, and uses the Malmquist index to assess the changes in total factor productivity (TFP) affecting the performance of alternative SWM options, recovery resource facilities and thermal process technologies. The original data consist of the annual benefits and costs statements for 2000 and 2005. The output data are measured by benefits, and the input data are measured by costs generated from resource recovery facility and thermal process technologies plants before being discounted to NPV, respectively. The productivity indices for the average unit are listed in Table 6, and include technical efficiency change (TEC), technological change (TC), pure technical efficiency change (PTE), scale efficiency change (SEC), and total factor productivity (TFP) change. Malmquist index value exceeding 1 indicates improved inefficiency while a value smaller than 1 denotes deteriorating efficiency.

Analytical results suggest that TFP in resource recovery facility is 1.207, larger than the 1.169 for the thermal process technology site. The thermal process technology is less efficient than the resource recovery facility based on the estimate of DEA, but the net benefit is larger than that for the resource recovery facility when estimated using CBA. Simultaneously, the technological change (TC) and TFP exhibit significant decreases of 76.4% and 78.1% during 2000-2005, respectively. Besides being consistent with the downwards trend in population growth in Metropolitan Manila, the thermal process technology site capital cost input is higher in the first year than in subsequent years. Thus the observed decrease in productivity growth is partly explained low input to 2001-2005, and partly due to output benefits been underestimated without non-market goods value. The total productivity growth information evaluated using DEA can support information for the traditional CBA analysis omitted. This study is the first to adopt DEA analysis in MSW, and offers valuable assistance in decision-making criteria.

Table 6 Malmquist productivity index of resource recovery facilities and thermal process technologies

Option	TEC (1)= (3)×(4)	TC (2)	PTE (3)	SEC (4)	TFP (5)=(1)×(2)
resource recovery facility	1.033	1.169	1.033	1.000	1.207
Thermal process technology	1.000	1.169	1.000	1.000	1.169
Annual average					
2000-2001	1.013	1.737	1.013	1.000	1.759
2001-2002	1.077	1.077	1.075	1.002	1.159
2002-2003	0.981	1.202	1.000	0.981	1.179
2003-2004	1.008	0.998	1.000	1.008	1.006
2004-2005	1.005	0.973	0.995	1.010	0.978

5. Discussions

Organization MSW must be unique and based on capitalizing on strengths and mitigating weakness that ultimately depends on differences of purposes, the condition of resources and capabilities, and the existing organizational culture. In this sense, MSW project selection is a MCDM problem. No standardized answer exists regarding what MSW is right, but this study makes MSW project selection more systematical and elaborate.

Numerous studies related to MSW provide valuable advice ranging sequential from essential factors weights for a successful MSW [25, 27]. However, few studies have provided methods for empirically evaluating and modeling MSW for Metropolitan Manila by systematically using complex criteria. This study thus proposes an effective solution to the problem of MSW selection, and one that is more reasonable and elaborate than other solutions. As a test case, the group of experts uses the proposed solution to logically deal with the complicated selection problem and finally obtained alternative method of MSW. The usefulness solution is proposed to depict the reason for the empirical results. The discussion results are summarized as follows.

It is widely understood that MSW purposes frequently emphasize expectation of improved performance. However, the result of decision criteria in the thermal process technology is less efficient than resource recovery facility by DEA; the net benefits of resource recovery facility are larger than those of thermal process technology by CBA. Reaching “established thermal process technologies” is easy and fundamental, which is relatively easier to achieve because it also involves numerous other complicated criteria that are not related to MSW. This means that “established thermal process technologies or established resource recovery facility before landfill can be assisted by successful MSW implementation, but efforts of other parties to formulate smart MSW strategies and employ effective management tools are still required to provide different points of view (efficiency and benefits).

Although numerous researches on MSW suggest that a sound method of MSW should be a hybrid one that integrates both “established thermal process technologies” and “established resource recovery facility before landfill” for waste procession. According to analyze efficiency and costs and benefits from alternatives, in practice MSW utilizes a mix of both procedures. As knowledge is becoming increasingly important strategically, government sees effective MSW as important for enhancing its environmental, economical, and social management and thus achieving national competitive advantage. More importantly, successful MSW starts with proper MSW that is achieved through robust evaluation. Dealing with the MCDM problem associated with MSW selection, it is better to employ MCDM methods to achieve affective problem-solving. The study results demonstrate that the most desirable purpose is to establish thermal process technologies and resource recovery facility before landfill procedure to realize efficiency and net benefits.

The controversy arising from the different solutions obtained using CBA and DEA is the processing and content of investigation data. Waste management programs always possess environmental externalities, creating difficulties in obtaining primary or secondary data. Specifically, the concept of total economic value includes nonuse value or passive value of environmental goods, since agencies cannot consider these values in CBA analysis. However, DEA does not require price information and needs minimal data. CBA thus can be developed as a approach to valuing use value and non-use value of environmental externalities using non-market valuation methods, such as the contingent valuation method, to remedy the traditional weaknesses. Furthermore, CBA can include intangible non-market effects, and thus captures the total economic value of environmental resources, increasing the precision of estimates regarding alternative projects. Further researches can develop total economic value including environmental nonuse vale or passive value, and can be extended to sustainability environmental CBA.

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