行政院國家科學委員會專題研究計畫 成果報告

不同政策目標下公用事業效率評估與民營化研究--以垃圾焚化廠為例(第 2 年)

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行政院國家科學委員會補助專題研究計畫 ■ 成 果 報 告
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（計畫名稱）

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執行單位：南華大學環境管理研究所

中 華 民 國 98 年 10 月 23 日

不同政策目標下公用事業效率評估與民營化研究-以垃圾焚化廠為例

摘要

本計畫的主要研究目的再探討政策目標改變下，公用事業廠的經營效率變化，並分析公民營事業效率差距的原因。本計畫利用國內各縣市垃圾處理相關資料和現有的19座垃圾焚化廠的歷年資料，以DEA 模式分析或是前緣曲線回歸模式分析各縣市垃圾處理效率，以及各焚化廠在不同目標下不同經營型態的技術效率、規模效率與能源回收效率。並以這些效率計算值(calculated scores by DEA methods)，利用Tobit model 來分析各種影響垃圾焚化與能源回收效率的相關因素。換句話說，本計畫的目的在探討股權結構(the owner structure，亦即公民營的不同)，以及不同政策目標下，垃圾焚化效率、能源回收效率、與環境績效的差異情形，並分析影響效率差異的可能因素。

本計畫為為二年期計畫，至今為止，已經完成四篇論文，如附錄。主要的研究目的是針對國內現有垃圾處理情形包含焚化爐的操作情形，分析垃圾處理以及焚化爐廠的技術效率，並比較各公民營焚化廠的效率差異。由於公用事業的營運目標除了考量經濟績效外，還需要考量社會福利與環保政策等其他目標，因此，本計畫歸納國內政策目標，並以政策目標作的產出變數，分析效率變化情形，並利用敏感性分析，探討政策目標對效率的影響。同時，本計畫並提出國內垃圾處理的此略，給予政府參考。

本計畫所產生的結果，除了提供有關民營化理論的相關模型外，在實務上也將具有相當運用價值。由於本計畫所運用的資料涵蓋最近10年的歷年資料，經營型態包含公辦公營、公辦民營、與私辦民營等三種，所得到的結論不僅具有時效性，而且充分運用本土的環境特色，在實務運用上，將減少失真現象。本計畫研究結果不僅可以提供給環保署在擬定民營化政策時參考，也可以提供給其他相關單位，例如自來水、電力、電信、能源、交通等公用事業。本計畫初步建議民營化之前的效率評估，除了考慮純經濟效率之外，政策目標的配合下所產生的效率，可能更為重要，而且，民營化可行性的評估，也必須把政策目標納入考量。如此，民營化在進行過程所遭遇到的困難，可能會大幅降低。

本計畫的實施，不僅在學術上產生一些新的作法，亦即將政策目標視為不可變動的投入要素，對於不同經營型態的受測單位，唯有將上級要求的政策目標納入考慮，才能彌補公營單位因為政策目標所給予的限制而下降的效率，如此，公民營的效率比較才有意義。

另外，本計畫的實施也提供學生參與計畫，瞭解如何觀察問題，如何切入問題並加以解決。也讓學生有更多的機會與師長互動，對於培養學生的學術研究能力，應該會有相當大的助益。

關鍵字：焚化爐、技術效率、規模效率、DEA、SFA、民營化, 政策目標、焚化爐、垃圾管理、MSW 回收、 AHP

Abstract

The major work of the first year focuses on the analysis of relative efficiency based on the panel data of 19 solid waste incineration plants in Taiwan, partly owned and operated by government, and partly owned by government but operated by the private firms. In the second year we will investigate the policy objectives by consulting with several experts composed of scholars and high ranking officials. The policy objectives will serve as the output items in calculating efficiency of each plant, and then the outcome will be compared with the efficiency without policy objectives calculated in the first year. The impacts of the policy objectives on efficiency will be examined through sensitivity analysis.

After the implementation of this project, we have completed four articles in English and submitted to internaitnal journals for reviewweing. In the coming future, we believed that more articles can be yieleded based on the data generated by this project. The results derived by this project can be extended to other public utilities such as telecommunication industries, transportation systems, etc. It highlights the relative important role of public objectives in evaluating operating efficiencies.

The implementation of this project highlights the role of policy objectives in affecting the operation of incinerating plants and other public facilities. The technical efficiencies may fall down when the policy objectives is considered only by the public firms. The incorporation of policy objectives into the evaluation model can compensate the efficiency loss of public firms and provide an equitable comparison of technical efficiencies between public and private enterprises.

Keywords: Incineration plant, technical efficiency, scale efficiency, DEA, SFA, privatization, policy objectives, incineration plant, MSW recycling, AHP

目錄

一、前言

自從民國七十三年，行政院環保署訂定「都市垃圾處理方案」，垃圾處理採用焚化方式，成為主軸，並於民國八十六年制訂「一個縣市，一個焚化爐」政策，並積極推動各縣市興建大型焚化爐，至今為止，台灣地區目前已經開始正式營運的大型公有焚化爐有二十一座（包含公有公營焚化廠公有民營焚化廠）和私辦民營的有7座（中華民國環境保護統計年報，2005）。根據行政院環保署於民國七十九年的統計，台灣地區的垃圾產生量為十八點七五三公噸/日，為了解決國內日益嚴重的垃圾問題，因此行政院於民國八十年九月核定「台灣地區垃圾資源回收（焚化）廠興建工程計畫」規定，共計興建二十一座垃圾焚化廠，其中台北市政府辦理之三座、高雄市政府辦理之二座採「公有公營」方式辦理，其餘十六座（前台灣省政府辦理三座、行政院環保署辦理十三座）則均採「公有民營」方式辦理，至今為止，尚有基隆市、宜蘭縣利澤、台南縣永康三座焚化廠還沒有完工，或是雖已完工，但營運時間不夠常資料取得不易，因此，這三座焚化廠未列為本計畫的研究對象。另外，桃園縣南區焚化爐則是透過BOO 方式辦理，亦即民辦民營；這些大型焚化廠均已完工並開始營運，因此，總共有19座焚化廠（如表一）可以提供相關數據做為本研究之用。

表一、國內現有垃圾焚化廠（2004 年以前正式營運）

廠房地點	容量（噸/日）	發電量（KW）	完工日期	經營方式
台北市內湖區	900	6,000	81.01 完工	公辦公營
台北市木柵區	1.500	12,000	83.03 完工	公辦公營
台北市局北投區	1,800	42,000	88.05 完工	公辦公營
高雄市中區	900	25,500	88.09 完工	公辦公營
高雄市南區	1,800	49,000	89.01 完工	公辦公營
台中市	900	13,000	84.05 完工	公辦民營
嘉義市	300	2,500	87.11 完工	公辦民營
台南市	900	15,800	88.02 完工	公辦民營
台北縣新店	900	16,300	83.09 完工	公辦民營
台北縣樹林	1350	24,800	84.08 完工	公辦民營
台北縣八里	1350	35,771	90.09 完工	公辦民營
新竹市	900	23,666	89.08 完工	公辦民營
高雄縣仁武	1350	33,700	89.02 完工	公辦民營
彰化縣溪州	900	22,600	89.09 完工	公辦民營
屏東縣崁頂	900	24,570	89.12 月完工	公辦民營
台中縣后里	900	25,000	89.04 完工	公辦民營
高雄縣岡山	1350	38,000	90.02 完工	公辦民營
嘉義縣鹿草	900	25,000	90.12 完工	公辦民營
桃園縣南區	1,200	35,000	90.10 正式營運	BOO

資料來源： 中華民國環境保護統計年報，2005

二、研究目的

這些焚化爐，大部分都是政府投資，但經營上可以分為公辦公營、公辦民營和民辦民營，這些分屬不同經營型態的焚化爐廠到底何者較具有效率，有哪些因素影響效率差

異。另外，對於環境政策的要求，例如能源回收，二氧化碳排放等，這些焚化爐廠是否充分支持環保政策，換句話說，哪種型態焚化廠比較具有能源回收效率或是環境績效，這些都是本計畫所要研究的目的之一。換句話說，本計畫的進行分兩年來實施，分別討論分析各垃圾焚化廠的技術效率、造成效率差異可能因素，政策目標對效率的影響，以及民營化可行性分析與策略。本計畫第一年計畫的主要工作內容則是探討垃圾焚化廠的技術效率、規模效率與影響各焚化廠效率差異的因素，詳言之，第一年計畫涵蓋3項主要研究目的包涵(1)以利潤為目的下垃圾焚化廠的歷年效率變化情形，(2)不同經營型態所產生的效率差異，(3)影響技術效率的因素分析。第二年計畫的主要是(1)分析歸納政府的政策目標，(2)並以政策目標為產出項目，分析垃圾焚化廠的效率差異情形，換言之，分析各焚化廠的能源回收效率、溫室氣體減量效率差異、服務效率等，(3)運用敏感性分析，探討政策目標變化對各廠效率變化的影響情形。

三、文獻探討

一般上用來探討各種企業或非營利事業的經營效率上，最常用的方法有隨機性邊界法 (stochastic frontier Analysis, SFA)、與資料包絡分析法 (Data Envelopment Analysis, DEA)。這些估計方法各有優劣，其相對優缺點，已有許多學者提出討論，在現行文獻中也都有學者加以採用，用來測量各種領域的效率問題。Pombo and Taborda (2006) 認為雖然兩種方法的差異，即是兩者相對缺點，也是優點。Berger and Mester (1997) 比較各種測量模式，利用相同資料，試圖找出效率值差異的原因，發現各模式所衡量出來的效率差異，基本上反應各種模式的觀念和測量技術，而非來自於數據。也就是說，模式的選擇或是函數形式的選擇，對於各單位的效率排序並無影響。

一般認為隨機性邊界法(SFA) 因採用隨機變數以及給定的生產函數的觀念來衡量要率，在理論上較DEA嚴謹，然而最近也有學者提出質疑 (Ruggiero, 1999)。SFA 涵蓋誤差項，並且事先假設一給定之函數形式，代表生產技術，尤其是誤差項可以吸收環境所帶來的衝擊，減少估算失真。SFA 由於必須先行決定生產模型，也又假設誤差項目的分配型態 (distributional form of the error term)，對於估算結果（效率估計值）非常敏感(Green, 1980)。

對使用DEA 的學者而言，DEA 不需要先行假設生產函數的格式，直接就可以透過模式運算決定前緣線並計算效率，而且，投入、產出項目皆可以涵蓋許多變數，因此，使用上，頗為方便。由於DEA 在處理各受測單位產出項目之差異時，並沒有任何誤差項包涵在模式內，因此，對於以利潤為目標的企業，所計算出來的效率值可能會有失真現象。同時，DEA 在應用上必須考慮環境上的差異對生產效率的直接影響，並經由模式運算，找出衝擊效果的大小，已減少所導致的效率差異。另外，DEA 對資料的誤差具有強烈敏感性，投入、產出項目是否有納入，樣本數的大小或所選擇的樣本，變數所選用的單位都會影響效率值和計算結果。

國外學者Vaninsky (2006) 以美國電廠1991-2004年的資料，利用DEA方法分析各發電廠的技術效率，他以操作成本、能源損失作為投入項目，淨產能的使用量為產出項目，並發現1994-2000年的美國電廠效率處於比較穩定狀態，效率值在88-100%之間，2000年後，效率值就下降到94-95%。並預測在2010年，效率值為96.8%。Pombo and Taborda (2006) 利用DEA 分法來測量發電民營化前後，輸配電(power distribution) 效率的影響。Pombo and Ramirez (2005)以Columbia 針對民營化火力電廠的效率，發現效率有上昇趨勢，主要由於引進比較有效率的生產技術(cost saving technologies) 。Garcia and Arbelaez (2002) 則分析電廠在合併之後所產生的效益差距。

在財務應用上，DEA 常用來測量效率，銀行兼併(mergers)時的評斷基準或是比較各銀行間的效率(e.g. Brown, et al., 1999; Worthington, 2000, 2001)。McKillop et al. (2002) 利用DEA 測量成本效率，發現沒國銀行效率的平均值為0.77. 許多研究發現銀行併購或是部門合併並沒有顯著改善效率(Brown, 2006). Puig-Junoy (2001)以美國各州在1970-1983年間的資料為依據，研究公共資本對生產技術效率的影響，Aw and Batra (1998) 也利用DEA法來探討台灣各產業之效率問題，Xu and Jeffrey (1998) 則利用DEA分析中國大陸各區稻米與雜糧

的生產效率等問題。

一般來說，對於不以營利為目的NGO 或公用事業，或是對於組織目標無法用金錢衡量的狀況，使用DEA具有相對優勢。因此，本計畫運用DEA BCC (Banker, Charnes, Cooper)模式，考量在不同目標下，探討各焚化廠技術效率以及能源回收效率差異的情形。本法的主要優勢是可以分析各受測單位的規模效率與技術效率，透過分解法，固定規模下的技術效率(constrant return to scale, CRS) 等於規模效率(scale efficiency, SE)和變動規模下的技術效率。本計畫第一年度將以國內19座焚化廠為研究對象，利用DEA 模式，分析各廠的技術效率、規模效率、與能源回收效率，並從DEA 所計算出來的各DMU (decision making units 受測單位) 之效率值，以Tobit model 分析導致效率差異的原因。在許多效率分析的文獻中，已有許多學者利用此一模式，探討效率差異的因素（例如 Dalmau-Matarrodona and Puig-Junoy, 1998 、 Pollitt, 1996、Raczka, 2001)。關於Tobit midel 的應用以及優點，Marin-Galiano and Kunert (2006) 已有許多有價值的討論,並比較Tobit model 和ANOVA 在分析檢查性試驗(sensory trial)的相對優勢。他們強調 如果受測數據是 0 的數目很少的話，the Tobit model 是ANOVA 的 一般式，兩者的結果幾乎是 一樣的。如果受測數據是 0 的數目很多的話，Tobit model 具有較大能力來檢查出來導致差異的因素。

四、研究方法

本計畫主要運用DEA和SFA 模式，分別計算各焚化廠的技術效率、規模效率、能源回收效率、溫室氣體減量效率、服務效率，並分析經營型態、政府現存的能源與環保政策對焚化效率的影響。第三年計畫則是探討影響垃圾焚化廠民營化的因素，並分析民營化之後對原先政策目標的影響。

DEA 模式在應用上，目標函數的決定會影響受測單位的技術效率表現，對於焚化爐而言，其目標函數不應該是純粹的市場利潤，應該含有非營利組織的部分功能，因此，其目標函數應該是追求整體社會福利最大，或是提供最多得垃圾焚化服務並減少污染的產生，因此，垃圾費收入越高表示居民的負擔加重，社會福利下降。過去的研究，幾乎都把焚化場當作營利事業，因此，對於服務地區的寬廣與服務民眾家庭戶數的多寡，往往忽略。

因此，本計畫將效率計算方式分為兩種：(1) 純粹考慮實質投入與產出方式，此一方式所重視的是各焚化廠的內部管理效率，(2)把政策目標列為產出項目，除了考慮實際垃圾焚化量之外，尚考慮為了把服務民眾家數，服務範圍，環保目標等列入產出項目。

一般學者在利用 DEA 來測量效率時，必須事先定義變數，乃些變數是輸出項目，哪些是輸入項目，哪些是環境變數。例如 Hjalmarsson and Veiderpass (1992)利用 DEA 來測量瑞典的電力輸配電系統的效率並 分析 Malmquist Productivity indices（MPI）， Førsund and Kittelsen (1998) 利用 DEA 來測量挪威的電力輸配電系統的效率，Miliotis (1992) 利用 DEA 來探討希臘輸配電系統的效率，並 分析政策和股權結構對效率的影響，Agrell et al. (2003)也利用 Scandinavia 的資料，深度探討 DEA 模式在應用在輸配電效率分析時的一些限制，並說明各種 DEA 模式的構建，以及變數的選擇。Thanassoulis (2001)對於 DEA 模式中變數的選擇，也提出一些有價值的意見，他認為研究者在選擇變數之前，必須對於功用事業的操作特性，要有先驗知識(prior knowledge) ，如果變數太多而受測單位(DMU)太少，則都部分的單位都會落在前緣曲線，因此，變數數不不宜過多。

假如考量垃圾焚化廠是公用事業，亦即是公共財，則產出項目可以選擇所服務的居民人數,輸入項目則是員工人數,設備裝置容量等,其餘則是環境變數或是外生變數(exogenous variables)。但是民眾對垃圾焚化的需求，可能受至於地理環境的區隔，各地區人口密度的差異，社會環境的不同因而影響焚化廠的裝置與投資。為了嚴謹的訂出政策目標等產出項目，本計畫將辦理專家訪談，徵詢國內環保專家學者，以確實能將目標量化為原則，作為產出項目。因此，本計畫的效率分析部分所運用的變數，除了政策目標之外，其餘的變數包含：垃圾處理量、 發電量（能源回收量）、垃圾處理設備容量、發電裝置容量、人力、二氧化碳排放量、操作成本等。

(1) 數據取得

本計畫採用1991-2004年的資料，涵蓋公辦民營，公辦公營、私辦民營等不同經營型態。由於各廠焚化爐裝置日期不一，所採用的技術也不一，因此，有可能新安裝完成的設備，會有較好的技術效率（垃圾處理效率與發電回收效率），或是由於學習曲線效應，操作人員尚未熟悉，生產技術效率較低。因此，2003年以後才開始運轉的焚化爐廠，尚處於試車階段，而且所提供資料量有限，因此，這些新廠排除在外。所取得的資料是屬於事後(ex post)型態，全省共有19家焚化廠（請參考表一），從1991-2004年的垃圾處理情形、能源回收量、使用人工數等資料，依照DEA模式，測量各焚化爐的垃圾處理效率，能源回收效率，以及二氧化碳減量後所取得的整體效率。所選用的樣本廠商涵蓋 98%以上的垃圾處理量，因此，應當具有充分的代表性。

目前，國內焚化爐的經營型態雖有公辦民營，公辦公營、私辦民營等不同方式，各焚化爐的製程或許由於國外設計廠商的不同，但是各焚化爐的設計、製造與安裝都是政府監督下所經辦，因此，本文假設設備安裝前的土地取得、設備採購的效率都是一樣，不會影響產出、投入項目的選擇，而且各焚化爐廠（受測單位）所運用的技術大抵相同，因此，環境上差異所導致的影響，非常輕微，亦即是各廠的資料具有同質性。為了避免季節性變化帶來的影響，原則上以年度資料為計算單位。各焚化場的歲修時間不列入考慮，亦即各場如果歲修時間過久，會導致效率降低。

Bauer et al., (1998) 認為好的測量工具必須具備有良好的一致性(consistency)，經過一段時間之後，測量結果仍能穩定的符合現實狀況，各受測單位在同同的年份所測出的相對效率直應差異不大，受測結果與其他測量工具所得結果的相對排序，應不致差異過大。為了測試一致性，Bauer (1998) 分析(1)各年度全部樣本所得之技術效率、(2)各年度分層資料（公辦民營或是公營）、所產生之 Spearman’s rank coefficient，歷年效率的相關係數，如果高，則表示穩定性強。

Megginson and Netter (2001) 討論股權結構對績效的影響時，認為有兩種主要的研究方法或途徑來切入，包含橫切面法（cross-sectional in nature）：比較民營化廠商與非民營化廠商的相對績效，一般研究發現隨著民營化程度提高，效率也跟著增加，另一種切入方式，由Megginson et al. (1994) 建議，比較民營化企業在民營化前後的績效比較。例如民營化3年後或5年後與民化之前的績效，相對比較。此一方式隱含著民營化一開始，就馬上生效，因此，變化產生是突變的，革命性的，不是漸進的。Megginson and Netter (2001) 的研究結論證明民營化要產生效率改進一定要同時，各種管制也要同時去除（deregulated.）。去除管制會影響產品市場的競爭性，對於不同產也會有不同影響。

DEA 在應用上最常見的問題，即是資料的差異性(heterogeneity)，主要來自於跨國性比較研究時，因為環境因素差異而產生，例如市場或制度的規範所產生的差異，對於財務單位的機系評估所提供的資料容易產生差異性。尤其對於跨國比較時，會產生失真現象，不易獲得有效的比較。DEA 主要在衡量一般決策單位(decision making unit, DMU) 與此一分析對象中最好單位所比較出來的相對效率，因此，決策單位資料如果失真，導致真實的最佳效率前緣線偏離時，則容易產生測量偏差。Zhang and Bartels (1998)也提出許多DEA 在使用上的限制，並檢視樣本數大小對電力輸送業的平均效率的影響，發現樣本數對於測量出來的效率具有強烈的影響。Staat (2001) 也支持此一論點，並以前人(Banker and Morey, 1986)資料，從新檢驗樣本數對於測量結果的影響，並證實此一論述。當受測單位數增加時，會有更多單位作為做家但 為，也即是許多受測單位會逐漸靠向前緣曲線，因此，所測得的技術效率會又降低趨勢。Bauer et al., (1998)認為此 一趨勢即是自我訂位(self-identifier)現象，當測量的輸入或輸出變數太少時，此一現象更為顯著。此一現象，如同離散值(outlier)問題，不一定是錯誤，雖然發生機率不大，但也可以提供有價值資訊。在此一狀況下，利用DEA 時，某些受測單位是否應被視為離散值而排除在外，值得考慮，是否因為績效太好或太壞，或是數據 錯誤。如果沒有詳細檢視，而輕易排除，可能導致平均效率的高估或低估現象。

一般學者也認為，由於DEA 是屬於無參數的測量方式，因此，變數（數據）的單位使用所造成的差異容易感染測量結果的正確性 (Fried et al., 2002)。Dyson et al. (2001) 認為

DEA 在應用上有許多缺失與限制，因此，充分理解這些問題並提出適當對策，可以顯著地加強或改善DEA 的應用。Brown (2006) 利用澳洲信用資料，說明在使用DEA 作為效率分析時，所碰到的問題與陷阱，並提出對應方案。Dyson et al. (2001)和Cook et al., (1998)等提出因應方案，透過程序上的改善，以減少這些影響。包含決策單位的同質化(homogeneity) ，將受測單位性質相接近分成不同群組(cluster)，或是利用層次分析，在加以分組。輸入項目與輸出項目的選擇，要符合目標函數的需要，因此，必須事先提出選擇基準(criterion) ，Dyson et al. (2001)建議四項準則，包涵：(1) 所有生產要素必須涵蓋所有資源，(2) 生產要素要能掌握各種生長活動水準和績效水準，(3) 生產要素對所有受測單位都是相同的，(4) 各受測單位所面臨的環境因素之間的差異，已經評估過，而且把差異性降至最低。

由於本計畫採用的是歷年資料（panel data），適合比較跨年的技術效率變動，透過Malmquist productivity indics (MPI) 分析，可發現技術不變下或是技術變動下生產力變化情形。因此，在資料處理上，本計畫將以經營型態分組方式或是以年份分組方式，分別計算各廠各年的效率，並比較各廠在各組中的效率排序，另一種方式，每一焚化廠每一年的資料，各自做為獨立的受測單位（DMU），整體比較每一受測單位的效率，將此兩種方式比較，效率計算直的排序是否具有一致性。

(2) 效率測量方法：

本計畫採用 BCC (Banker, Charnes, Cooper) 模式，計算各垃圾焚化廠的技術效率以及能源回收效率。BBC 的模式簡述如下，假設有 N 個受測單位，K 個投入，M 個產出，則廠商的個別效率如以下的線性規劃：

$$\min_{\theta,\lambda} \theta$$

s.t._ $- y_i$ _$+ Y\lambda \geq 0$,

$- x_i - X\lambda \geq 0$,

$N1'\lambda = 1$,

$\lambda \geq 0$

其中，

θ 是數字常數 (a scalar)

λ 是 N x 1 常數向量

yi 是第 i 個受測單位的產出向量

Y is the M xN 產出矩陣;

xi is是第 i 個受測單位的投入向量

X is the KxN 投入矩陣;

N1 is the Nx1 的1 組成的向量.

在此模型中，θ 相當於變動規模下的技術效率，如果去除$N1'\ \lambda = 1$ 限制式，所得到的效率則是固定規模下的技術效率。本法的主要優勢是可以分析各受測單位的及效率與技術效率，透過分解法，固定規模下的技術效率(constrant return to scale, CRS) 等於規模效率(scale efficiency, SE)和變動規模下的技術效率(variable return to scale, VRS) 的乘積(Pombo and Taborda, 2006; Coelli, et al., 1998)，亦即

CRS = SE X VRS

如此，小廠的技術效率在扣除規模因素之後，可以比較清楚的呈現。

五、結果與討論

本計畫的實施，至今為止，共產生四篇論文，都已經投稿到國際期刊，詳細內如如附錄。主要研究目的如下所述：

第一篇 A performance evaluation of MSW management practice in Taiwan： 主要的目的

在探討國內故縣市垃圾收集、回首處理的效率，並分析影響效率的原因。

第二篇 A development of MSW management practice in Taiwan： 本篇主要的目的再分析國內現有垃圾處理的困境，並探討國內外對於垃圾處理嗲關管理制度，以提出適當的管理策略，給政府環保單位參考。

第三篇 The role of policy objectives in affecting technical efficiency for a public facility: using data envelopment analysis: 本篇論文分析國內各焚化場的效率，並探討政府經營與民間經營的差異，另外，探討政策目標對效率的影響。

第四篇：Spatial inequality in MSW disposal across regions in developing countries：本篇論文主要再探討社會經濟等人口變數對處理效率的影響，並分析不同區段（地理位置不一樣）是否具有充分的影響效果。

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計畫成果自評

本計畫的進行，不僅在學術上發現有了充分進展，在實務上的應用，也開啟另一扇窗。由於一般公用事業單位在經營上，往往要遷就政策需要，例如交通事業或電力事業，為了滿足社會福利的要求，對於偏遠地區或比較弱勢民眾，通常給予較低的價格，因此，一般上如果不把這些政策目標納入經營效率的評估內，很難讓經營者信服，理論上，也不能反應真實的狀況。本計畫所建構的理論模式可以避免上層組織所要求的政策需要對下層組織（亦即公用事業單位）的經營效率產生干預，因為這些政策需要都已經納入模式考量。在這種狀況下，公用事業單位的獎金計算，也比較有依據，不會雜亂無章。另外，本計畫的研究結果也充分的說明公用事業民營化對民眾與業者的影響，依據本計畫所建構的模式，政策

社記者可以分析公用事業是否應開放民營。

本計畫透過DEA模式或是SFA模式，以垃圾焚化爐場為研究對象，分別考慮政策目標納入和不納入模型內的效率差異情形，並深入分析導致效率差異的原因，以作為政策設計的參考。在學術上，本計畫的推動已產生四篇論文，並投稿在國際期刊上，相信很快就會有進一步的結果。本計畫研究結果彰顯(1) 各焚化廠的作業效率和能源回收效率的比較，尤其是公營與民營之間的效率差異，不同政策目標下的效率差異，並分析導致差異的主要原因，(2) 台北市在1999年開始採用隨袋徵收環保費政策，其他縣市（台灣省）則至今仍然採用隨水費徵收的方式，透過歷年資料的比較，可以顯示台北市與台灣省之間的效率差異，以及政策變化是否對效率有充分的影響。

由於台北市於2000年採取隨帶徵收的垃圾政策，垃圾量也呈現顯著的下降，其他各縣市也積極鼓勵垃圾減量，必推動資源回收政策，因此，各垃圾場也產生垃圾進入量不足的現象，由於本文採用垃圾處理量為輸出項目，因此，垃圾不足的現象，可能導致北部焚化爐的效率降低。然而，垃圾量不足可能是上層組織（環保署）推行政策成功之處，也有可能是當時設立焚化爐時，並未詳細分析需求，草率投資，才導致今日垃圾不足的現象。如果是前者，亦即垃圾量不足是政策的需要，為了避免此一陷阱， 應該將之導入模式內，如此，經營效率才不會導致偏差。

垃圾處理民營化後所產生之垃圾處理業的市場力量的來源可能包含以下因素：(1) 市場佔有率，市場佔有率越高，廠商月有能力抬高價格、或是改變服務型態或內容，也比較會提出各種策略以擴大其利潤率。價格的提高，必須預防其他廠商對此市場產生興趣，並加入此一市場，換句話說必須預防新加入者的加入機會。(2) 規模經濟：由於資本投入越高，越能阻止新廠商的加入，同時，也會產生規模經濟。但是規模的擴大必須考慮市場的成長，以及資本投入時機另外，新投資所產生的沈入成本(sunk cost) 也會帶來投資者一大負擔。(3)政策變化：環境政策的變化，例如提高空污染標準，或是課徵碳稅。由於乁加廠商所使用的設備標準不一樣，所使用年齡也不一樣，因此，環境政策變化都會影響廠商市場力量的消長。(4)代替商品（服務）的有無：廠商所生產的商品或勞務如果有替代品，而且價格低廉，廠商控制商品價格變成薄弱，反之，市場力量則增強。

垃圾焚化一般受制於地理位置，焚化廠並非到處都有，遠距離運輸垃圾不僅增加運輸成本，而且，會受到當地居民的抵制。垃圾場在經營時，如何考慮當地居民需求並製作納入公共政策目標，作為經營效率的一部分，如此，公用事業或者是具有林避效應設施的運作，可以更圓滑，更有效。

本計畫的實施，使得政策社記者或效率評估者可以充分瞭解：公用事業效率評估時，不能只是考慮純物裡面或經濟面的技術效率，尚且要把政策目標納入考量基準，因此，在分析民營化時，也必須將政策目標納入考慮。換句話說，民營化之後的民營廠商，在經營上除了考慮經濟利潤易，政府必須滿制訂適當規範，要求民營廠商滿足公共政策目標。此外，透過本計畫所蒐集到的資料和所產生的模式，可以進一步擴展到其他議題上，在後續的研究上，可以進一步有成果逞現。

另外，本計畫的實施，可以引導學生復習其已得之知識，並運用到社會上的實際工作上，以印證其所認知與理論是否一致。本校研究生在與社區民眾的互動中，了解人性因素與個人或社會價值觀對環境政策的影響，並從其中，找出素材，作為研究的主要議題。培養學生運用圖書設備收集相關文獻的能力，訓練學生如何製作問卷，收集資料，利用統計分析工具，分析並解讀資料的技巧，強化其實務操作能力。

附錄

附件一：A performance evaluation of MSW management practice in Taiwan

附件二：A development of MSW management practice in Taiwan

附件三：The role of policy objectives in affecting technical efficiency for a public facility: using data envelopment analysis

附件四：Spatial inequality in MSW disposal across regions in developing countries

附件一：

A performance evaluation of MSW management practice in Taiwan

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Abstract

Traditionally, the performance of MSW management is almost assessed based on the recycling rate or the collection cost per unit of waste collected only. It neglects the impact of the different role in the society on the performance assessment. In practice, the increase in MSW (Municipal Solid Waste) recycling requires the total participation of stakeholders including households, producers, local authorities and the central government. Moreover, lower recycling rate may also attribute to low waste generation and is probably good for the environment.

In this paper, we evaluate the integrated efficiency of MSW management that is divided into three stages: MSW generation, sorting and collection by using the tools of Data Envelopment Analysis (DEA) and Analytical Hierarchical Process (AHP).

The relative efficiency in proxy of performance at each stage for each DMU is calculated by DEA and the weighting factor at each stage in affecting the integrated efficiency of MSW management is measured through the support of AHP. We compare MSW management performance between urban and rural regions in Taiwan and attempt to examine the factor that affect the efficiency variation, by using data of 23 cities/counties in 2006. The results find that urban regions have higher sorting efficiency but lower generation efficiency than rural regions. On the other side, both the two regions have the same collection efficiency.

Keywords: MSW recycling, AHP, DEA, performance, technical efficiency.

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1. Introduction

In 2007 Taiwan generated 7,949,499 ton of Municipal solid waste (MSW) and 38.7% of the generated waste was recycled in amount of 3,076,456 ton that is composed of resource recyclables (2,382,242 ton), food waste (662,791 ton) and bulk waste for reuse (31,230 ton). Recycling rate has been increased rapidly in Taiwan from 1.25% in 1998 to 38.7% in 2007. The data of recycling rate seems fantastic and attractive but it seems to have lost the environmental objectives of "reduce, recycle and reuse" for MSW management. MSW generation play vital role in affecting MSW management performance, but it is, in general, ignored and has not impact on performance assessment. Moreover, the recycling rate is calculated by the formula of x/y where x is tonnage of recyclables collected for recycling and y is total tonnage of household waste collected by the local authorities. This formula neglects the role of MSW composition influenced by green consumption. Furthermore, MSW collection performance is evaluated by the amount of money spent per ton of solid waste collected. It ignores the geographical difference between rural and urban regions.

Municipal solid waste (MSW), in practice, involves the cooperation of several parties including households, local authorities and implemented through a series of process, mainly consisting of MSW generation, sorting, collection and disposal. Central government is, in general, responsible for environmental policy planning and making while local authorities are responsible for the management of the MSW disposal from the initial point of collection to final processing. Local governments are responsible to collect the MSW by the method of door-to-door, which is done once every night. Households are required to sort their waste generated into general wastes and recyclables at home[1]. Households should throw the general waste into the collecting truck and hand over the recyclables to collectors at a given time and point of location every day.

In this case, the integrated efficiency of MSW management is composing of three parts: MSW generation, sorting[2] and collection. The assessment on the performance at each stage may provide more information for policy makers to set up appropriate policies and strategies. Prior studies in solid waste management mostly focus on the performance assessment of MSW collection and recycling only and neglect the contribution of household's efforts in the reduction of waste generation and the increase of sorting at home. For example, Massoud et al., (2003) assess the MSW collection service quality by examining the key issues and differences of the two cities in Lebanon but the performance of waste generation and sorting is neglected.

This paper develops an integrated assessment model to assess the MSW management in Taiwan, consisting of three steps: firstly the Data envelopment analysis (DEA) is employed to measure the relative efficiency of each decision making unit (DMU) for each stage and then we use AHP technique to determine the weighting factor among generation, sorting and collection and eventually the integrated efficiency of each DMU is calculated. The data of MSW generated, sorted, and collected in each city (or county) in Taiwan is obtained from Yearbook of Environmental Protection Statistic (2007). We also attempt to examine the spatial difference across regions in the efficiencies of waste generation, sorting and collection.

2. Research method

The measurement of the integrated efficiency consists of three steps: firstly the DEA tool is employed to measure the relative efficiency of each decision making unit (DMU) for each stage and then we use AHP technique to determine the weighting factor among generation, sorting and collection and eventually the integrated efficiency of each DMU is calculated. The DEA was pioneered by Charnes et al. (1978) based on the theoretical concept of frontier production developed by Farrell (1957). It is a linear programming technique to estimate production or cost efficiency by measuring the ratio of total inputs employed to total output produced for each decision making unit. It has been employed to evaluate the relative efficiency in various

[1] Recyclables are categorized into (1) containers including plastics bottle, metal can, Al can etc., (2) plastics film, (3) old paper, (4) food wastes and (5) bulk wastes in Taiwan.

[2] Solid wastes generated by the business/commercial sector must entrust private collecting systems (PCS) for waste collection while local authorities are responsible for the collection of household wastes. The recycling performance via PCS is seen as the contribution of sorting efficiency.

application and proved to be an effective approach in identifying the best practice frontiers. For example, a great number of literature employ DEA to calculate the technical efficiency and scale efficiency in power generation plants or energy industries (e.g. Pacudan and de Guzman (2002), Pombo and Taborda (2006) and Vaninsky, 2006). Pacudan and de Guzman (2002) employed to evaluate whether privately-owned service enterprises are more efficient or not. Vaninsky (2006) estimates the efficiency of electric power generation in the United States by using the data during 1991-2004. Cooper et al. (2003) has provided a comprehensive description about the theoretical background and applications of DEA. The major merits of DEA are (1) it can be easily applied to a multiple input–output framework to examine the relative efficiency of the examined power plants, and (2) it can produce detailed information on the efficiency of the unit, not only relative to the efficiency frontier, but also to specific efficient units which can be identified as role models or comparators (Hawdon, 2003).

The service of MSW management at each stage is executed by a technology whereby N DMUs transform multiple inputs $x \equiv (x_1, \ldots, x_m) \in \Re_+^m$ into multiple outputs $y \equiv (y_1, \ldots, y_s) \in \Re_+^s$. The basic DEA model of CCR is employed to estimate the efficiency of MSW generation, sorting and collection in each region in Taiwan. The CCR model, which is under the hypothesis of constant returns to scale, is expressed as follows:

$$
\begin{aligned}
&Min \quad \theta \\
&\quad s.t. \quad \theta x_0 - X\lambda \ge 0 \\
&\qquad\quad Y\lambda \ge y_0 \\
&\qquad\quad \lambda \ge 0
\end{aligned}
\tag{1}
$$

where y_0 is output, x_0 is the input, X, Y is the data sets in matrices, λ is a semipositive vector, θ represents the technical efficiency.

The relative importance of each stage in affecting MSW management is measured by the method of Analytical Hierarchical Process (AHP) that was developed by Saaty (1980). The AHP utilizes pairwise comparisons between criteria or between units, assessed subjectively by respondents. This method provides a logical and systematic process for making better decision. The good merits of AHP has been discussed (e.g. Winkler, 1990; Barzilai et al., 1987) and thus a great number of researchers have used it in real life applications.

The pairwise evaluation matrix generated through the survey on governmental officials, experts and housewives is utilized to rank the weighting factor of each stage in affecting MSW management. In this study, a total of 5 respondents including 1 governmental official working in Taiwan EPA, 2 professors in the fields of environmental education and environmental management respectively, and 2 housewives, are asked which stage of MSW management practice is more important in affecting MSW management performance. Each survey took about 30 minimizes to complete.

The eigenvector of the maximal eigenvalue of each pairwise comparison matrix is obtained and utilized as the weighting factor of each stage. The obtained weighting factor reflects the relative importance of the activity at each stage in affecting MSW management performance. The integrated performance is given by adding up the partial weighted assessment components:

$$\eta = F_g \eta_g + F_s \eta_s + F_c \eta_c \tag{2}$$

where η is the performance, F represents weighting factor, subscripts g denotes MSW generation, s the sorting of recyclables from general waste conducted by households, and c MSW collection handled by local authorities.

2.1 The variables

The input/output set specified is based on the objective function of MSW management including the minimization of resource, and maximization of service area and population. Four key criteria are suggested for the selection of inputs and outputs for a DEA frontier estimation including: (i) the factors cover the full range of resources used; (ii) the factors capture all activity levels and performance measures; (iii) the factors are common to all units; and (iv) geographical and demographical variation are assessed and captured if necessary. The input and output variables are listed in Table 1.

-MSW generation efficiency

The efficiency of waste generation is measured by a per capita approach to calculate the amount of waste being generated. A rising level of prosperity or economic development may lead to an increasing number of products and services for production and consumption. The income level of households in the service area may affect consumption that is inevitably accompanied with MSW generated. For example, the growth rate of the economy as a whole may affect plastics consumption. And thus, household disposal income is seen as an output variable[3].

Clean production through product redesign and process innovation in consideration of environmental impact is another factor to influence MSW generated. The diversity of products and services makes a continuous creation of new products and generates a more and more serious problem for MSW management. Of course, minimization of waste generating through green consumption and increasing the supply of green products through clean production are vital to prevent from solid waste problems. However, this paper does not incorporate the role of producers in calculating the waste generation efficiency due to lacking the data about the degree of clean production.

-MSW sorting efficiency

The recycling system, in general, requires the cooperation from households and the public to separate their waste into different waste types and not bringing mixed general waste to the site. Additionally, all the recyclables sorted rely on the public collecting system to collect. Therefore, the resource recyclables collected and food wastes collected are treated as output variables while general wastes, population, man power for waste collection are treated as input variables.

Insert Table 1 about here

- MSW collection efficiency

Local authorities are responsible for the day-to-day operation of MSW collection service with given man power, budgets and equipments. Equipment referred to here are those used in MSW collection including compacting packer with lifting device, compacting vehicle, trucks, motorized vehicles and resource recycling vehicles. The quantity of each type of equipment is summated and the aggregated number of equipment is treated as an item of input variables. The central government focuses on the effectiveness of MSW management in linking with environmental equity and thus size of service area and population served are considered as output variables in addition to MSW collected to measure MSW collection efficiency. The measure of MSW collection efficiency that considers the policy objectives appears fair to the rural regions as rural regions have low population density and thus require more resource inputs for unit output of waste collected.

2.2 The data

We use the data of MSW generated, resource recyclable collected, food waste collected, general waste collected, budgets, equipments, and population in 2006 are drawn out from Yearbook of Environmental Protection Statistics, Republic of China (Taiwan EPA, 2007)and the size of service area and household disposal income are provided by Directorate General of Budget, Accounting and Statistics (DGBAS, 2008). The observed county/city is categorized into two classes: the urban regions and the rural regions. The former includes 2 municipalities and 5 cities (Taipei Municipality, Kaohsiung Municipality , Keelung City, Hsinchu City, Taichung City, Chiayi City, and Tainan City) and three counties that locate in north Taiwan with income over NT$ 900,000 (Taipei County, Taoyuan County, and Hsinchu County). The remaining counties are categorized into the rural regions. The income of the two regions is listed in Table 2.

Insert Table 2 about here

MSW recyclables are classified into resource recyclables (e.g. PET bottle, metal can), food

[3] As the waste generation efficiency reflects the performance of household participation in MSW management, and thus it is the inverse of per capita (or per income) waste generation.

wastes and bulk wastes for reuse. Taiwan's environmental policy at earlier stage focused on the recycling of resource recyclables only and then it started to encourage the recycling of food waste in 2002 and the remanufacturing whole products for reuse (bulk wastes) in 2005[4]. The data for bulk waste recycling is still missing and not available in some counties in 2006. In 2006, the resource recyclables and food wastes between the two regions are listed in Table 3.

Insert Table 3 about here

3. Results and discussions

3.1 MSW generation

Based on the CCR model, the relative efficiency of waste generation across regions (cities and counties) is listed in Table 4. In order to compare with the traditional indicator of per capita waste generated, we put the two indicators in Table 4. Taichung County ranks the highest efficiency in waste generation calculated either by per capita waste generated or by DEA. Rural regions (89.46% waste generation efficiency) have better performance in waste generation than urban regions (79.95%). An ANOVA analysis has been conducted to test the difference of waste generation efficiency between the two regions and proves a significant existence of the difference in waste generation (please see Table 5). This result seems to contradict with previous researches as some researchers argue that green consumption has been initiated and become a major force to affect MSW generation through the awareness of human's environmental consciousness while economic development grows and education level increases (Godoy et al., 1997; Scott and Willits, 1994). More educated people investing higher effort in green consumption and behave more environmentally-friendly (Scott and Willits, 1994). In fact, rural regions have lower disposal income and education level, but the waste generation efficiency is higher.

Insert Table 4 about here

Household waste generation is conducted through the understanding and changing of household consumption into green consumption to reduce and prevent waste. Therefore, the waste generation efficiency can be seen as consumption efficiency. Nowadays, per capita waste generation shows large differences between urban and rural regions. The possible explanation for the cause of higher MSW generation efficiency in rural regions may attribute to less consumption in food and general commodities rather than the awareness of environmentalism. On a whole, the per capita MSW generation decrease over time as the population and economy grow in the past few decades in Taiwan (Chen and Chen, 2008).

Insert Table 5 about here

3.2 MSW sorting

The result of the analysis on MSW sorting efficiency is listed in Table 6. The data of recycling rate[5], extracted from extracted from Yearbook of Environmental Protection Statistics (2007), is also listed in Table 6 for comparison with DEA sorting efficiency. Sorting at home is conducted by two ways in Taiwan currently: voluntary sorting encouraged by economic incentives, conducted in Taipei Municipality and Taipei County, and compulsory sorting conducted in the remaining regions. TM charge the service fee based on the general waste collected and the collection for recyclables is free of charge. In other counties MSW service fee is based on the potable water consumption. The Spearmann correlation ship coefficient between sorting efficiency and recycling rate is significantly found to be 0.969. This demonstrates that the two indicators for measuring sorting performance are significantly correlated. The efficiency scores derived by DEA can be more accurate to reveal the information about the improvement directions. For example, Taipei Municipality ranks 8 in DEA efficiency scores but it ranks 3 in

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[4] After 2005, Taiwan EPA started to encourage households to engage in the recycling of bulk wastes such as furniture. The bulk waste collected is transferred to the repairing plant for repairmen and reuse.

[5] The recycling rate is calculated based on the formula of MSW recyclables collected/MSW generated. MSW recyclables is categorized into: resource recyclables, food wastes and bulk wastes for reuse by Taiwan EPA.

recycling rates. This difference is caused by its lower output of food wastes. At present, food wastes are collected and transferred to pig farms directly in rural areas while most food wastes are transferred to composting plants for production of fertilizers in urban areas[6].

Insert Table 6 about here

Sorting of household wastes into separate items of recyclables and general wastes is important to match the need for the goal of sustainable development and partially involves with governmental operation of waste collection. The role of individuals and households, of course, play the primary role in affecting MSW management performance but the performance of sorting reflects the cooperation of two parties at least. Therefore, we test for the proposition that the sorting performance of rural regions might differ from urban regions and find that it significantly different in the two regions (80.44% for urban regions and 66.18% for rural regions). Table 7 shows that the urban regions have significantly better performance in sorting (under confidence level of 90 %). Voluntary recycling (household sorting) may be affected by economic motives, environmental conscience, or self-benefits-driving motives, and regulated pressures. Thus, the better sorting performance in urban regions can be explained by following reasons.

Insert Table 7 about here

(1) A great number of empirical studies suggested a great variety of policy instruments for encouraging recycling (e.g. Chen and Chen, 2008). A variety of service charge systems for MSW disposal vary across regions in Taiwan. For example, Taipei Municipality uses the ‘unit pricing’ of waste disposal. Households must purchase the particular sacks for general waste packing and hand out to MSW collectors. In other words, Taipei Municipality charges a disposal fee for general waste through a predetermined price of a plastic sack. As to the collection of resource recyclable and food waste, the charge is free. Taipei Municipality has provided an incentive for householder to sort waste at home while other cities/counties is lacking of incentives or penalty to encourage households participating in recycling schemes as their waste fees are included in the potable water consumption as an additive rent or charged as a lump sum tax for each individual in the household. All the households, however, should sort the waste into general wastes, resource recyclables, and food wastes, and store them at home until collection by the collector at night. Otherwise, the collector can reject to collect.

(2) Some researchers find that age, gender, income, social and occupational status, and educational level plays important factors to affect recycling and sorting. Household income is an important factor to affect recycling behaviors (household sorting) with a positive relationship (Derksen and Gartrell, 1993; Vining and Ebreo, 1992). Higher income also leads to higher education level. Evison and Read (2001) suggest that the good quality of public education can enhance the implementation of recycling programs on a regular basis in seeking waste minimization and material recovery.

(3) As the resident is largely unaware of what the environment is going on and will be affected by human activities, environmental education becomes an important role in providing environmental knowledge and promoting environmental consciousness. In practice, many communities have been very successful in creating public education action that provides environmental programs from nature conservancy that is a leading issue by environmentally educating outside of the formal school network to the waste recycling that involve our living lives.

3.3 MSW collection

The efficiency scores of MSW collection are listed in Table 8. In order to compare the collecting efficiency between the two regions, an ANOVA test is conducted and we

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[6] Due to health risks, Taiwan Agricultural Bureau oppose the application of food wastes on pig farms, and thus Taiwan EPA regulate to recycle food wastes for bio-composting as food wastes, soon or later, are normally decomposed and become nutrients for the vegetation. Residents, whenever composting is mentioned, express their dislike and health risk arising from the smell released from rotting rubbish during collecting and warehousing of food waste. How to design a quality process of composting to warrantee no leaking of smell is a factor to affect residents support.

find that there is no significant difference. In other words, the central government have financed the appropriate budget, and provided sufficient manpower and equipments to cover the huge difference in the size of service area. This result also demonstrates that rural regions have equal access as urban regions to enjoy the living environment surrounding them irrespective of their location and population densities.

Considering municipalities have higher budget, more man powers and equipments but smaller service area and high population density than other cities/counties, we compare the two municipalities with other regions and find a significant difference between municipalities and general cities/counties. The mean collection efficiency of the two municipalities is 48.88% only while that of the other cities/counties is 90.4%. The two municipalities have significantly lower collection efficiency with p-value of 0.000536 through ANOVA test. This result implies that the two municipalities perform less than they get from the central government.

Insert Table 8 about here

3.4 The integrated efficiency of MSW management

In the analytic hierarchical process, we firstly construct a hierarchy of relative importance of each stage in affecting MSW management. The relative importance of the three stages interviewed with five respondents including one official, two scholars and two housewives is listed in Table 9. Based on the pair wise comparison scale, the respondents are asked, and then we build up a preference multiplicative matrix. The weights of the three stages are calculated by finding the eigenvalues of the matrix and we obtain the weighting factors: F_g = 0.359, F_s = 0.114 and F_c = 0.527 according to the AHP procedures. Although solid waste generation is not technically a part of the waste management system, it has strong impacts on the integrated performance of MSW management with 30.4% of weighting factor. Waste prevention[7] is regarded as an effective tool to solve MSW problem and should be assigned the highest priority to form a policy guideline. Minimizing waste generation means to reduce the relevant waste stream and thus all the respondents consider it is more important to sorting in affecting MSW management practice.

Insert Table 9 about here

MSW sorting into general wastes and recyclables at source (home) is a vital part in affecting MSW management performance. Household waste sorting has become a habit and gain popularity in Taiwan even though the number of double income family increase. The attitude of the housekeepers in the family is decisive in the success of recycling activities. Chen and Chen (2008) present evidence that MSW management policy has significantly impacts on recycling (sorting) in Taiwan. Most respondents consider sorting is important, but cannot determine the integrated efficiency of MSW management practice. Due to resource limitations, the decrease in waste generation seems to bear the same level of importance as the increase in sorting (recycling rate) in improving public health risks and environmental impacts in Taiwan or even contributes more.

An important point here is that in case of waste collection, the government has a fully responsibility and might consider social objectives as a primary guiding principle in formulating management practice. Table 8 lists the integrated efficiency of MSW practice in Taiwan. It is roughly estimated that there is no evidence to find a significant difference of the integrated efficiency between urban regions and rural regions.

Table 8 indicates the two municipalities rank the bottom among the regions, and thus, we compare the integrated efficiency of the two municipalities with the remaining regions

[7] Preventive measures cover waste minimization, reduction at source and reuse of products.

through ANOVA test. The result shows that a significant difference exists with 63.35% of mean integrated efficiency for the two municipalities and 85.09% for the other cities/counties (p-value of 0.001726). The low integrated efficiency of the two municipalities is caused by their low collecting efficiency since the weighting factor of waste collection is much higher than the other two activities. It implies that the two municipalities seem not so careful and concerned in administration and waste management practice as other cities/counties.

The result shows that the equality of the waste collecting and integrated efficiency is recognized between the urban and rural regions but a significant difference exists between the two municipalities and other cities/counties. The possible explanation may be due to the given and legalized resource allocation. The resource allocation including man power, equipments and budgets are determined by the level of the city/county in the governmental hierarchy, the population and size of service area according to the relevant laws.

4. discussions

The food waste in Taiwan constitutes the major portion of municipal solid waste (MSW), accountable for 27.19% in 2003 and 34.57% in 2006, but its recycling rate is still low even it increased from 2.27% in 2003 to 8.31% in 2006. The high proportion of organics in the MSW suggests the possibility of converting the organic component of the waste into a state in which it can be handled and reused without adversely affecting the environment. Composting of solid wastes is economically, environmentally, and socially beneficial to almost all the stakeholders. When the health consciousness arises and yields high demand for organic agricultures that suggests a reduction in dependence on chemical fertilizer. Organic fertilizers composted from food waste become economic and beneficial to the producers.

Facing the depletion of exhaustible resource and cost increase of extraction, more and more voices call for the state intervention to regulate the recycling rate. Recycling is optimistic for a society as a whole that the competitive struggle between primary and secondary producers increase the prospects for maintain the long run sustainable development. Many economists emphasize that recycling method provides two benefits: resource recovery and environmental cleaning. Complete recycling is impossible but it can serve as an auxiliary tool to reduce environmental impacts of resource scarcity. Recycling or reuse diminishes the environmentally detrimental flow of waste for incineration or landfilling, and also economizes on the use of scarce natural raw materials. However, some researchers suggest that energy recovery from MSW incineration is more economically favorable than material recovery through MSW recycling system in presence of the district heating system (Holmgren and Henning, 2004; Holmgren and Gebremedhin, 2004).

Recycling rate can be motivated through monetary incentives and rewards, but it may returns to normal low rate once the incentives have ceased. Environmental education on households (consumers) and producers may be a more effective way to improve MSW management efficiency as MSW generation involves with two activities: green consumption and clean production. To achieve sustainable development, it is crucial that we should persuade households to change their living style into green consumption and encourage producers in clean production. In other words, we must work in partnership/with businesses, local authorities, community groups and the public. To increase the participation rate in behaving environmentally including green consumption and clean production[8], public education is vital to aware environmentalism (Evison and Read, 2001; Thomas, 2001; McDonald and Oates, 2003; McDonald and Ball, 1998) or an economic incentive is proved to be effective (Noehammer and

[8] Clean production through product redesign or process innovation becomes of increasing importance in environmental management. .

Byer 1997; Dahab et al. 1995).

Governmental organizations face multiple objectives for MSW management such as the environmental cleanness, social securities, environmental protection etc., but their practices are also constrained by limited budgets. In this paper the additional costs of increased sorting at home is not incorporated into the model since it is unclear and uncertain to what extent households actually perceive their contribution as a cost. The aesthetic and environmental sanitation improvement on the ground in the service area is also not incorporated into the assessment model due to the unavailability of data acquirement. The characteristics of the service area (e.g. size and population density) reflect the difficulty of MSW collection in the service area. For example, it makes the collection more difficult when the service area is hilly. The larger the service area is the more difficult and more costly to collect it.

5. Conclusions

Traditionally, efficiency reflects the internal capabilities in production and effectiveness may align to and oriented by organizational objectives. They appear a somewhat elusive concept, and more or less tends to have a positive relationship with performance. A great number of authors criticize the excessive focus on efficiency only and suggest that the appropriate balance in each case between efficiency and effectiveness as well as between long-term and short-term perspectives should be conducted (Hauser, 1998; Karlsson et al., 2004). The efficiency in this paper has incorporated governmental objectives into calculation to reflect the effectiveness of MSW management.

Most research on the performance of solid waste management practice has focused on MSW collection and recycling only while this paper looks in more detail at waste generation, sorting and collection in Taiwan and the research results provide some valuable information. Due to the regulation of compulsory sorting at home, this paper suggests that the efficiency for waste generation and sorting involves with household environmental behaviors while MSW collecting depends on the organizational management of local authorities. This paper sheds the light on the significance of waste generation and sorting at home that most local authorities have underestimated. The separation of MSW management performance into waste generation, sorting and collection can fully reflect the objectives of environmental management that are the mix of environmental education on households, organizational management of local authorities, environmental policy affecting clean production. These results can be translated into a municipal policy and consequently affecting MSW management practice and the assessment on the performance of each stage in the MSW collection process forms a paradigm shift in dealing with MSW management in complying with the objectives of sustainable development.

This paper also focus on the comparison of the urban regions (in general have high incomes) and the rural regions that is believed to be poorly developed in MSW management practice, and examines the impacts of urbanization on waste generation, sorting and collection. We employ DEA techniques to analyze the relative efficiency of DMUs in proxy of performance assessments are easily understood and can improve actual efficiency through a collaborative, participative change program. Based on the performance of individual local authorities for MSW collection and households for waste generation and sorting assessed in this paper, a series of statutory recycling targets for individual local authorities should be set for future management practice use. The target setting may bring about consequent actions planned by local authorities to implement and modify recycling and composting strategies in order to meet their respective targets. Perrin and Barton (2001) emphasize that policy makers should be cautious and aware of the consequences of their decisions as regards the number and effectiveness of participants in a scheme to design, implement the kerbside recycling schemes. In the future, the greenness of the products on the market should be provided on the product label for customer's guidance.

The proper assessment on MSW management practice is essential to the environmental and economic well being of our society and its sustainable development in the future when the measurement is design to reduce waste generation and increase recycling rate. The performance measurement on each stage of MSW management practice may provide criteria for local authorities and the central government to prepare the planning of public waste collection services and MSW management. It also can reduce the negative aspects such as the scarcity and insufficiency of planning, as well as nonscientific, disorganized, and informal MSW management. The framework presented in this paper can work as a guide for the future analysis and discussion of the effects of environmental education on sustainability.

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Table 1. The input and output variables in generating, sorting and collection stage

stage	Involved parties	Input variables	Output variables
MSW generation	Households	MSW generated	Population, and household disposal income
MSW sorting	Households, local authorities	General wastes, population, man power for waste collection	Resource recyclables collected, food wastes collected
MSW collection	Local authorities and central government	Manpower, equipment and budget for MSW collection	general waste collected, resource recyclables collected, food waste collected, size of service area and population served.

Table 2. The household disposal income in 2006 between the urban and the rural regions.

	Number of county/city	Mean value	variance
Urban regions	10	NT$ 967,730	2.28E+10
Rural regions	13	NT$ 750,668	3.98E+9

Table 3. the descriptive statistics of recyclables collected in 2006

	Urban regions	Rural regions	Whole regions
Resource recyclables (ton/yr)	1,456,424	643,630	2,100,054
Food wastes (ton/yr)	356,150	209,375	565,525
Total (ton/yr)	1,821,574	853,005	2,665,579
Per capita resource recyclables (ton/yr)	0.111	0.067	0.092
Per capita food waste (ton/yr)	0.028	0.022	0.025
Per capita recyclables (ton/yr)	0.139	0.089	0.117
Population (10^3)	13,121	9,617	22,738

Table 4. the performance of municipal waste generation among regions

City/county	Rank	Per capita waste Generated (kg/yr)	DEA rank	DEA efficiency
Taichung County	1	270.7458	1	100%
Yunlin County	2	276.8454	1	100%
Taichung City	3	287.6756	5	95.76%
Hsinchu County	4	287.7826	1	100%
Changhua County	5	296.038	7	91.82%
Miaoli County	6	306.6714	6	92.06%
Nantou County	7	319.7799	9	88.31%
Tainan County	8	321.8499	11	84.66%
Taitung County	9	324.2954	6	92.82%
Chiayi County	10	325.0595	10	85.92%
Taipei County	11	328.798	14	82.34%
Pingtung County	12	331.0804	13	82.86%
Kaohsiung County	13	334.2508	16	81.09%
Yilan County	14	337.1432	12	84.26%
Penghu County	15	360.0652	1	100%
Taipei Municipality	16	364.9851	19	74.18%
Chiayi City	17	365.2243	15	82.14%
Hualien County	18	365.2514	17	79.19%
Taoyuan County	19	366.0738	20	73.96%
Keelung City	20	374.9974	18	76.80%
Kaohsiung Municipality	21	386.4038	21	70.41%
Hsinchu City	22	431.1349	22	69.69%
Tainan City	23	517.9314	19	74.18%

Table 5. The result of ANOVA on waste generation efficiency between urban areas and rural areas.

source	SS	df	MS	F	p-value
factor	0.05117	1	0.05117	6.669937	0.0017364
source	0.161105	21	0.007672		
total	0.212275	22			

Table 6. The ranking of sorting efficiency and recycling rate across regions

City/county	DEA Rank	Sorting efficiency	rank	Recycling rate
Taichung City	1	100%	1	50.21%
Yilan County	1	100%	5	44.27%
Tainan City	1	100%	2	49.21%
Hsinchu City	1	100%	6	42.36%
Hualien County	5	92.89%	4	44.44%
Taoyuan County	6	89.90%	7	41.76%
Nantou County	7	88.58%	8	40.88
Taipei Municipality	8	88.53%	3	44.58%
Keelung City	9	81.78%	9	40.16%
Penghu County	10	79.30%	10	39.11%
Kaohsiung Municipality	11	76.70%	11	37.23%
Taitung County	12	67.94%	13	30.98%
Hsinchu County	13	65.78%	12	32.01%
Kaohsiung County	14	62.56%	14	29.59%
Taichung County	15	61.28%	16	28.78%
Changhua County	16	60.31%	17	27.76%
Miaoli County	17	60.01%	18	27.45%
Taipei County	18	58.47%	15	29.09%
Pingtung County	19	50.00%	19	24.35%
Tainan County	20	47.46%	20	22.16%
Yunlin County	21	45.77%	21	21.51%
Chiayi County	22	44.24%	22	20.57%
Chiayi City	23	43.06%	23	19.14%

Table 7. The result of ANOVA on waste generation efficiency between urban areas and rural areas.

source	SS	df	MS	F	p-value
factor	0.114646	1	0.114646	3.181498	0.088936
source	0.756737	21	0.036035		
total	0.212275	22			

Table 8. The MSW generation, sorting, collection and integrated efficiency

	generation	sorting	collection	integrated	ranking
Taichung City	95.76%	100%	100%	0.98711	1
Yilan County	84.26%	100%	100%	0.95215	2
Nantou County	88.31%	88.58%	100%	0.939567	3
Tainan City	74.18%	100%	100%	0.921507	4
Hualien County	79.19%	92.89%	100%	0.921238	5
Taitung County	92.82%	67.94%	98.85%	0.902785	6
Hsinchu City	69.69%	100%	100%	0.891187	7
Taichung County	100%	61.28%	94.63%	0.889922	8
Miaoli County	92.06%	60.01%	100%	0.888684	9
Changhua County	91.82%	60.31%	100%	0.888609	10
Yunlin County	100%	46%	99.96%	0.881587	11
Hsinchu County	100%	65.78%	87.58%	0.866033	12
Taoyuan County	73.96%	89.90%	92.55%	0.863209	13
Tainan County,	84.66%	47.46%	96.20%	0.820665	14
Kaohsiung County	81.09%	62.56%	88.54%	0.806116	15
Chiayi County	85.92%	44.24%	87.02%	0.773596	16
Chiayi City	82.14%	43.06%	88.60%	0.767084	17
Pingtung County	82.86%	50%	80.72%	0.746736	18
Keelung City	76.80%	81.78%	65.01%	0.7225	19
Taipei County	82.34%	58.47%	71.25%	0.718353	20
Penghu County	100%	79.30%	47.49%	0.703876	21
Kaohsiung Municipality	70.41%	76.70%	53.48%	0.636887	22
Taipei Municipality	74.18%	88.53%	44.27%	0.630113	23

Table 9. The relative importance revealed by the five respondents

Respondents	#1	#2	#3	#4	#5
Waste generation: waste sorting	5	3	2	2	4
Waste sorting: waste collection	1/9	1/9	1/5	1/3	1/3
Waste generation: waste collection	1/3	1/2	1/2	1	1

附件二：

A development of MSW management practice in Taiwan

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Abstract

The generation of municipal solid waste (MSW) in Taiwan has reached to a peak of 8,992,240 ton in 1987 and gradually decreased from then. The portion of MSW delivered to landfill sites for final treatment decreased while MSW for incineration increased. The pressure of MSW management problem seems reduced, but the attention of MSW management has shifted to focus on efforts to prevent pollution through green consumption and clean production (the re-design of products or modification of production processes) when resource scarcity becomes evident and the call for sustainable use of natural resources to go towards the ultimate aim of sustainable waste management emerges.

An integrated MSW management system is required for efficiency and effectiveness in achieving objectives of sustainable development. This paper outlines the municipal solid waste (MSW) disposal process and identifies the objective in each stage of the process, derives the environmental implications of the currently operated wastes management practices, and develops the strategies for effective MSW management and environmental measures adopted by the government for MSW disposal. The anlysis on Taiwan's current operated MSW management, we find that Taiwan face following challenges: (1) the encouragement of clean production and green consumption for the reduction of per capita MSW generation, (2) the incentives for encourage sorting and voluntary recycling through a user-charge system, (3) the extension of service coverage of incumbent facilities (including land-fills and incineration plants), (4) effective legal and economic instruments to promote waste reduction and resource recovery, (5) to facilitate public/private partnership to implement waste minimization and product responsibility schemes. Based on these challenge, we developed a MSW management practice.

Keywords: municipal solid waste, collecting, recycling, income-based disposal fee

1. Introduction

The focus of MSW management has been shifted to the sustainable use of natural resources in addition to the removal of pollution thorugh waste prevention, material recycling and energy recovery in developed countries (Kettunen and Vuorisalo, 2005). The MSW management system currently operated in Taiwan is decentralized to a variety of departments including Energy Bureau (responsible for energy policies), Financial Department (responsible for tax reduction of product sales), Education Department (responsible for environmental education), etc. and urgently requires integrating this department for achieving a sustainable development in the long run. An integrated MSW management system is required for efficiency and effectiveness in achieving objectives of sustainable development.

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2. The current problem of Taiwan's MSW management

In general, the treatments of solid waste are divided into four categories: land-filling, incineration, recycling and composting. Table 1, based on (1) final disposal, (2) food waste recycling, (3) resource recycling and (4) macro article for reuse categorized by Taiwan EPA (Environmental Protection Agency), describes the general trend during 2001-2005. This table provides some special features of MSW management in Taiwan:

Waste generation: The yearly total MSW generated has reached to a stable state since 2001, fluctuating from 7,355,355 tons to 7,839,175 ton, and yearly per capita MSW generation ranged from 326.99 to 351.86 kg during 2001-2005 (please see Table 1). Chen and Chen (2008) finds a Kunzites curve exists for MSW generation in Taiwan with a peak point occurred in 1997. This demonstrates that MSW generation has reached to a flat trend and is difficult to reduce since it is affected by economic development and consumers' environmental consciousness. Such a change in the amount of municipal wastes generated in recent years results mainly from the Kuznets effects and policy modification (Chen, forthcoming). The amount of MSW generated has keep paced with developed countries, for example, Greece, Slovenia and Germany (0.30–0.32 ton), OECD[9] at average of 360-620 kg per year per capita.

Waste collection and recycling: The MSW collected for final treatments (by land filling or incineration) has reduced from 7,254,626 ton in 2001 to 5,525,253 ton in 2005, i.e. per capita MSW collected is decreased from 325.64 kg in 2001 to 243.08 kg in 2005. In the meantime, MSW recycled for resource recovery increased from 584,333 ton in 2001 to 1,756,305 ton in 2005 with recycling rate of 7.45% in 2001 and 22.67% in 2005. Per capita waste recycled increased from 26.22 kg in 2001 and 77.25 kg in 2005. On the other hand, food waste recycling increases from 216 ton in 2001 to 463,400 ton in 205. The total MSW recycling (resource recycling and food waste recycling) has been increased from 584,549 ton (7.45% of total MSW generation) in 2001 to 2,219,435 ton (28.65% of total MSW generation) in 2005.

Although food waste recycling rate has been improved from 216 tons (0.0027% of total MSW generation) in 2001 to 463,400 tons (5.98% of total MSW generation) in 2005, the space for further improvements is still very large when we consider waste food accounts for 38.14% for Taiwan's MSW generation (please see Table 2) in 2005 which is much higher than 24% in UK (Porterous, 2005, Table 2). As the heat value of waste food is very low, it is not efficient to recover the energy through incineration process. A centralized composting for food wastes is an effective to improve resource use by converting it to biological fertilizer. In Taipei, food wastes are collected separately from the general waste stream and transfer for further composting.

Waste treatments: When MSW cannot be recycled or re-used technically, it should be generally treated by land filling or incineration. In the past decade, land filling was once believed an effective way and rational alternative to manage waste and provides a convenient and cost-effective solution to disposal of solid waste in practices (Mills, et al., 1999). However, land-filling can not solve environmental problems completely since some materials such as plastics, complex materials, etc. can not decompose in the soil and the anaerobic decomposition of waste in landfill site will generate gas, leachate and disamenity. It just hides the problem under the ground and postpones the problem to the next generation. Moreover, land-filling space is becoming a scarce resource and difficult to find out an appropriate sites in many countries because of the opposition from the near-by inhabitants who consider the possible risk of the environmental contamination problem even the administrator emphasize the minor effect on environment. Keeler and Renkow (1994, p. 206) state: "Since that time [1950] available landfill space has diminished while the cost of siting and building new landfills has increased tremendously, fueled by rising land values and by the political and transactions costs of reckoning with increased local opposition to new facilities." Collins (1996) states, "Toward the end of the 1980s there was a sudden awareness in the USA and several European countries, especially (West) Germany, that they were rapidly running out of landfill space." In Taiwan, we face the same problem of lacking of available land-filling space. In Table 1, the solid waste disposal by land-filling increased from 12,147 ton/day in 1986 to a peak of 20,912 ton/day in 1994, and after

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[9] The data is cited from Grodzinska-Jurczak (2001).

then decreased continuously to 3,342 ton/day in 2005.

In contrast, incineration method gradually and constantly increased from 191 ton/day in 1986 to 11,864 ton/day in 2005. As the total designed capacity of incineration process is 20,000 ton/day (please see Table 4) and more new incineration plants will be completed in the coming few years, the disposal of household waste by incineration process is expected to keep increasing.

Table 1. General statistics of MSW collected and recycled in Taiwan

	2001	202	2003	2004	2005
Final disposal (MSW collected)	7,254,626	6,719,935	6,139,050	5,862,891	5,525,253
Incineration	3,736,891	4,316,049	4,304,573	4,307,737	4,300,399
Landfill Sanitary	2,996,805	2,116,375	1,700,438	1,474,166	1,184,599
Landfill General	433,330	224,477	113,115	63,647	35,217
Dumping	73,040	55,076	20,190	16,140	4,934
Others	14,560	7,958	734	1,201	104
Food waste recycling	216	3,706	167,304	299,264	463,400
Composting	216	3,706	22,290	66,562	97,535
Pig Feed	-	-	139,614	223,841	359,021
Others	-	-	5,400	8,861	6,844
Resource recycling	584,333	878,319	1,048,981	1,392,715	1,756,035
Macro article for reuse	-	-	-	-	29,575
Total MSW generation	7,839,175	7,601,960	7,355,335	7,554,870	7,744,688
Population#	22,278	22,396	22,494	22,647	22,730
per capita MSW collected (kg)	325.64	300.05	272.91	258.88	243.08
per capita resource recycling (kg)	26.22	39.21	46.63	61.49	77.25
Per capita waste generated (kg)	351.86	339.26	326.99	333.59	340.72

#: unit: 1,000 Persons

source: Taiwan EPA (2006).

Waste composition: The waste characterization of MSW collected which is finally delivered to incineration plants or land filling sites for final treatments plays essential impacts on the development of an effective MSW management. A typical analysis of Taiwan MSW composition is given in Table 2. Based on the refuse characteristics, we find that the portion of incombustibles reduces from 9.57% in 2002 to 4.03% in 2005 and waste food increases from 23.34 % in 2001 to 38.15% in 2005. The organic matter in MSW is still high because of low efforts to the recycling of food wastes, or relatively much better in resource recycling on the other hand. Considering the weak point of incineration process for waste food, Taiwan EPA starts a plan to recycle waste food for pig farms or bio-composting in 2001 and from then on the food waste recycled increase.

Table 2. The nature of MSW collected (unit: %)

		2002	2003	2004	2005
combustibles	Paper	30.01	32.97	31.56	38.64
	Textiles	3.65	3.78	4.9	2.38
	Trimmings Garden	4.43	3.88	4.91	1.93
	Wastes Food	23.34	27.19	29.76	38.15
	Plastics	20.23	21.36	20.6	13.78
	Leather& Rubber	0.6	0.22	0.87	0.43
	Others	8.17	3.58	0.98	0.67

	Sub-total	90.43	92.98	93.57	95.97
Incombustibles	Iron	3.07	2.58	1.89	0.85
	Other Metal	n.a.	n.a.	n.a.	0.29
	Glass	4.11	3.54	3.61	2.08
	Others	1.56	0.69	0.61	0.8
	subtotal	9.57	7.02	6.43	4.03

Note that the plastics content in MSW is dramatically reduced from approximately 20.8% in 2002-2004 to 13.78% in 2005, which is still higher than 11% in UK. This result can be explained by the implementation of plastics limitation policy in 2004, which prohibit retailers to use plastics bag as packaging. The quantity of plastics in MSW is quite high. There is still left space for improvement in reducing plastics consumption or increase recycling. However, some authors argues recycling is not the unique method to improve the resource use when recovery is difficult and uneconomic (Chen, 200?).

In fact, plastic production requires much less manufacturing energy/kg than other packaging materials such as paper, Aluminum, steel, glass (Porteous, 2005). Porteous (2005, p. 452) argues that “It is clear that with energy recovery via EfWI [energy from waste incineration], there is a case for more plastics use, not less, if EfWI is used as a recovery route after use, where recycling is impracticable as it often is with soiled food packaging.”

Table 3. Energy recovery from incineration plants in Taiwan

year	Refuse Incinerated (Tonnes)	Power Generation (MWH)	energy recovery (KWH/ton)
2001	3,922,387.43	1,662,327.11	423.80
2002	5,310,999.74	2,503,212.17	471.32
2003	5,470,736.00	2,616,000.80	478.18
2004	5,611,504.81	2,769,920.77	493.61
2005	5,614,930.09	2,852,242.16	507.97

Comparing to the MSW composition in UK (please see Table 2 in Porteous, 2005), the paper content of MSW in Taiwan is 38.64%, higher than 31% in UK, and the plastic content in Taiwan 13.78% in Taiwan is also higher than 11% in UK, and the overall combustible in Taiwan is 95.97 in 2005 is also higher than 83% in UK. This means that incineration plants have more efficiency to recover energy from the MSW incineration in Taiwan. Porteous (2005) calculated the energy recovery performance in UK is about 500 KWH per ton of waste incinerated while Taiwan has improved its performance from 423.80 KWH per ton in 2001 to 507.97 KWH per ton in 2005 (Please see Table 5). It is apparently that the two countries have the same performance of energy recovery from MSW incineration plants. Taiwan, however, seems to perform worse since MSW in Taiwan contains more combustible waste and generates less electricity per ton of waste. The improvements of energy recovery in Taiwan can attribute to the adoption of energy recovery system which are equipped as a standard option with more and more capacity of energy recovery for newly-built incineration plants (please see Table 4).

Table 4. Refuse incineration plants in Taiwan

Location	Incineration capacity (ton/day)	Power generation capacity (KW)	Ratio of power to incineration	Starting date
Taipei Neihu	900	6,000	6.67	1992,10
Taipei Mucha	1,500	12,000	8	1994, 3
Taipei Shinten	900	16,300	18.11	1994, 5
Taipie Shulin	1,350	24,800	18.37	1995, 6
Taichung	900	13,000	14.44	1995, 5
Chiayi	300	2,500	8.33	1998, 11
Taipei Peitou	1,800	42,000	23.33	1999, 5
Tainan	900	15,800	17.55	1999, 8

Kaohsiung chungchu	900	25,500	28.33	1999, 9
Kahohsiung nanchu	1,800	49,000	27.22	2000, 1
Kaohsiung Jenwu	1,350	33,700	24.96	2000, 5
Taichung Houli	900	25,000	27.77	2000, 8
Shingchu	900	23,666	26.30	2000, 10
Pingtung	900	24,750	27.50	2000, 12
Chanhua Shichou	900	22,600	25.11	2001, 1
Kaohsiung Ganshan	1,350	38,000	28.15	2001,7
Taipei Pali	1,350	35,771	26.50	2001, 9
Chiayi Luchau	900	25,000	27.77	2001, 11
Keelung	600	14,300	23.83	2006, 3
I-Lan Lizer	600	14,300	23.83	2006, 4
Tainan Yunkang	900	21,500	23.88	Under construction

Considering the current operated characteristics of MSW management, Taiwan face a great challenge to achieve these objectives and the following issues should be addressed for further improvements:

-the encouragement of clean production and green consumption for the reduction of per capita MSW generation

-the incentives for encourage sorting and voluntary recycling through a user-charge system.

-the extension of service coverage of incumbent facilities (including land-fills and incineration plants).

-enhancement in sorting motives to increase recycling rate.

-effective legal and economic instruments to promote waste reduction and resource recovery

-to facilitate public/private partnership to implement waste minimization and product responsibility schemes.

3. MSW management practice: objectives and guiding principles

In responding to the increasing challenge to Taiwan MSW management, the management practice should meet the general objectives of MSW services which are: (1) protecting public health and well being of the communities, (2) mitigating the opposition to NIMBY facilities, and (3) the overall objective of sustainable development which presented by WCED in 1987 and has been generally accepted as a supreme objective for environmental management since then. The management practice developed in this paper is guided by these objectives and thus it is holistic and tailored to the social, cultural, economical and environmental circumstances.

MSW management practices comprise a series of inter-linked activities and involves many social actors, in general, including the manufacturer for final products, consumers (households) as well as service users, the service producers or contracted units by the government for MSW disposal, disposal utilities (for example, incineration plants, resource recovery plants, etc.) and the policy planners or the regulators (please see Figure 1). All the activities by these social actors are directed and guided by the social objectives that are formulated through the interaction among stakeholders.

Miller, Jr. (1999) proposes a low-waste society model based on the three thermodynamics laws and concludes “the best long-term solution to our environmental and resource problems is to shift from a society based on maximizing matter and energy flow (throughput) to a sustainable low-waste society or earth-wisdom society. The sustainable development of a society is done through "(l)reusing and recycling most nonrenewable matter resources, (2)using potentially renewable resources no faster than they are replenished, (3) using matter and energy resources efficiently, (4) reducing unnecessary consumption, (5)emphasizing pollution prevention and waste reduction, and (6) controlling population growth” (Miller., Jr., 1999, p. 67). Many economists suggest using prevention methods to reduce the generation of solid waste at the source. The reduction of solid waste generation not only yields significantly beneficiate to the environment but also can reduce the investment in disposal. Montague (quoted from Miller, 1999, p. 69) argues, "To deal with these [environmental] problems, industrial societies must abandon their reliance upon waste treatment and disposal and upon the regulatory system of numerical standards created to manage the damage that results from relying on waste disposal instead of waste prevention. We must - relatively quickly – move the industrialized and industrializing countries to new technical approaches accompanied by new industrial goals -namely, "clean production" or zero discharge systems" and suggests, "Goods manufactured in a clean production process must not damage natural ecosystems throughout their entire life cycle, including (1) raw materials selection, extraction, and processing; (2) product conceptualization, design, manufacture, and assembly; (3) materials transport during all phases; (4) industrial and household usage; and (5) reintroduction of the product into industrial systems or into the environment when it no longer serves a useful function" (quoted from Miller, 1999, p. 69).

Under such a circumstance, the basic objectives of the proposed management practice are proposed including: (1) Avoid the generation of waste through clean production (responsible by manufacturers), and green consumption (responsible by consumers) which should be supported by environmental education (by the government). (2) Re-use unavoidable waste through the implementation of environmental policy that regulates the use of disposal products, (3)waste minimization and resource recovery inducing material recovery and energy recovery should be undertaken through economic mechanism, (4) minimization of environmental impacts by choosing the disposal option with the least environmental impact if recycling is not economic, (5) Clean technology should be innovated through incentive system (responsible by the government), (6) information transparency, and (7) stakeholders’ participation.

The traditional MSW management assumes that the governments has sufficient capacity to manage pollution by employing appropriate policies to clean up accumulated contamination and control pollution emission at a regulated level through either by command-and-control system or economical instruments. By the 1990s, a new perspective emerges and focuses on an integrated management system that requires a prevention or avoidance of pollution at the beginning stage of product life cycle. And thus, the work of governments is shifted to all departments and agencies of governments and all the stakeholders.

Among the social actors, households play the most important role in affecting the operation of MSW management. Household collaboration is crucial to achieve the goal of waste minimization and avoidance. The impact of human behaviors (e.g. household consumption) on resources managements, the environment, and human health must be perceived by the public through appropriate environmental education which not only provide the development for human ability but also shape a sharing value as a constructive agency of improvising society which we intend to form. In fact, the environmental variables outside the environmental institution such as social values, environmental attitudes, and others organize the major part of factors affecting consumption behavior.

The role of service providers is to design a sorting/collecting and disposal system through the government’s policy support. When recycling system (including food waste composting) and sorting operation (separation process) are adequately set up and performed perfectly, the mixed solid waste for final disposal (land-filling or incineration) becomes less. As a consequence, collection of multiple waste fractions, which should be processed through different types of processing operations, becomes the focus for MSW management.

Producers play as a preventive role in affecting waste generation by adopting clean production or through product design for minimization of packaging. ISO 14000 offers two supporting tools in association with products to assist producers to reinforce environmental concerns. One is Environmental Life Cycle Assessment and the other is Environmental Labeling Standards. The former can generate information on the environmental aspects of their products, activities and services which can help the producers to make an appropriate choice with regards to materials, processes as well as to increase operating efficiency and reduce waste generation. The latter serves as a bridge between producers and consumers for communication of environmental aspects of products.

The role of the government is to coordinate the various viewpoints of all parties and integrate their opinions into a feasible plan or policy through the presentation of social objectives and provision of financial incentives to achieve the social objectives. Most environmental groups intend to review the performance of policies implementation and expect to participate in the decision of public policies. On the other hand, it also attempt to aware public environmental consciousness and to enhance strength in rational criticism and cooperation in responding a NIMBY facility.

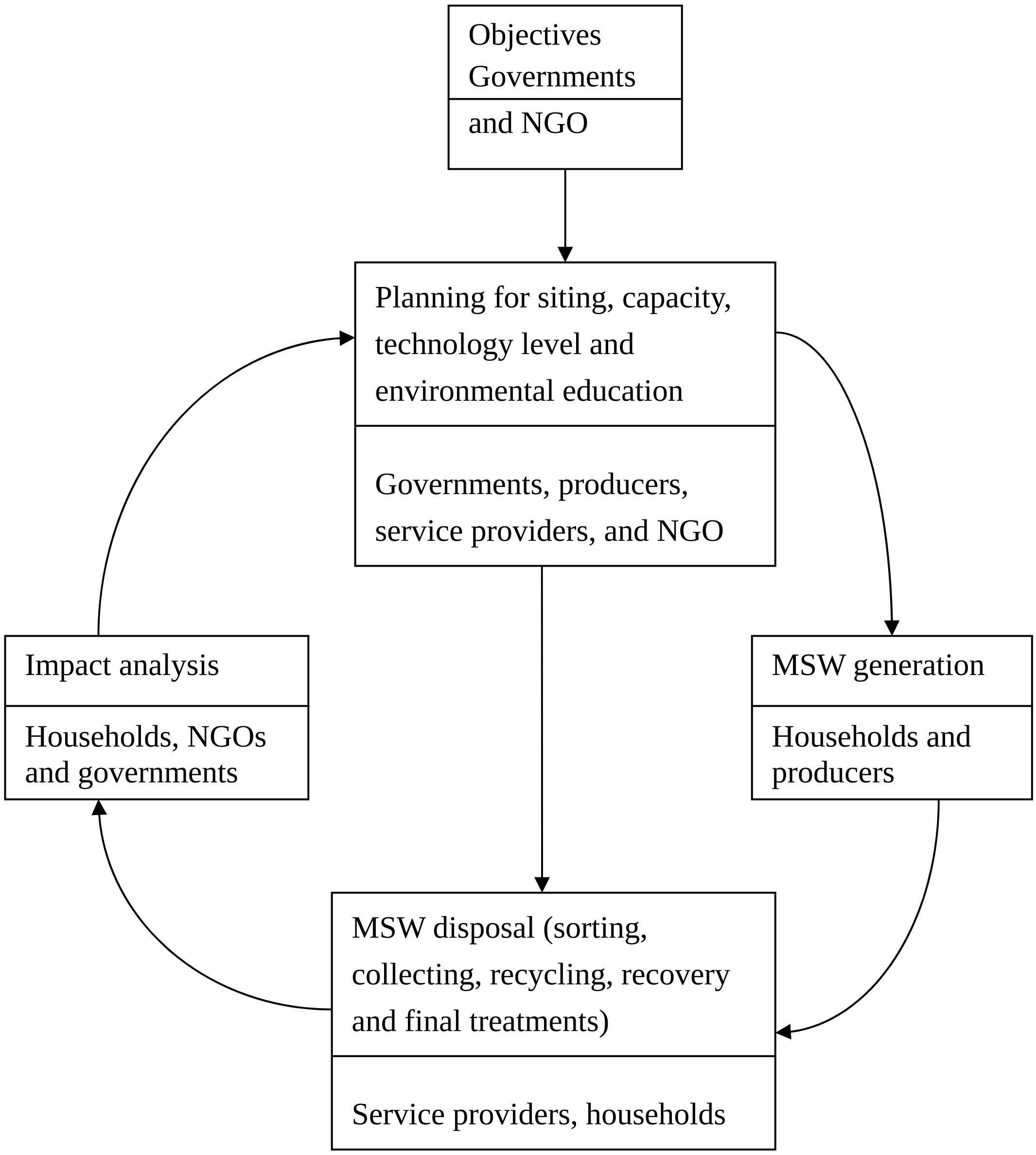

Figure 1. Schematic of MSW management process

4. Solid waste management practices

The development of MSW practices must comply with the aforementioned set of issues and to achieve sustainable and effective waste, especially it must consider the implementabiilty in association with the public acceptability. The strategic plan for MSW management practice provides a basis for integrating the roles of stakeholders including government authorities, service providers and other actors in the society for achieving a sustainable future. The management practice starts from the waste generation which is resulted from human and production activities and ends planning for siting, capacity and technology level of facilities, and environmental education (please see Figure 1). The proposed MSW management practice shown in Figure 2 describes the objectives, the involved social actor, the planned target and the performing strategy. The objectives and social actors have been discussed in the previous section. The target for each step of MSW management practice should be considered and set up for further assessment and improvement. In the practice, the target for each operation should be set up substantially and clearly with corresponding strategies. And the target must be reviewed and corrected periodically over time to keep a continuous improvement.

(1) MSW generation: The problem of MSW generation may be seen as a by-product of industrial development and human's over-consumption. In other words, it involves with the interactions of humans behaviors including human's green consumption and producers' clean production. The consumption patterns are also a factor to affect the total amount of solid waste generation in a society. Sustainable consumption[10] is considered and proclaimed to reduce the waste generation. A target about per capita MSW generation or per capita resource consumption can be set up. For example, the current per capita MSW generation is expected to reduce from 340.72 kg to 300 kg.

A product that cannot satisfy human needs or bring human disutility is called waste or residual. In this case, it is unavoidable that the pollution also comes from production system. In addition to clean production, the original manufacturer should also responsible for the collection of the goods that breakdown or reach the end of their usable life, for refurbishing[11]. A statutory regulation on producer's role in reverse logistic management for waste collection should be established.

(2) MSW disposal: the objectives of MSW disposal is not only to minimize the environmental impacts through the successful integration of sorting, collecting, composting, recycling and energy recovery to form successful waste management practice but also to increase resource supply due to resources scarcity (Chen and Chen, 1998). In other words, the MSW disposal process described in the practice is divided into (2.1) pretreatment: sorting and collecting, (2.2) recycling, recovery and composting and (2.3) final treatment: incineration and landfilling.

(2.1.1) Sorting: Sorting (separating the recyclable wastes from the rest of the refuse and dropping them off in the corresponding bin) at home is essential to resource waste recycling and material recovery in cost down and efficiency increase. Empirical studies find that households will be encouraged to participate in sorting and recycling if they bear the cost of waste disposal (Salkie, et al., 2001).

(2.1.2) Collecting: Currently, the collection of household wastes in Taiwan is carried out by the municipality and a small portion of household waste is collected by private haulers. Taipei Municipality imposes a waste treatment fee on households based on waste collected through garbage bag selling, but has a free charge on recyclable wastes[12]. The solid waste management implemented by Taipei Municipality by asking households to bear the cost of waste disposal shows that the recycling rate has increased and waste generation (collected for final disposal) has fallen.

The collection schemes are classified according to a number of important logistical characteristics in the empirical study of Jahre (1995) who survey on 47 collection schemes for household waste. He presents the major shortcomings about theoretical concepts and typologies in the prior

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[10] Sustainable consumption is defined as "the amount of consumption that can be continued indefinitely without degrading capital stocks including natural stocks" (Costanza et al., 1991, p. 8).

[11] A growing number of firms have taken a proactive approach by adopting clean production technology or thorugh product redesign for less waste generation and thus reduces the potential for liability (Thomas and Griffin, 1996).

[12] This policy has encouraged households to sort waste into recyclables and non-recyclables according to governmental regulations before waste collecting. According to Taiwan EPA, recyclable waste is classified into Category A (i.e. packaging containers) and Category B (i.e. objects where reverse recycling is deemed possible, such as motor vehicles, lubricating oils, tires, lead accumulators, dry batteries, pesticide containers, special environmental sanitary chemicals containers, and electronic appliances). Each item of recyclable waste should be recycled and separate recycling foundations are required to be developed. The recyclable wastes are separated into metal, glass, papers, and plastics for recycling by households before waste collecting.

research. In his study, the collection channel can enhance the understanding of the performance and high impact on the performance of collection. Jahre (1995) study the relationships between types of collection schemes and performance. The planning of refusal collection must consider household density (population distribution) in the region, the location of the facility and the route of waste transportation, market demand for MSW services, and the disposal technologies. The current MSW collecting rate has reached 99.0% (Taiwan EPA, 2007). This data shows that the collecting system is viable to satisfy household needs.

(2.2) recycling/recovery/composting: Complete recycling[13] is impossible due to Second Law of Thermodynamics. Ayres (1999, p. 475) argues that "It is true that the secondary recovery process will never be 100% efficient, due to the second law. So there will always be some waste from the recovery process itself". The useful matter in circulation however diminishes gradually in the absence of recovery process and thus recycling of solid waste is required because it is a way to re-use the material. Kitchen wastes can be collected for animal feedstock's or composted into fertilizers which are seen as two appropriate mechanisms for waste food materials as conditioners and fertilizers to be returned to the soil, thus providing a clear life-cycle benefit. The integration of recycling/recovery/composting into waste management practice can yield the benefits of conservation of natural resources, prolonging lifespan times of disposal sites, and the reduction of secondary pollution (Hassan et al., 2000; Vencatasawmy et al., 2000; Bai and Sutanto, 2002). A target of per capita resource recycling and per capita food waste recycling rate is set up in this practice plan.

(2.3) MSW treatments (incineration/flanfilling): All waste that stores in a storehouse or waste basket without any treatment will generate harm to the earth and thus the wastes that cannot be recycled and recovered should be delivered for final treatment that is a key issue in overall MSW management practice. In general, it is processed through incinerating or land-filling.

(2.3.1) Incineration is a process to convert solid waste into harmless gases suitable for atmospheric release and small amount of ash which can be more easily handled for ultimate disposal of land filling. Even though flue gas treatment such as scrubbing or filtration is added to lower concentrations to acceptable levels prior to atmospheric release[14]. Porteous (2005) argues that energy recovery is an essential part of a waste management strategy in operating incineration plants and considered as an integral part of an environmentally responsible and sustainable waste management strategy, where suitable quantities of waste are available. In this case, the target for flue gas emissions, utility consumption and energy recovery rate should be clearly set up.

(2.5) On-job training on facility practices: In the management practice, the training in occupational health and safety in MSW management is very important to identify the health hazards and thus build up safety and health protection measures required in MSW movement practices. A periodical and repeated training on the collectors should be conducted.

The working condition for collecting workers, however, is neglected in the developing country. Due to the exposure to hazardous situations, workers in general face high health risks. And thus a better design for working routines and equipment is required.

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[13] Ayres (1999, p. 474) says "… perfect recycling is 'categorically impossible', whence matter becomes dissipated and unavailable for human use in the same way that the second law prescribes for energy". Perfect recycling may be possible only if exogenous energy flux is unlimited. Ayres (1999) presents a stable recycling system in which it includes active element and inactive masses to explain the equilibrium of the ecological system.

[14] Some atmospheric release of undesired materials like dioxin still take place due to technology uncertainty.

Table 1. The process of MSW disposal and corresponding strategy

Process	objectives	Actor/target	strategy
MSW generation	Waste avoidance: Clean production green consumption Reuse	❶ composition of MSW, energy intensity, carbon intensity ❷ per capita MSW generation ❷❹rate of green purchasing	Producers should take responsibility for the design and manufacturing of environmental friendly products, i.e. recyclable, bio-decomposable, and re-use through the incentives of environmental policies. Consumers (householders) are voluntary to minimize the MSW generation through environmental education. A policy of tax deductions is designed to stimulate households to use secondary (recycled) materials or environmentally friendly products. The sale of products regenerated or manufactured from recycled materials is granted for tax reduction.
Disposal: sorting at home	Waste minimization	❷ sorting rate, per capita resource recycling, per capita food waste recycling	MSW disposal fee is charged by sack, not by water consumption.
collecting	Waste minimization	❷❸ collecting rate ❸service to households ❸ cost down	Improving collecting patterns such as collection day, collection frequency, routes etc.
Recycling, resources recovery, composting	Waste minimization, resource recovery	❷ per capita resource recycling, per capita food waste recycling ❸recovery rate, utility consumption (e.g. power, water, etc.), emissions	Households are motivated to participate in voluntary recycling and composting programs. The choice of best available technology for resource recovery and operation management should be continuously improved.

incineration with energy recovery	minimization of environmental impacts and waste	❸ utility consumption (e.g. power, water, etc.), energy recovery rate, emissions	The choice of best available technology for incineration plants and operation management should be continuously improved for the increase in incineration efficiency and energy recovery rate, and the reduction in secondary pollution
Land filling	minimization of environmental impacts and waste	❸ secondary pollution, e.g. water contamination	Operation management should be continuously improved to avoid secondary pollution and extending the service life of facilities.
Impact analysis: Monitoring	Avoid potential impacts	❹❺ gases emissions	Effective monitoring on pollution released from waste treatment facilities and surveillance programs including post-closure maintenance of facilities should be provided.
Assessment	Avoid potential impacts	❹❺ health, environmental risks	Risk profiles for the concerned environmental impacts should be examined. periodical reporting
Environmental reporting	Increase stakeholder participation	❹❺ a periodical report through web sites or mass media	Information transparency should be reinforced so that more participation from residents can improve operating efficiency.
Planning for siting, capacity , and technology level of facility, and environmental education	mitigation of environmental impacts	❸ ❹ utility consumption (e.g. power, water, etc.), emissions	Incentives for technology improvements for facilities including recovery, incinerators etc.
	waste avoidance	❶❹ number of products certified by eco-label.	Incentives for clean production
	High participation in MSW management	❹❺ expense per year on environmental education, citizen's environmental attitudes	Environmental education is conducted on the public to aware households of environmental consciousness.

❶ represents producers ❷ households (consumers) ❸ service providers (disposal facility), ❹ governments (regulators), and ❺ environmental groups (NGOs).

(3) Impact analysis:

The continuous monitoring and environmental assessment on each operation of MSW management practice should follow since each operation of MSW management process (including sorting, collecting, waste transporting, inventory, land filling, incineration or recovery) inevitably yields more or less secondary pollution and results in health concerns. For example, the major pollutant deposition from gaseous emissions of facilities (e.g. incinerators), in general, is limited to a confined zone near the plant. Several monitoring sites chosen in the areas and some placed quite far from the plant in the direction of minimum dispersion are a minimum requirement to guarantee minimum impacts through periodical and continual monitoring. Since the secondary pollution may produce remarkable environmental impact and leads to NIMBY effect, further environmental assessment and environmental reporting is equipped to keep a transparent communication among stakeholders.

(3.1) monitoring: The monitoring network (e.g. sampling points, the control center, etc.) is fixed and analysis on the designed spot surrounding the facility location should be undertaken for following emissions at least:

-emissions from the stack of incineration plants and recovery plants

-emissions from the transport of solid residues from recovery plants to landfill

-residual emissions from landfill

-emissions related to waste handling facilities

(3.2) Assessment: Morselli, et al., (2005) present an integrated environmental monitoring system by using the concept of a life cycle assessment to obtain complete information about the incineration process and its environmental impact. In this system, some important peculiarities must be considered to avoid invalidity when the LCA technique is used to assess different waste management strategies (White et al., 1995; Finnveden, 1999). According to ISO 14040 (ISO, 2000), the impact assessment propose four basic steps through the tool of life cycle assessment including goal and scope definition, life cycle inventory, life cycle impact assessment, and life cycle interpretation. “Life cycle impact assessment” aims at evaluating environmental impact of the activity accompanied with the development of the project through appropriate tools of impact indicators. This step requires aggregate impact indicators for the inputs (materials, energy, capital) required by the production process and then an aggregation of different indicators to obtain a single figure of merit. The step is in practice critical because residents in most cases refuse to accept the outcomes calculated by purely scientific methods and keep on opposing attitudes.

(a) “Goal and scope definition” should describe at least the background and aims of the project, the social requirements and current supply in association with the supply of the products or services provided by this project, the benefit and cost analysis of the project, and the boundaries of the project. Each function unit for MSW management should be assessing on the impacts of each unit of revenue or profit. Although CO_2 emissions are not seen as pollution according to statutory environmental laws at present and no penalty system on CO_2 emissions is conducted, the impact of each function unit in association with carbon emissions should be assessed. The goal of LCA is to compare different sites for a NIMBY facility.

(b) “Life Cycle Inventory” should be based on a scientific data bank that focuses on the quantification of mass and energy fluxes and identifies the emissions of each function unit into the environment.

(c) Life Cycle Impact Assessment (LCIA), where the environmental impact of the activity is assessed by means of impact indicators. The purpose of LCA is to assess all possible environmental impacts from “cradle to grave” arising from an activity. These impacts can be either direct – like atmospheric emissions and water consumption of the production process itself – or indirect – like extinction of bio-diversity, or the destruction of natural beauty. The assessing sequence starts from the crude oil as inputs and terminates when the waste become inert and the product leaving the system, entering the life cycle of another product through recycling.

(d) “Life cycle Interpretation” attempts to bridge the gap of the scientific assessment and social assessment for possible changes or modifications of the system for reduction of more environmental impacts. Life Cycle Interpretation, which aims at evaluating possible changes or modifications of the system that can reduce its environmental impact.

(3.3) Environmental reporting: Bailey (1999, p. 255) argues that "Social reproach from local community newspaper reports provides a powerful incentive for local manufacturing plants to improve their polluting behavior. The right-to-Know Act, passed in 1986, has turned out to be a most effective environmental law". Many researchers argue that an effective management system required adequate communication and transparent informaiton to the public (Watts and Probert, 1999, Read, 1999b). In developed countries, a dramatic increase in the practice of corporate environmental reporting is going on. The information release to the public should be frequently and repeatedly through mass media system or through school institutions to educate the potential consumers. In this case, a facility needs to report the status quo of its operation like gas emissions, energy consumption, etc to the public.

4. Planning for siting, capacity and technology level of facilities, and environmental education:

(4.1) The major work of planning is to determine the facility location, the type of disposal type (by land-filling or incineration process), the extent of service area, the capacity, and the best available technology for handling MSW for proposed waste facility. Many researchers argue that the privatization of public service may be more efficient and provide better service to households (Brook, 1996, Jannuzzi, 2005) and the privatization of solid waste management has become a trend in many parts of the world. The privatization of MSW services may reduce risk and costs in operation, but it may sacrifice environemtnal justice. Thus, the planning for siting, capacity and technology level of facilities is governed not only by cost basis, but also rely on stakeholders environmental concerns (social utility).

(4.2) environmental education: Although external motivation is required to motivate households to make amenable to radical change, internal motivation through environmental education plays a more activated role and effective in achieving the overall objective of sustainable development. Ecologists suggest that environmental education may be more effective in reducing resources over consumption through an effective scheme of mind reform and social behavior reform (Dierking and Falk, 1985; Orams and Hill, 1998) in order to attain the social objectives when facing resource depletion or to avoid ecological disruption (e.g. Common and Perrings, 1992; Barbier, 1989; Barbier and Markandya, 1990). Environmental education is designed to lead to voluntary cooperation of environmental behaviors and as a seed to reinforce the environmental societal awareness of environmentalism and help the general public to develop their environmental consciousness and manage their daily lives in accordance with the objectives of sustainable development. Many researchers attempt to encourage the public in participating with recycling behavior and expect these environmental behaviors become the norm through repeated education and implementations of environmental programs. More educated people invest more effort in green consumption and more cooperated in MSW managements (Scott and Willits, 1994). A functioning public relations program may provide a high linkage with the implementation of a management system and feedback to the planning stage. The positive attitude of household collection and source separation in general, will lead to future improvements. In other words, the environmental education through the total participation, via the support of mass media to shape a common value system may be the most successful means to assure the goals of sustainability by enduring reduction in resource consumption.

5. Conclusion

The integration of MSW management mainly involves the activities of households, producers, service providers, NGO and the government. The proposed MSW management practice is developed based on the idea of integration and the challenges Taiwan currently face. It describes the interrelationships of the various actors in the filed and shows how the role of each actor fit together to achieve the overall objective. It also generates a process to encourage producers to become more environmentally efficient through the governmental policy of incentives on reusing and reducing the amount of materials used. The planning of the proposed has consider the impacts of economic efficiency and social response (including public acceptance, participation in planning and implementation, consumer behavior) on the implementation, and thus it can not only avoid damage to the environment, but also to satisfy the needs of households and stimulate operating efficiency of the facilities.

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附件三：

The role of policy objectives in affecting technical efficiency for a public facility: using data envelopment analysis

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Abstraction

Public–private partnerships in MSW disposal service have increased in recent years. Such a shift from public-operated mode to private-operated mode is primarily due to reform the weak performance of the public sector, reduce cost, improve efficiency, and ensure environmental protection. Privatization, especially in developing countries, is seen as fundamentally unfair both in conception and execution, and it is widely and increasingly unpopular. In this paper, we examine the disposal efficiency across the incineration plants operated either by purely public or by the public-private partnerships by using DEA technique to determine whether they are more effectively performed by the private sector.

This paper uses Data Envelopment Analysis (DEA) to compute the operation efficiency of MSW (Municipal Solid Waste) incineration plants in Taiwan based on various policy objectives. Due to the complex nature of service provision and its impact on policy objectives, we separate the overall efficiency into technical efficiency and service efficiency through the support of AHP. The results show that private-operated have a higher technical efficiency.

Keywords: DEA, technical efficiency, policy objectives, incineration plants

1. Introduction

Many researchers focus their attention on the contrast between environmental performance and business performance (e.g. Arlow and Gannon, 1982; McGuire et al., 1988). Aggregate measure of environmental performance must be able to reflect the objectives of environmental management that are the mix of abatement and prevention, compliance and control. It is very interesting to compare the relative efficiency among these incineration plants. However, it is difficult to measure the performance of local public goods or services such as MSW disposal, school education in case of different methods of financing and providing local public goods. To increase performance of local pubic goods or services, some system is commonly requested to implement. Different systems such as vouchers, privatization, and decentralization are proposed. Many empirical studies show that privatization is a powerful tool to improve the financial and operating performance of state-owned enterprises (SOEs). Omran (2004) compare the privatized firms with SOEs as control firms over 1994–98, and find that privatized firms do not exhibit significant improvement in their performance over SOEs.

The liberalization of MSW service sector since 2000 in Taiwan opens up new opportunities for the creation of the more efficient technology to increase competitiveness, but it also increase pressure on the service providers because of increasing environmental concerns. In order to avoid giving rise to an adverse effect on the environment, incineration plants attempt to increase their investment in energy recovery and enforce electricity conservation policies to reduce CO2

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emission, and thus new technologies should be adopted to minimize CO_2 emissions in order to abide by the recommendations of the Kyoto Protocol. There are three systems for MSW incineration service in Taiwan including: (1) purely public-owned public operated by local governments, (2) a system of cooperation between private parties and local governments, i.e. government-owned but operated by private firms, and (3) completely owned and operated by private providers.

In recent years, a variety of methods have been developed to measure environmental performance. Environmental performance is measured in terms of pollution control indexes, annual corporate environmental reports, reputation surveys, environmental surveys, independent third-party ratings etc. These methods have often been reported to be conflicting or ambiguous through many empirical analyses (Russo and Fouts, 1997). Traditionally, an environmental performance index (EPI) that is calculated by a designed indicator, is employed to provide condensed information about environmental related issues. A large collection of wide-ranging environmental indicators have been developed and widely applied to many fields (Althorn et al. 2001).

In contrast, DEA (Data Envelopment Analysis) as a robust and effective management tool that has been widely used for efficiency assessment in various sectors, especially in utility service sector. It identifies efficient frontiers for decision making units (DMUs) by mathematical programming. The advantage of this methodology is that it particularly suited for estimating multiple input and multiple output production correspondences. On the contrary, the major criticism of this method is that it neglects the existence of measurement errors and disturbances. The efficiency calculation can be done without any financial data. The special merit of this method is particularly appropriate for non profit-seeking organizations.

DEA has been employed to evaluate the relative efficiency among different organizational decision making units (DMUs) in various application and proved to be an effective approach in identifying the efficient frontiers (Abbott and Doucouliagos, 2003; Boufounou, 1995). Data envelopment analysis (DEA) has gained great popularity in measuring relative efficiency among non-governmental organizations and business sectors. Recently, it is also employed in measuring environmental performance since it can provide a synthetic standardized environmental performance index (Zhou, et al., 2007). For example, it is employed to estimate the technical efficiency of energy industries (Thompson et al., 1992; Hawdon, 2003), assess energy efficiencies of different organizations (Boyd and Pang, 2000; Ramanathan, 2000) and measure ecological efficiency (Dyckhoff and Allen, 2001; Korhonen and Luptacik, 2004). Fare et al. (1989b) evaluate the opportunity cost of transforming a technology by using radial measures of technical efficiency. In energy studies, DEA has been widely used to calculate the technical efficiency and scale efficiency in power generation plants or energy industries. See, for example, Raczka (2001), Kulshreshtha and Parikh (2002), Pacudan and de Guzman (2002), Jamasb et al. (2004), Pombo and Taborda (2006) and Vaninsky (2006).

The objective of this paper is to measure the operating efficiency of MSW incineration plants in Taiwan based on a list of selected policy objectives, and attempt to develop improved methods for accountability and evaluation of policy performance. This study also attempts to compare the relative efficiency of MSW disposal and policy compliance with MSW management.

3. Methodology

CCR model is a methodology for constructing an efficient frontier based on the observed data of the inputs and outputs provided by decision-making units (DMUs). The relative performance of a DMU is evaluated in comparison with the efficient frontier.

The service of MSW incineration service is executed by a technology whereby N DMUs transform multiple inputs $x \equiv (x_1, \ldots, x_m) \in \Re_+^m$ into multiple outputs $y \equiv (y_1, \ldots, y_s) \in \Re_+^s$, accompanied with policy objectives $z \equiv (z_1, \ldots, z_r) \in \Re_+^r$ (please see Fig. 1). In Fig. 1, the void line connecting policy objectives and production system of MSW incineration service demonstrates that policy objectives does not maintain a direct relationship with production system, but a by-product. In other words, incineration plants may neglect the policy objectives while the authority (the owner of the public facility) cares.

In this case, we review the environmental policy objectives and related polices released by EPA and the environmental reporting practices released by each plant. The stated objectives of Municipal Solid Waste Management in Taiwan EPA includes (1) the reduction of MSW generation for sustainable use; (2) increases in recycling of waste resources and energy; (3) the improvements of service in the rural areas, and to promote scientific research on MSW.

Community has common interests and shared norms and thus, the relationship with community is central to the success of MSW management. Democratic development and participation requirements from stakeholders represent the interests among each class in the society should be respected and the majority of stakeholders can assure for successfully achieving stated policy objectives.

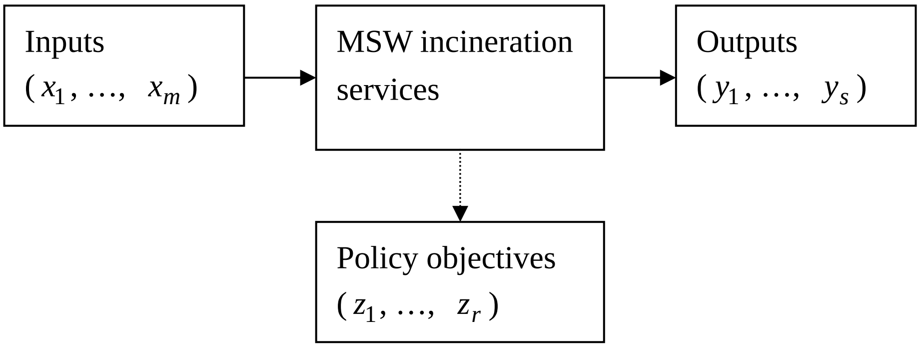

Figure 1. the production diagram for MSW incineration

During the incineration process, it may emit pollutions and damage the environment, and thus the resident's satisfaction may become an indicator to measure the overall efficiency of MSW incineration service. In this paper, we apply a two stage model and separate the overall efficiency into purely technical efficiency and service efficiency.

At the first stage, we measure the technical efficiency by BCC model that suppose the existence of variable returns to scale, expressed as:

$$\begin{aligned} &\min \quad \vartheta \\ &\text{s.t.} \quad \sum_{j=1}^{N} \lambda_j y_{jr} \geq y_{or} \qquad \forall\ r = 1, \ldots, s, \quad \forall\ j = 1, \ldots, N \\ &\qquad \sum_{j=1}^{N} \lambda_j x_{ji} \leq x_{oi} \qquad \forall\ i = 1, \ldots, m \\ &\qquad \sum_{j=1}^{N} \lambda_j = 1, \\ &\qquad \lambda_j \geq 0 \end{aligned}$$

Using the solved value of ϑ^*, we solve the following LP using (λ, s^-, s^+) as variables:

$$\begin{aligned} &Max \quad \sum_i s_i^- + \sum_r s_r^+ \\ &\text{s.t.} \quad s^- = \vartheta^* x_o - X\lambda \\ &\qquad s^+ = Y\lambda - y_o \\ &\qquad \lambda \geq 0, \ s^- \geq 0, \ s^+ \geq 0 \end{aligned}$$

Since the objective variables are fixed and cannot be changed, it should be treated as non-discretionary variables. When these objective variables are incorporated into the model, it can help to measure the effectiveness. In fact, efficiency and effectiveness are two indicators to measure two distinctive performances in an organization. Effectiveness indicators own the ability to state desired goal and to meet the goal while efficiency indicators related to benefit realized or resources used (Cooper, et al., 2000). The effectiveness measuring model is expressed as

$$\min \quad \vartheta - \varepsilon \left(\sum_{i \in D} s_i^- + \sum_r s_r^+ \right)$$

$$\text{s.t.} \quad \sum_{j=1}^{N} \lambda_j y_{jr} - s_r^+ = y_{or} \qquad \forall\, r = 1, \ldots, s \qquad \forall\, j = 1, \ldots, N$$

$$\sum_{j=1}^{N} \lambda_j x_{ji} + s_i^- = \vartheta\, x_{oi} \qquad i \in \text{D, where D is the set of general input variables}$$

$$\sum_{j=1}^{N} \lambda_j x_{ji} + s_i^- = x_{oi} \qquad i \in \text{ND, where ND is the set of objective variables}$$

$$\lambda_j \geq 0, \quad s_i^- \geq 0, \quad s_r^+ \geq 0$$

2.1 The variables

The common procedures for applying DEA to measure environmental performance are to first incorporate undesirable outputs in the traditional DEA framework. We attempt to create some broad insight form the analysis of the data in association with air pollutants and CO2 emissions to analyze the motives and incentives or some hidden causes to support the continuous improvement of environmental performance by renewing the production technology.

The input/output set specified is based on the objective function of incineration service including the minimization of resource, and maximization of number of households. The variables used for the computation of the operating efficiency for MSW incantation plants is listed in Table 2, in which it contains input variables and output variables. Four key criteria are suggested for the selection of inputs and outputs for a DEA frontier estimation including: (i) the factors cover the full range of resources used; (ii) the factors capture all activity levels and performance measures; (iii) the factors are common to all units; and (iv) environmental variation has been assessed and captured if necessary.

Since energy recovery is necessarily incomplete and limited by the second law of Thermodynamics, the composition of MSW before incineration should be examined to assure low moisture content but high heat value. MSW management practice should focus on waste generation and sorting that is mainly affected by household behaviors, and MSW collecting. Waste management prior to final disposal either by incineration or land filling is requested to meet a target of MSW composition, a target of recycling rate.

Waste disposal must reduce or even avoid environmental damage. Unfortunately, pollutants may be released from incineration process into the air (gas) or the ground (seepage) and yields deterioration of ecological systems. Some other researchers treat the undesirable outputs as inputs or to apply a monotone decreasing transformation (e.g.,1/yb, where yb represents the undesirable output proposed by Lovell et al., 1995). Seiford and Zhu (2002) propose an approach to reflect the real production process. It is invariant to the data transformation within the DEA model.

Table 2. The descriptions of inputs and outputs in model 1 for efficiency calculation

Variable descriptions	unit	remarks
Outputs -waste incinerated, y_1	Ton/year	The data is obtained from Taiwan EPA (2007)
-electricity generated, y_2	KWH/year	The data is obtained from Taiwan EPA (2007)
Inputs		

-man power,	Persons	The data is obtained by consulting with plant managers of each incineration plant.
- ash generation, x_1	kg	As ash is generated with the incineration of MSW and seen as a secondary pollution, and thus it is treated as input.
-operating costs, x_2	NT$	It is estimated by the sum of utility consumption.
Objective variables		
-installed incineration capacity, z_1	Ton/day	The data is obtained from Taiwan EPA (2007)
-installed electricity generation capacity, z_2	KWH/day	The data is obtained from Taiwan EPA (2007)
-heat content in MSW z_3	Kcal/kg	The data is obtained from Taiwan EPA (2007)

2.1 data

The relevant data of environmental aspects and impacts (raw materials, energy, emissions, waste, and noise), legal requirements and the organization of environmental protection at the site are checked and discussed firstly. Data for the research was primarily provided by Taiwan EPA, providing a comprehensive understanding on the historical operation of MSW incineration in Taiwan (please see Table 1). The chosen databases covered the aggregated, the public-operated, the public-owned-private-operated, and the private-owned. Data on emissions of air pollutants by all the incineration plants are compiled by Taiwan EPA covering the period of 1990-2006. The data for actual outputs including MSW incinerated and electricity generated is published by ???, the data for installed incineration capacity and power generation is compiled in Taiwan Environmental Protection Agency (Taiwan EPA, 2006), the data of man power in some incineration plants is obtained from the websites of each incineration plants and some is obtained by consulting the plant managers. The bad output data consists of emissions of SOx, NOx and CO by the manufacturing.

3. Results and discussions

The technical efficiency of each incineration plant based on CCR model and BCC model is shown in Table 3 and Table 4. The results show that the production frontier is composed of Hsin Chu Incineration Plant, Chiayi-Luchau Incineration Plant, I-Lan Incineration Plant, Taoyuan Incineration Plant, and Taichung-Wuji Incineration Plant. All these five plants are installed and operated after year 2000, with more up-date technologies than other plants. The overall efficiency depends on the type of incineration plant and the type of energy recovery technology. Old-fashioned technology may account for the low operating efficiency and high polluting index.

Table 3. The overall efficiency based on CCR model

DMU Name	Input-Oriented CRS Efficiency	Σλ	RTS	Benchmarks	
台北木柵	0.83158	0.688	Increasing	0.406	新竹市
台北內湖	0.83689	1.000	Increasing	1.000	台北內湖
台北北投	0.49561	0.677	Increasing	0.183	新竹市
高雄中區	0.89741	0.829	Increasing	0.169	新竹市
高市南區	0.68206	0.988	Increasing	0.234	嘉義鹿草

台中市南屯	0.93974	0.626	Increasing	0.225	新竹市
台南市安南	0.73239	0.561	Increasing	0.132	新竹市
台北縣新店	0.77477	0.589	Increasing	0.093	嘉義鹿草
台北縣樹林	0.82046	0.747	Increasing	0.747	桃園縣
台北縣八里	0.92970	0.973	Increasing	0.026	嘉義鹿草
嘉義市	0.91974	0.193	Increasing	0.044	新竹市
台中縣后里	0.97134	0.770	Increasing	0.107	新竹市
彰化縣溪州	0.87873	0.879	Increasing	0.007	新竹市
新竹市	1.00000	1.000	Constant	1.000	新竹市
嘉義鹿草	1.00000	1.000	Constant	1.000	嘉義鹿草
高雄縣岡山	0.69871	0.742	Increasing	0.285	新竹市
高雄縣仁武	0.84784	0.912	Increasing	0.088	新竹市
屏東縣崁頂	0.95560	0.956	Increasing	0.359	新竹市
宜蘭縣利澤	1.00000	1.000	Constant	1.000	利澤
基隆市	0.69887	0.401	Increasing	0.066	新竹市
桃園縣	1.00000	1.000	Constant	1.000	桃園縣
台中縣烏日	1.00000	1.000	Constant	1.000	烏日

Taoyuan Incineration Plant is constructed by the policy of Build-Operate-Own (BOO) and the other four plants are constructed by the pattern of Build-Operate-Transfer (BOT). In contrast, the public-owned and public-operated plants including the three plants in Taipei and two plants in Kaohsiung has lower technical efficiency (in average of 0.7487) compared to other plants with technical efficiency of 0.8922. The results imply that BOO or BOT could be a win–win solution due to the market mechanism is incorporated into the plant operation. It seems that public –owned public-operated inevitably had a negative effect on their technical (operating) efficiency. Some researchers suggest that the cause for the inefficiency of public-owned public-operated plants may attribute to low market competition. Competition is, in general, believed to be the major means to improve performance through the incentive provision to minimize costs. And thus the enhancement of competition mechanism may greatly increase incentives for production efficiency and improve the overall operation (Vickers and Yarrow, 1991).

Table 4. The technical efficiency based on BBC model

DMU Name	Input-Oriented BCC Efficiency	Σλ	RTS	Benchmarks	
台北木柵	0.85238	0.688	Increasing	0.406	新竹市
台北內湖	0.83959	1.000	Increasing	1.000	台北內湖
台北北投	0.51561	0.677	Increasing	0.183	新竹市
高雄中區	0.90897	0.829	Increasing	0.169	新竹市
高市南區	0.71682	0.988	Increasing	0.234	嘉義鹿草
台中市南屯	0.94994	0.626	Increasing	0.225	新竹市
台南市安南	0.74819	0.561	Increasing	0.132	新竹市
台北縣新店	0.79447	0.589	Increasing	0.093	嘉義鹿草
台北縣樹林	0.86926	0.747	Increasing	0.747	桃園縣

台北縣八里	0.93470	0.973	Increasing	0.026	嘉義鹿草
嘉義市	0.92354	0.193	Increasing	0.044	新竹市
台中縣后里	0.98123	0.770	Increasing	0.107	新竹市
彰化縣溪州	0.88345	0.879	Increasing	0.007	新竹市
新竹市	1.00000	1.000	Constant	1.000	新竹市
嘉義鹿草	1.00000	1.000	Constant	1.000	嘉義鹿草
高雄縣岡山	0.72171	0.742	Increasing	0.285	新竹市
高雄縣仁武	0.85394	0.912	Increasing	0.088	新竹市
屏東縣崁頂	0.96568	0.956	Increasing	0.359	新竹市
宜蘭縣利澤	1.00000	1.000	Constant	1.000	利澤
基隆市	0.75984	0.401	Increasing	0.066	新竹市
桃園縣	1.00000	1.000	Constant	1.000	桃園縣
台中縣烏日	1.00000	1.000	Constant	1.000	烏日

A BOT project should be feasible in financial competition and technical availability before it is undertaken. It is too risky to be undertaken by private parties without government guarantee to get a loan. The government may provide bank guarantee to a BOT project in order to speed up the project and practice it. The debt guarantee is a liability to the government and is seen as an asset to the BOT firm.

The comparison between Table 3 and Table 4 can derive the scale efficiency based on following equation:

Overall efficiency = Pure technical efficiency x scale efficiency

Based on this equation, we find that Keelung Incineration Plant has the lowest scale efficiency of 0.9196. This may attributes to its low designed capacity of incineration. Due to environmental concern about the negative impacts and energy scarcity, a pressure is created to dispose less waste and increase energy recovery. Implementation of new policies has created a need to improve the existing incineration practices in association with technical efficiency and energy recovery. The incineration plants are able to recover energy through a steam cycle, with an electrical efficiency of around 20% to 30% that are calculated through heat content in MSW and electricity generated. The expansion in investment on energy recovery increases the output, but decreases the technical efficiency for energy recovery efficiency. This may be explained by the energy content in MSW is decreasing over time when recycling rate increases.

The direct impact of pollution abatement (such as energy recovery, pollution reduction etc) may depends on the plant's age, size, and technology, while the benefits are related to the amount of the pollution being generated and the number of people affected. Impose stricter regulation on plants located in areas may bring about greater benefits from pollution abatement. Energy recovery efficiency varies widely with the age of the plant (representing the type of technology used) and plant capacity.

4. Conclusions

This paper finds that private-owned-operated plants and public-owned private-operated plants have better technical efficiency than public-owned public-operated plants. This result is coincided with previous studies. However, some other empirical studies on the effectiveness of privatization policies provide conflicting results. In this paper, we did not provide theoretical framework to explain the effectiveness of privatization. In the further studies, some efforts may be focused on management theories such as agency theory, institutional theory, and organizational and strategic management theories to develop a theoretical framework of privatization. Ramamurti (2000) proposes a multilevel framework by considering the level of firm, industry, and country levels to explain how and why an SOE choose privatization, and how privatization can improve performance.

In developed countries, most of public utilities have been operated by private firms that seek for maximization of profits. In developing countries, there is a trend of liberalization and privatization for public service that aims for efficiency improvements through the introduction of competition and by the modification of the ownership rights on the assets of those firms. However, privatization is not an easy job. It requires changes in ownership, legal identity, organization or even strategic orientation. This paper suggests that policy implementation gaps still exist in slowing down policy implementation of privatization because the privatization of public facility involves problems such as cost, staffing levels, stake holder's opposition and reduced funding.

The NIMBY effects also impact the policy planner's decision on siting of a notorious facility and take appropriate strategy on waste management. Without adequate and well-managed disposal facilities, the waste generated may deteriorate our life of pattern and living standard. However, residents know the necessity of a notorious facility but they oppose to the construction of a notorious facility where is neighboring to our residence. It is a good issue to discuss the effect of recycling on the public and the mutual effects of public attitude and recycling in association with the management of MSW. In facing the municipal solid waste dilemma, we require a new approach to resolve the solid waste management problem through an appropriate waste management, including recycling collections, collection of compostables, and conducting education programs (Blowers, 1992).

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附件四：

Spatial inequality in MSW disposal across regions in developing countries

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Abstract

The purpose of this paper is to examine the spatial inequality in the pattern of relationship between per capita GDP and municipal solid waste (MSW) disposed, and in the characteristics of the population living nearby. Results suggest that urban areas initially increase their MSW for final disposal to a peak and then the MSW for final disposal declines as incomes grow. On the contrary, rural areas execute an inverted N-shaped EKC that decrease at initial stage (below a critical income level, the first turning point), then increase at second stage, and eventually decrease again at the final stage (after the second turning point).

In this paper we incorporate economic, social, and geographical factors into the model that explains variation in MSW disposal across regions in Taiwan and find that there are distinct and often growing differences in MSW generation and recycling. The results demonstrate that income can explain a portion of variation only while the other social and geographical factors contribute a lot to identify the difference of MSW disposal between urban and rural areas.

Keywords: spatial inequality, environmental Kuznets curve, municipal solid waste, recycling behavior

1. Introduction

The hypothesis of the Environmental Kuznets Curve claims that economic development is inevitably accompanied with pollution at the beginning stage, but eventually the pollution can be controlled and improved by its economic growth. The EKC represents a statistical connection of some environmental degradation in terms of environmental indicators with income levels. It provides a systematic regularity over the past although some criticize that past empirical analyses leave much debating and are lacking of prediction (Koop and Tole, 1999). Even though, there are a great number of literature has examined the existence of EKC in a widely application including SOx, NOx, CO2, water pollutants, etc. (Kahn, 1998; List and Gallet, 1999; Skonhoft and Solem, 2001; Stern and Common, 2001; Harbaugh et al., 2002; Merlevede, et al., 2006; Dinda (2004) and Copeland & Taylor (2004) have made a critical survey).

Torras and Boyce (1998) prove the significant existence of EKC for air pollutants and show that sulphur dioxide and smoke peak at a per capita income in the neighborhood of US $4000. The empirical study of Kahn (1998) also confirms such an inverted u-shaped relationship between vehicle emissions and median household income. Merlevede et al., (2006) incorporate firm size into the standard EKC model in a reduced form regression as an explanatory variable by using the data of some pollutants. On the contrary, many researchers can not find a significant support for such an inverted U-shaped curve. Skonhoft and Solem (2001) examine the relationship between the relative amount of wilderness land (wilderness land as a fraction of the total area within each county) and the level of economic activity (measured by GDP per capita) and give no support for any Environmental Kuznets Curve (EKC) relationships.

The hypothesis of EKC postulates a relationship between economic development and environmental degradation based on a global basis and it may fail when it is applied to regional

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economy that differs in industrial structure and urbanization. Income inequality exists across regions and environmental quality is also found to differ very much. In practice, urban areas have higher levels of economic development with more service industry, and more educated citizens with increased environmental awareness. On the contrary, people in rural areas receive less education levels and most of them rely on farming or manufacturing industries and thus residents confront with more pollution. For example, Gray and Shadbegian (2004) in their empirical study find that pulp plants emit more pollution in poor areas, using data of 409 US pulp and paper mills for 1985–1997.

Until now, very few researchers focus on the EKC of MSW for final disposal (waste generation minus waste recycling). As waste generation and recycling are strongly considered to relate with consumption and disposal income, this paper attempts (1) to test whether an EKC for MSW disposed exists across regions, and (2) to examine the factors other than income as explanatory variables in analyzing regional inequality of waste disposal. Prior researches have identified a number of factors to explain the pattern of EKC (please see Dinda, 2004 and Copeland and Taylor, 2004). In this paper, we present some geographical and social factors across counties other than income to explain the causes for the pattern of EKC. These factors may affect consumption levels and eventually affect the trend of waste disposal.

2. Research method

MSW for final disposal W_f either by landfill or incineration equal to MSW generated W_g minus waste recycled W_r, i.e. $W_f = W_g - W_r$. MSW generation is determined by income and consumption pattern while recycling behaviors depend on a variety of social and geographical characteristics. In reality economic growth impacts upon both components of W_g and W_r since income is a major cause of consumption and social characteristics such as education levels. Consumption may increase per capita waste generation because MSW generation is inevitable accompanied with consumption. However, consumption patterns and behaviors like green consumption[15] also provide a positive force to mitigate environmental impacts through the choice of less environmentally harmful products (Ebreo et al., 1999).

Recycling of municipal solid waste (MSW) is now recognized as the most environmentally sound strategy for tackling MSW problem and has become an effective way to minimize the environmental impacts. The success of recycling involves with some situational factors including MSW management practice and its infrastructures, and the educational and communication media on waste management practice. The infrastructure system like space for storing objects to reuse/recycling, facilities for recycling objects etc. may induce conservation practices and affect the recycling performance. Some researchers find that the connection between environmental education and its effect on the environmental system has strong support for the achievement of sustainability. Thus, waste collectors/recyclers still require successful education and awareness raising programmers to participate effectively and maximize diversion rates (Evison and Read, 2001; Thomas, 2001; McDonald and Ball, 1998).

Furthermore, household behaviors also play a vital role through their involvements and participation in affecting MSW management (Tonglet, et al., 2004; Mattson, et al., 2003; Williams and Kelly, 2003; McDonald and Oates, 2003; Salhofer and Isaac, 2002; Perrin and Barton, 2001; Price, 2001; Thomas, 2001). Without public engagement[16], the MSW volume for final disposal may keep growing due to increasing waste generation and decreasing recycling performance. In reality the cooperation and integration between the governments and households are paramount to the success of MSW management.

[15] Green consumption has become a commonly accepted guiding principle as an effective tool to tackle MSW problem and served as a core policy objective in solving environmental problem even though a detailed planning has not yet in practice.

[16] The public may play a role as purchasers and users of goods will ultimately become waste, as a voluntary recycler and as educators to encourage other in engaging green consumption.

Environmental behaviors, in general, involves environmental attitudes and beliefs towards the relationship of the society and nature. A great number of researchers attempt to explore the determinants of pro-environmental behaviors and some focus on the factors that affect consumer preferences and their consequent purchase behaviors towards green products (e.g. Blend and van Ravenswaay, 1999; Teisl et al. 2002; Wessells, 1999). Among these authors, some suggest that the concern with environmental problems are the major determinant to affect pro-environmental behaviors (e.g. Bamberg, 2003; Iwata, 2002) and others find that recycling behaviors are positively affected by environmental knowledge (Katzev and Johnson, 1984; Bell et al., 2001 and Gardner & Stern, 1996 have made an overview). The empirical study of Kotchen and Moore (2007) finds the evidence to support that environmentally concerned consumers engage in voluntary restraint by consuming less electricity.

Some researchers link environmental behaviors with social characteristics. For example, Bickerstaff and Walker (2001) argue that the socio-economic status is negatively related with the concern for air quality. Ewing (2001) and Scott (1999) suggest that old people are found to be more participated in recycling behaviors to a larger extent than the young, but Werner and Makela (1998) finds no significant relationship between age and recycling. Howel et al., (2002) find that the pollution concerns are not so much as the concern on crime and unemployment. In brief, economic development, urbanization and improving living standards may lead to the quantity change in waste generation and waste composition. In line with the above discussion, we suggest that MSW for final disposal is determined by social characteristics such as population density, education level, the age composition of the society, and the unemployment rate in addition to income and thus we estimate a model of the following form:

$$w_{it} = \alpha_0 + \alpha_1 I_{it} + \alpha_2 I_{it}^2 + \alpha_3 I_{it}^3 + \alpha_4 popd_{it} + \alpha_5 old_{it} + \alpha_6 unemp_{it} + \alpha_7 edu_{it} + \alpha_8 dum_i + \varepsilon_{it} \qquad (1)$$

where w is the per capita MSW disposed, I refers to personal disposal income, $popd$ is population density, old is the age composition, $unemp$ denotes unemployment rate, and edu is education level, dum represents a dummy variable: 0 for urban areas and 1 for rural areas, and the subscript i denotes the region and t refers to time. The error term ε_{it} is assumed to be identically, independently distributed over a normal distribution with zero mean. In model (1), household income works as the explanatory variable, which can be seen as the key variable of interest in an empirical investigation on the Environmental Kuznets Curve. Two separate models were estimated in this paper. The first model, expressed in Eq. (1), includes the set of explanatory variables in addition to personal disposal income. The second model includes only the income variables.

2.2 The data

Some authors argues that spatial autocorrelation[17] is a typical problem in treating environmental data that may be affected by events in neighboring states, and thus the estimate of a conventional EKC may lead to estimate biases (Dubin, 1998; Maddison, 2006). In order to avoid spatial autocorrelation, we select 6 separated regions in Taiwan. Among the urban areas, we select Taipei Municipality, Taichung Municipality, and Kaohsiung Municipality to represent urban areas and Yilan County, Hualien County and Taitung County as the rural areas. Taipei Municipality, located in north Taiwan and being Taiwan's capital, has the highest per capita income. Taichung Municipality has the highest income in middle Taiwan, and Kaohsiung Municipality is an industrial city with the highest income in South Taiwan. The three municipalities are located in the western part of Taiwan that is composed of plains, basins and foothills, and neighboring to seashores (please see Figure 1).

On the contrary, the three counties representing rural areas locate in Eastern Taiwan, isolated by geographical barrier of the central mountains that are mostly forested with more than two hundred peaks over 3,000 meters and divide Taiwan Island into two parts: the Eastern and

[17] Anselin (2002) and Florax and van der Vlist (2003) have made an overview and critical survey on the prior published literature.

Western Taiwan. The eastern part of Taiwan is almost occupied by the East Coast Mountains that consist chiefly of sandstone and shale and are mostly composed of large hills (please see Figure 1).

Insert Figure 1 about here

In order to examine the determinants accounting for MSW for final disposal between urban areas and rural areas, the data covering the MSW disposed, personal disposal income, population density, age composition, unemployment rate and the education level is provided by DGBAS (2008) covering the period 1998– 2006. Personal disposal income I is measured in terms of NT$ per capita per year and population density $popd$ is measured by number of residents per square kilometer. We use the eldness index as the proxy variable of the age composition old. The eldness index is defined as ratio of the number of the aged (65 years old or older) to the children (below 14 years old). Education level edu is measured by the proportion rate of the citizens who graduate from college or higher levels. The MSW disposed in the six regions are listed in Figure 2, in the unit of kg per capita per day. The data indicates that per capita MSW disposed decrease over time as the population and economy grow in the past few decades in Taiwan. The general public may have been educated about the behavior change in MSW generation and perceived of the advantages of MSW recycling.

Insert Figure 2 about here

Table 1 reports summary statistics for the data. Comparing these statistics of urban areas with rural areas reveals that there is a large difference in income, MSW waste disposed, age composition, unemployment rate, and education levels between the two areas. The three counties in the rural areas have the highest shares of families living under the poverty line in 2007 with the lowest mean household incomes while the three municipalities in the urban areas have more incomes and are wealthier. Urban areas in general have higher income levels and education levels (please see Table 1) that are seen as primary factors to affect MSW generation and sorting performance. The measurement and modeling of waste disposal demonstrate its uneven distribution across regions. The spatial inequality of waste disposal will be discussed in relation with geographical characteristics. The quality of the data are believed to be reliable and to yield no bias in the estimation results since the publication of this edited statistical data is run by the government and has been lasted for many years.

Insert Table 1 about here

3. The results

The estimates are listed in Table 2 and we find that an inverted N-shaped curve exists- as the personal income rises, per capita MSW waste disposed firstly declines, and then grows at the second stage, finally decreases again for the pooled data covering the whole regions and the group of urban areas. The regression line covering the whole regions in Table 2 has been fitted with a cubic term of income for the full model with R-square of 0.7576 and for the reduced form with R-square of 0.1943. The estimated results seem to be satisfactory since the cubic term for income is always statistically significant. All the variables including income and geographical and social characteristics are found to influence the waste disposal significantly. It demonstrates that the socio-economic characteristics including population density, age composition, and unemployment rate and education level are determinants of MSW disposed.

The empirical evidence in this paper finds a significant difference in the waste disposed by employing the same pattern of EKC across the two areas by model A using the pooled data but it shows no significant evidence to support the difference by model B. This result implies that the waste disposal difference between urban areas and rural areas attributes to the geographical and social characteristics rather than income. In other words, the MSW disposal is explained partly by income levels that differ strongly between urban and rural areas, but greatly depends on geographical and social factors including population density, age composition, unemployment rate and education level.

Population density, age composition, unemployment rate and education level are found significant in determining waste disposal for this particular sample in Taiwan. Higher population density in urban areas may reflect lower cost of service for MSW collection and better waste collecting efficiency, and consequently results in higher waste collection rate. Furthermore, many households living distantly from the place that waste collecting truck can arrive, may throw away household wastes into the surrounding environment. As the data of MSW disposed is based on the waste collected, the direct throwing of MSW may account for lower MSW disposal in rural areas with lower population density.

Clark and Oswald (1994) and Theodossiou (1998) examine the utility levels of the jobless and find that unemployed persons perceive of lower levels of well-being. In this case, the unemployed may cut down the consumption budget due to future uncertainty even if they are wealthy, and consequently MSW generation is accordingly reduced. The possible reason to explain the significantly negative coefficient of the age composition is attributable to the relatively low consumption of the aged since most of the aged beyond 65 years old prefer to stay at home and some of them incur sickness and require impatient medicare. The negative coefficient of education levels coincides with the findings of the prior studies that raising educational attainment levels is one means to enhance recycling behaviors and modify consumption pattern, and eventually reduce MSW disposal.

When the data is divided into two groups: the urban areas and rural areas, the results show that both the two areas execute the inverted N curve for the full form. The rural areas, however, cannot support the inverted N curve by the reduced form (Model B) while urban areas have a significant result of the inverted N-shaped curve (please see Table 2). This means that geographical and social characteristics are more significant than income to account for the shifting of MSW disposal.

Insert Table 2 about here

To test the existence of EKC, we remove the variable of cubic income in Eq. (1) and the estimated results are shown in Table 3. We find that an EKC curve significantly exists in a reduced form for urban areas under 90% confidence level, but it does not receives the support in a full form that incorporate the geographical and social characteristics. The EKC hypothesis is not supported when it applies to the pooled data covering the whole regions and rural areas.

Insert Table 3 about here

Integrating the estimated results of an inverted N-shaped curve in Table 2 and an EKC for urban areas in Table 3, we depicts the trends of MSW disposal, generation and recycling along with disposal income in Figure 3 and divide the inverted N-curve into three stages by the two turning points that occur at income of $I = \frac{-\alpha_2 \pm \sqrt{\alpha_2^2 - 3\alpha_1\alpha_3}}{3\alpha_3}$. This figure demonstrates that the disposal income below a critical level (the first turning point) exhibits a decreasing pattern of MSW disposal, while it beyond the critical level exhibits an EKC curve. Along the EKC path, the MSW disposal will reach a peak at a certain income level (the second turning point) and decline afterwards with income increasing further. Since urban areas execute an EKC pattern of MSW disposal, we can suppose that the disposal income of each municipality at each stage is higher than the critical income level (NT$ 197,680, the first turning point). After checking with Table 1, our supposition is proved since the minimum disposal income is NT$ 248,757 in the urban areas over 1998-2006.

The personal disposal income below the critical point is labeled as Stage I, where most people are poor, consuming almost all their incomes on food and living in a relatively bad living condition. Thus the waste generation keeps almost the same, unrelated with income, but the recycling rate increases along with income levels. In this stage, $\frac{dw_f}{dI} = \frac{dw_g}{dI} - \frac{dw_r}{dI} < 0$.

When personal disposal income falls between the critical income level and the second turning point, it is labeled as Stage II. After the income level reaches to the critical point (the first turning point), the consumption increases and diversifies. Consumption partly serves basic, existential needs for most people. Firat and Dholakia (1998) argue that the driving force for consumption is shifted from the satisfaction of basic needs to joyful and playful activities for the construction of identities. Material consumption[18] is, however, seen as the primary way towards welfare and thus MSW generation rapidly increases in Stage II, where $\frac{dw_f}{dI} = \frac{dw_g}{dI} - \frac{dw_r}{dI} > 0$, even though recycling rate still keep growing.

After income reach to the second turning point, it steps into Stage III where $\frac{dw_f}{dI} = \frac{dw_g}{dI} - \frac{dw_r}{dI} > 0$. At this stage, consumers tend to shift their consumption pattern from manufacturing products to services, seek for more spiritual life and shift their consumption pattern from current culture of limitlessly material consumerism to spiritual aspirations. They like to travel to rural areas very often and consume outside their home. Since service industry yields less pollution intensive, MSW generation does not keep growing. The special features of wealthier people are less consumptive, greater mobility and shorter residence times. Rich people concern more about their well-being and generally have a wider range of options available and a greater capacity to change their consumption pattern. As material welfare does not yield happiness absolutely, the rich prefer to senses of security, clean environment, family ties and friendships, or at least see them as important as material possessions. At this stage, the rich may focus on the pursuit of social status and their value adhere to group norms (Sobel, 2005) that attempt to live a sustainable lifestyle featuring recycling, political activism and minimalist consumerism.

Insert Figure 3 about here

Rising disposal income may increase the propensity to consume and yields MSW, but the recycling rate increases along with increasing education levels that is positively related with income levels. We suggest that recycling rate keeps an increasing trend covering the three stages even though some researchers also reveal that poor people exhibits a higher degree of concern and awareness than the rich (Dunlap et al., 1993; Dunlap and Mertig, 1995). Tarrant and Cordell (1997) also find that low-income groups have higher correlation between attitude and behaviors. In reality, a lot of unemployed labors in rural areas are forced to work as a rag picker to collect recyclable wastes and sort them out further. The results concerning the relationship of income and recycling behaviors are ambiguous and mixed. Conventional perspectives indicate that wealthy people are concerned more with environmental protection and participate in environmental activities to a larger extent than the poor. Environmental attitudes and behaviors have a significantly positive correlation with income (Domina and Koch, 2002; Diekmann and Franzen, 1999; Brechin and Kempton, 1994; Inglehart, 1995) but other researchers refuse to recognize the significant relationship between income and recycling (e.g. Do Valle et al., 2004; Scott, 1999). In fact, education plays an important role in affecting environmental behaviors including green consumption and recycling behaviors. Since there is a strongly positive relationship between education level and personal income, we suggest that higher income can lead to engage in environmental behaviors such as green consumption or recycling behaviors.

4. Discussions and conclusions

Some researchers provide theoretical explanations about the determinants of the EKC

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[18] Ropke (1999) argues that consumption levels and patterns are influenced by the industrial development that achieves low production costs with over production. To keep up with the increased production volume, the stimulation to roar up the demand and consumption becomes an effective way and eventually lead to overconsumption.

(Andreoni and Levinson, 2001; Stern, 2004; Copeland and Taylor, 2004). Among these factors, scale effects, that has a negative impact on the environment in the early stages of development, and composition effects that has positive impacts on the environment in the later stages, have prominent roles in explaining the EKC (Stern, 2004). The composition effects occur ‘’at higher levels of development, structural change towards information-intensive industries and services, coupled with increased environmental awareness, enforcement of environmental regulations, better technology and higher environmental expenditures, result in leveling off and gradual decline of environmental degradation (Panayotou, 1993, cited from Stern, 2004, p. 1421). Through the interaction of the two effects, the production level and the production structure changes with economic development. These two effects are, however, derived from production activities while MSW disposal in this paper relates strongly with household consumption and social factors. This paper suggests that income and social characteristics may affect the consumption level and pattern (whether to consume green products or not) and consequently the MSW generation while MSW recycling is determined by environmental attitudes and social cultures.

In this paper we incorporate economic, social, and geographical factors into the model that explains variation in MSW disposal in Taiwan and find that there are distinct and often growing differences in MSW for final disposal between urban and rural areas in Taiwan. The results demonstrate that income can explain a portion of variation only and the other social and geographical factor contribute more significantly to identify the difference of MSW disposal between urban and rural areas.

This paper highlights some findings by integrating the economic income with geographical and social characteristics through which it may provide some meaning or direction for policy making. The regional inequalities in income, population density, age composition, unemployment rate and education level may bring about variation in waste generation, recycling and collection. This result implies that the sustainable MSW management should be focused on the integration of economic, social and environmental dimensions and thus the efforts to prevent MSW generation through cleaning process and green consumption should be focused. In fact, the environmental variables outside the environmental institution such as social values, environmental attitudes, and others organize the major part of factors affecting consumption and recycling behaviors. Except for the most basic goods, consumption behaviors are affected by the social context rather than preference. A social value leading to be altruistic and ecological is growing in the world. This value system reflects an alternative value system to promote our lifestyles and lowers consumption levels. This result also improves the understanding of the determinants of MSW generation and recycling at the macroscopic level and can have methodological implications for regional development.

Furthermore, this paper makes a useful contribution to the research on the existence of an inversed N-shaped EKC for MSW disposal. A great number of prior studies have found an N-shaped EKC by incorporating the term of cubic income into the model (Grossman and Krueger, 1992, 1995; Friedl and Getzner (2003); Galeotti and Lanza, 2005; Merlevede and Verbeke, 2006). Their results suggest that pollution increase constantly with the level of development beyond a turning point. For example, Merlevede and Verbeke (2006) conclude a N-shaped EKC by incorporating firm size as an explanatory variable for the pollution of SO2. Galeotti and Lanza (2005) find that an N-shaped cubic formulation proves to be an adequate choice for CO2 emissions by examining the data from 1971 to 1995 for 108 countries. Friedl and Getzner (2003) find that an N-shaped EKC significantly fit for CO2 emission in Austria. On the contrary, this paper finds an inverted N-shaped EKC with negative coefficient of the cubic income. It implies that the MSW disposal will automatically lead to eventual environmental improvement through decreased MSW generation and increased recycling along with economic growth when the regions attain to a critical point of income levels. In summary, the evidence presented here may provide some valuable suggestions for sustainable development of an integrated MSW management. This result derived form this paper challenges a number of important assumptions that are the basis for MSW policy making.

We suggest that the social and geographical factors cannot be ignored in the process of policy making. In reality many factors influence the waste generation and recycling such as economic and demographic developments, technological change, resource endowments, institutional frameworks, and lifestyles. Among the social characteristics, education plays a vital role in producing more environmentally behaviors such as green consumption and recycling behaviors and works as a foundation for achieving sustainable development. It can expand understanding, enhance skills and knowledge, and motivate society towards sustainable development (Hawken, 1993; Shmidheiny, 1992).

Figure 3 suggests that the automatic remedy for MSW for final disposal through economic development depends not only on recycling behaviors but also on green consumption and levels of consumption. Human behaviors are critical to the successful attainment of desired targets for MSW management practice. It is necessary to find out the factors to predict pro-environmental behaviors[19], such as the adoption of desirable waste reduction, reuse or recycling practices. We suggest that improved knowledge in association with waste sorting stream and enhanced environmental education on the public may help improve the MSW management that should be interdisciplinary by integrating socioeconomic, environmental, and technological aspects. And thus, the aims and actions derived from environmental policy are required to comply with more integrated and sustainable waste management solutions. Only all the parties are integrated and effectively involve in this apparent culture change, sustainable MSW management may be successful.

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[19] A great number of literatures have attempt to link the environmental attitude with pro-environmental behavior, but the relationship is still not clear. Some researches suggest that general concern for the environment is not a good predictor of specific proenvironmental behavior (Ebreo et al., 1999) while some argues that environmental beliefs is used to predict waste control behavior and has a positive effect of proenvironmental behaviors on a reduced consumption and increased recycling, reuse and garbage separation(Corral-Verdugo and Armendariz (2000).

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Table 1. The descriptive statistics

	Urban areas				Rural areas			
	Mean	S.D.	Max.	Min.	Mean	S.D.	Max.	Min.
w	0.7851	0.275	1.43	0.39	0.9285	0.262	1.39	0.51
I	298988	45737	392385	248757	212793	19117	256628	168942
popd	8499.8	1766	9861	5615	120.4944	69.11	217.29	67.12
old (%)	42.31	12.55	70.5	26.2	57.5293	7.001	70.68	43.6
unemp	4.1	0.838	5.5	2.6	4.2481	0.791	5.5	2.8
edu (%)	45.3	8.807	63.47	30.41	17.89	5.57	27.63	8.69

Table 2. The estimated results of the pooled data, urban areas and rural areas (standard errors in brackets)

	Pooled data		Urban areas		Rural areas	
	Model A	Model B	Model A	Model B	Model A	Model B
I	-5.1E-05* (2.73E-05)	-1.3E-04*** (4.33E-05)	-2.7E-04* (1.42E-04)	-3.9E-04* (2.24E-04)	-3.2E-04* (1.5E-04)	-5.4E-04 (4.6E-04)
I^2	1.94E-10* (1.03E-10)	4.59E-10*** (1.63E-10)	8.79E-10* (4.58E-10)	1.3E-09* (7.2E-10)	1.55E-09** (7.33E-10)	2.55E-09 (2.19E-09)
I^3	-2.2E-16* (1.24E-16)	-5.4E-16*** (1.99E-16)	-9.4E-16* (4.87E-16)	-1.4E-15* (7.5E-16)	-2.5E-15** (1.15E-15)	-4.0E-15 (3.45E-15)
popd	1.17E-4*** (2.36E-05)		1.1E-04* (5.14E-05)		2.1E-03*** (2.8E-04)	
old	-0.0224*** (0.00394)		-0.0178 (-0.0115)		-0.033*** (0.0027)	
unemp	-0.0901*** (0.0302)		-0.1371*** (0.0349)		-0.0363 (0.0246)	
edu	-0.01556** (0.00604)		-0.0148 (0.0133)		-0.00434 (0.00518)	
dum	1.461*** (0.3026)	0.163 (0.144)				
R^2	0.7576	0.1943	0.8658	0.2408	0.9330	

Table 3. The estimated results of the pooled data, urban areas and rural areas (standard errors in brackets)

	Pooled data		Urban areas		Rural areas	
	Model A	Model B	Model A	Model B	Model A	Model B
I	-4.5E-06 (4.69E-06)	-9.3E-06 (7.94E-06)	4.02E-06 (1.08E-05)	3.7E-05* (2.24E-04)	9.6E-06 (1.4E-05)	-6.8E-06 (3.68E-05)
I^2	1.57E-11* (1.03E-10)	1.46E-11 (1.31E-11)	-4.3E-13 (1.73E-11)	-5.9E-11* (3.33E-11)	-2.2E-11 (3.35E-11)	2.77E-12 (8.7E-11)
popd	1.25E-4*** (2.37E-05)		1.74E-04*** (3.98E-05)		-0.00216*** (0.00031)	
old	-0.0227*** (0.00402)		-0.0318*** (-0.00946)		-0.033*** (0.002933)	
unemp	-0.1074*** (0.0292)		-0.1602*** (0.0349)		-0.0495* (0.0259)	
Edu	-0.01487** (0.00616)		-0.00248 (0.0138)		-0.00281 (0.00557)	
dum	1.474*** (0.309)	0.01126 (0.141)				
R^2	0.7019	0.0956	0.8419	0.1185	0.9167	

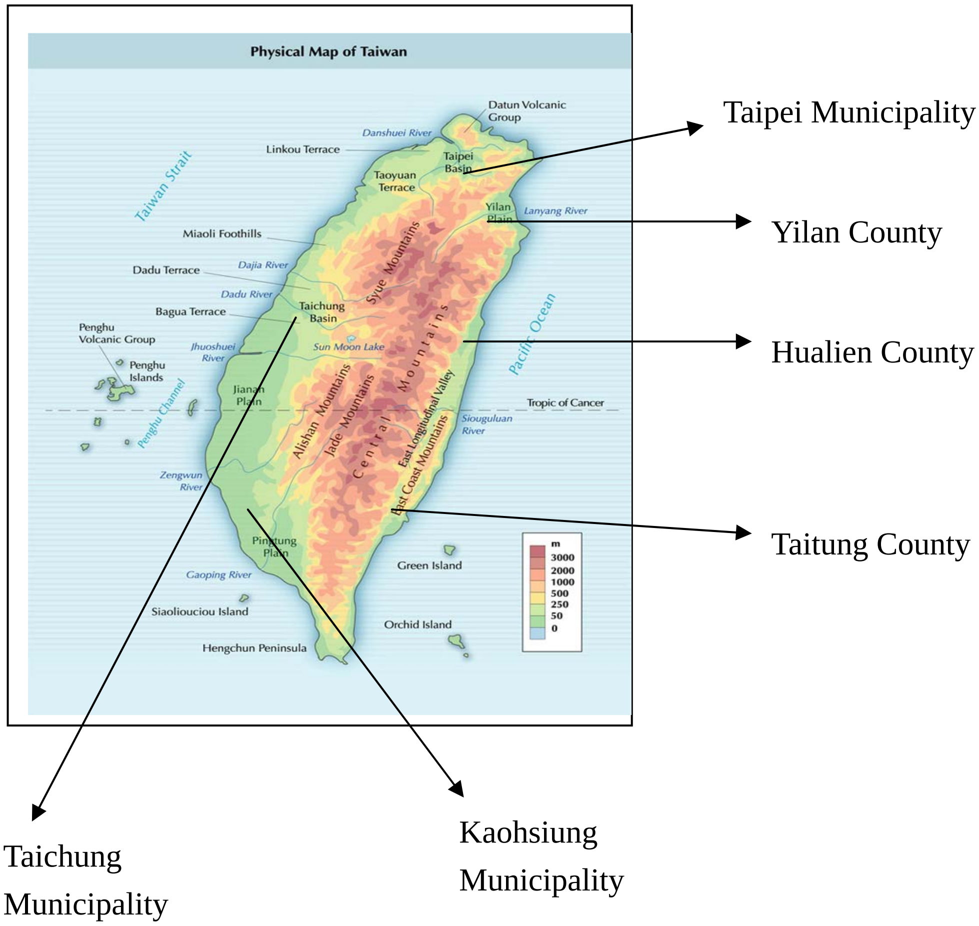

Figure 1. the physical map of Taiwan

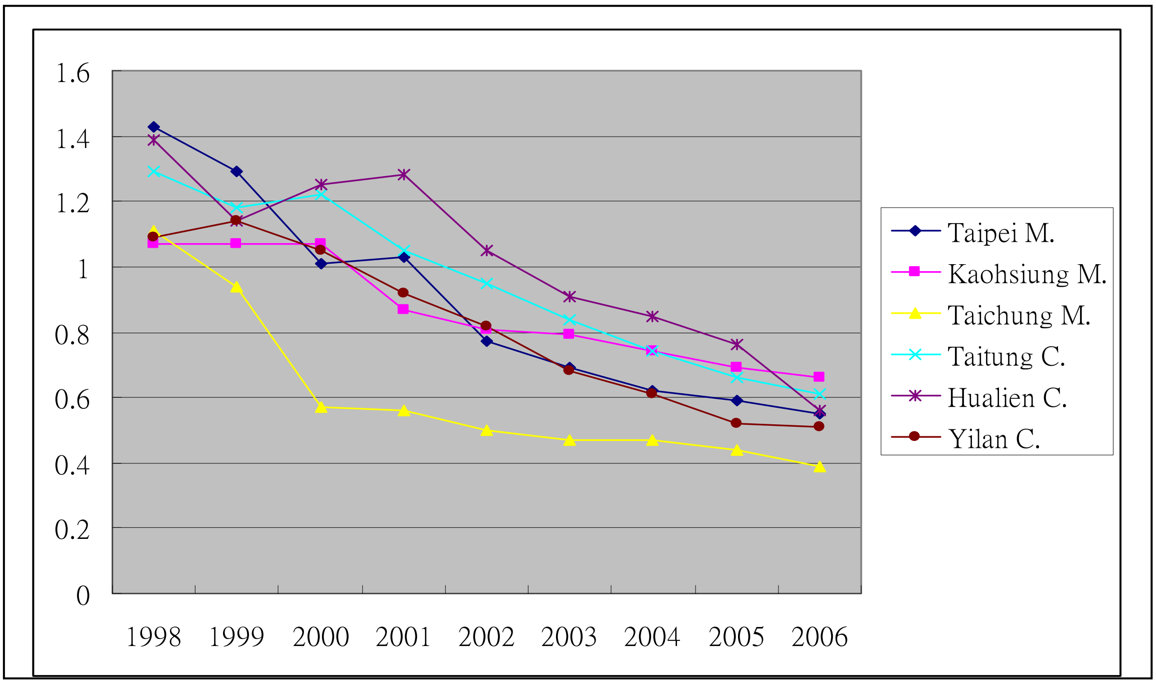

Figure 2. the MSW disposed in the six regions over 1998-2006

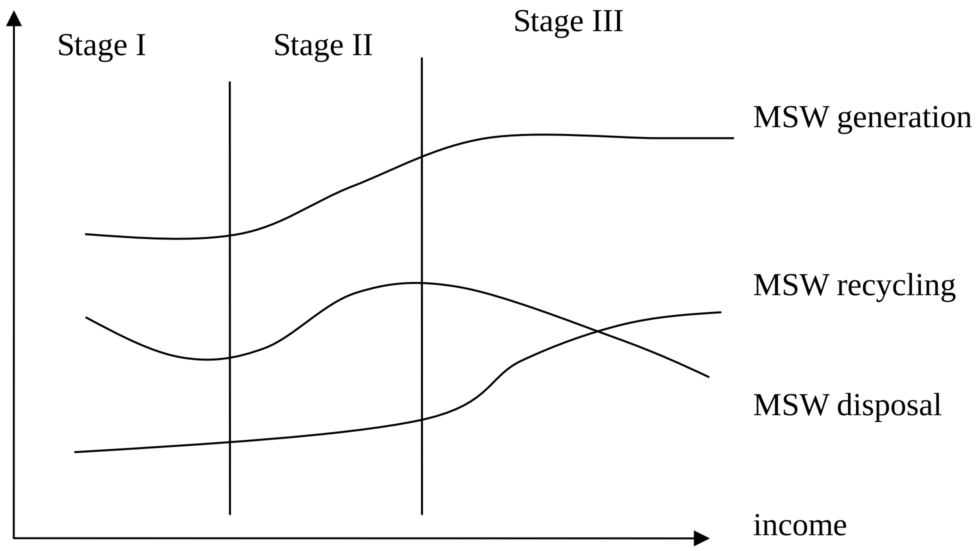

Figure 3. the inverted N-curve of MSW disposal