

COST-BENEFIT ANALYSIS OF A RECYCLING PROGRAM IN TAIWAN

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ABSTRACT

A resource material recycling program organized and operated by a private, non-profit foundation in Taiwan is investigated. Emphasis of the present study is placed on the operation, analysis of the annual amounts of recyclable material collection, the operational cost-benefit analysis of the resource material recovery center, and the implications of this pilot program for the municipal solid waste disposal. After close examination of the results of the analysis and of current operations of the recycling center, some improvement measures are identified which could significantly enhance the operation and financial health of the center.

INTRODUCTION

Disposal of municipal solid waste (MSW) is a problem confronting all nations around the world. Taiwan is no exception. An island country, Taiwan has a total surface area of slightly more than 36,000 km² and a population of more than twenty-two million. Population density is among the highest in the world. Rapid industrialization and economic growth during the past several decades have considerably elevated the standard of living with a correspondingly rapid increase in municipal solid waste generation. Understandably, the MSW disposal problem in Taiwan is particularly acute because of a severe shortage of landfill sites and solid waste incineration facilities. To deal with this complicated MSW disposal problem, an overall program of waste minimization and recovery of resource

materials was launched by the government several years ago with an aim at suppressing the MSW growth rate [1].

According to the statistics of Taiwan's Environmental Protection Agency (EPA), the total amount of solid waste produced daily in Taiwan grew from 11,726 tons in 1984 to 23,268 tons in 1994, translating to an annual increase of 7.1 percent over the eleven year period [2]. During the same period, the per-capita MSW generated increased from 0.67 to 1.10 kg/day. Of the daily 23,268 tons of MSW production, only about 5 percent was incinerated and the rest used as landfill. The rapid increase in the total amount of MSW placed a considerable strain on the landfill and incineration facilities nationwide. To alleviate the MSW disposal problem, measures of waste minimization and recycling appear to be the only alternative.

Since the launch of the program of waste minimization and recycling in 1989 by Taiwan EPA, participation of various organizations from the public and private sectors has been quite strong. Even though it is too early to assess the overall success of the program, some tangible results are already apparent. In this report, a cost-benefit analysis of a pilot program initiated by a private, non-profit organization, and supported by the Taoyuan County government in northern Taiwan, is carried out. The detailed operations of the recycling center and the measures taken for operational improvements are also identified.

LUNGTAN RESOURCE RECOVERY CENTER (LRRC)

Taoyuan County is the second most populous of the sixteen counties in Taiwan. The county's area is 1,221 km², and its population is roughly 1.5 million. As shown in Table 1, daily MSW generation by the county had more than tripled growing from 530 tons/day in 1982 to 1,670 tons/day in 1994, representing an annual increase of 8.5 percent [3]. Currently, the per capita MSW generation is 1.12 kg/day which is higher than the national average, reflecting the much higher industrial growth compared to those of other counties. Because there is no incineration facility, the MSW must be landfilled. The MSW disposal problem confronted by the county government is that all landfill sites will be completely full within the next few years. Without new landfill sites or costlier incineration facilities built soon, the MSW disposal problem will become extremely difficult to deal with. Realizing the urgency of this problem, the county government and

Table 1. MSW Growth in Taoyuan County

Year	1982	83	84	85	86	87	88	89	90	91	92	93	1994
Amount	530	583	670	685	773	778	793	858	968	1267	1440	1394	1670

Note: The amount in tons/day.

organizations from the public and private sectors have joined hands to promote waste minimization and recycling in an attempt to slow down the MSW growth.

The MSW roughly can be divided into two categories: general and market MSW. General MSW is generated in households, offices, institutions, and etc. Market MSW is generated in market places. Table 2 compares the compositional characteristics of the general and the market MSW data at the point of generation in Taoyuan County and in Taiwan [2]. Combustible MSW refers to components that can be burnt in an incinerator. The combustible portion constitutes the great majority of the MSW. MSW can also be divided into recyclable and non-recyclable categories. The materials that have been mandated by the Taiwan EPA for recycling include waste paper, plastics (bottle, sheet and others), metals (iron, aluminum and copper) and glass. Based on the fact that MSW consists of approximately 82 percent of the general type and 18 percent of the market type, Table 2 shows that the recyclable materials amount to more than 55 percent. Thus at least theoretically, recycling of all recyclable materials can lead to a MSW reduction by more than one half. This provides a very strong impetus to waste minimization and recycling.

In view of the potential of recycling to help reduce MSW, the Taoyuan Environmental Protection Foundation (TEPF), a private, non-profit organization, started organizing the Lungtan Resource Recovery Center (LRRC) in early 1992. By September, 1992, the center began formal operation with a goal of collecting

Table 2. MSW Percent Composition in Taoyuan County and in Taiwan

Category	Type	General MSW		Market MSW	
		N	T.C.	N	T.C.
Combustible	Paper	29.98	32.26	23.39	25.81
	Clothes	4.81	2.44	1.77	0.37
	Wood, tree leaves, etc.	4.69	2.81	9.61	3.46
	Kitchen residues	23.50	25.76	39.72	45.23
	Plastics	18.90	22.16	14.21	17.29
	Leather, rubber	0.80	0.46	0.08	0.24
	Miscellaneous	4.31	0.19	4.31	0.09
	Subtotal	86.99	86.45	91.81	92.50
Non-combustible	Metals	5.78	8.75	2.73	1.03
	Glass	4.94	6.16	2.75	1.00
	Ceramics	0.98	1.29	1.71	5.27
	Sand, gravel	1.32	0.49	1.00	0.19
	Subtotal	13.01	16.69	8.19	7.50

Note: N = Nationwide, T.C. = Taoyuan County

recyclable materials from all urban and rural areas in the county. The center is centrally located in the county. To promote the establishment of the center, Taoyuan Environmental Protection Bureau, the supervising government body, contributed some seed capital for purchasing the trucks, machinery and the running expenses.

The LRRC is managed by a director who performs all managerial and planning duties. Other employees include eight drivers, five on-site workers, and a secretary. Two drivers are assigned to a truck which goes out daily to collect recyclable materials from the collection points along a pre-assigned route. The on-site workers are responsible for sorting of the recyclable materials collected. Because of active promotion by local members of the Taoyuan Environmental Protection Foundation, more than 250 collection points across the county were established at the outset. All those collection points were covered by eighteen truck routes. Each collection point serves as the focal point of collection activity of recyclable materials in a predefined area and is manned by a person charged with the responsibility of ensuring that all recyclable materials were properly sorted into paper, plastics, PET bottles, aluminum cans, etc. A truck may complete two to four truck routes every day to gather all the recyclable materials at the collection points. The recyclable materials gathered by each field collection point vary in both the kind and quantity. Once a week, the LRRC truck would come to pick up the gathered recyclable materials and the person in charge in each field collection point was paid a set price on the spot, according to the kind and the amount of recyclable materials collected.

Seven kinds of recyclable materials were collected by the LRRC center: waste papers, plastics, PET bottles, steel cans, aluminum cans, copper, and glass. PET (polyethylene terephthalate) bottles, widely used as soft drink, mineral water, cooking oil, and soy sauce containers, were separated from the plastics as a single category because of the nationwide compulsory customer deposit levied on each of these bottles. Hence their resale value was considerably higher than that of other plastic materials. Although papers were lumped in one category, they were in fact further sorted into paper boxes, newsprint, xerox papers (etc.) due to different resale prices. After sorting, all recyclable materials were bundled and shipped to various recycling plants as raw materials.

ANNUAL AMOUNTS OF RECYCLABLE MATERIAL COLLECTION

Among the recyclable materials, papers were by far the largest component collected [3]. Table 3 demonstrates that papers constitute about 66 percent of the total 13,600 tons of recyclable materials collected by the center over the three year period from September, 1992 to September, 1995. This was followed by steel cans (14.2%), PET bottles (13.2%) and plastics (2.9%). The rest of the recyclable materials constitute 3.7 percent. It is further noted that the total

Table 3. The Monthly Average Amount of Each Recyclable Material Collected by LRRC^a

	Paper	Plastics	PET Bottle	Steel Can	Aluminum Can	Glass	Copper	Misc.
1992	407.8	36.41	87.66	109.42	14.84	21.42	0.009	0.258
1993	297.7	8.02	43.76	54.49	9.56	4.23	0.104	0.062
1994	195.2	12.29	43.18	37.06	7.35	1.94	0.101	0.389
1995	158.8	8.36	32.18	43.93	4.25	1.60	0.097	0.891

^aAll entries in tons/month. 1992 data were averaged for the last four months only while those of 1995 were the average for the first nine months.

monthly average collection in 1992 was about two and one half times that of 1995. Total monthly average collection has further decreased slowly. There are two main reasons for such a decrease. The first was that as the center was first launched, there was considerable enthusiasm among local members of the Taoyuan Environmental Protection Foundation. Thus those members were much enthused and strongly motivated to participate in the collection activities of recyclable materials. As time progressed, enthusiasm waned significantly and this was reflected in a decrease from 250 field collection points to less than 150 in 1997. In addition, there has been a significant turnover among the employees of the center in the past two years, which strongly influences the normal operation of the center.

Table 3 also shows the average monthly tons for each type of recyclable materials collected since September 1992. The total amounts, which are the sum of all figures across each row, are 677.8, 417.9, 297.5, and 251.1 tons/month for 1992, 1993, 1994, and 1995, respectively. There appeared to be a sharp decrease in the total monthly collection between 1992 and 1993 due primarily to the reason noted earlier. Closer examination of the raw data collected (not shown here) reveals that within a year, there were only slight variations in the monthly amounts of each type of recyclable materials, except for PET bottles and aluminum cans. The monthly amounts of the two latter types show a significant pickup during the spring and summer months each year, perhaps reflecting the increased consumption of carbonated and non-carbonated soft drink and mineral water during that period.

COST-BENEFIT ANALYSIS OF OPERATION

In performing the cost-benefit analysis of the center, the income and all expenses need to be considered. The income of the center solely comes from the sale of sorted recyclable materials to manufacturers as raw materials. The expenses include operating cost of the center and prices paid to persons in charge of the

field collection points. Both of them are expected to be sensitive to price fluctuation of the raw materials in the market place.

The operating costs of the center consists of salaries for employees, utilities (telephone, water, electricity, etc.), upkeep of trucks (insurance, taxes, maintenance, gas, etc.), annualized depreciation of trucks and machinery, and site rental. The total expenses for each year are listed in Table 4. The center has two large trucks (10.5-ton), one medium one (8.8-ton), and four small ones (3.5-ton). In addition, it also has a compacting machine, a shredder, a conveyor, and a weighing station. The total initial investment for truck and machinery came to slightly less than \$245,000 (all cost figure in U.S. currency). The usable life of the equipment permitted by the government is eight years. Assuming an 8 percent interest rate, the annualized depreciation of equipment amounts to \$56,680. The other costs in this table were based on the data supplied by the center.

The cost-benefit analysis is performed and listed in Table 5. The second row represents the total amount of recyclable materials sold by the center for each year and the third row the income derived from the sale. The average unit sale

Table 4. Operating Costs of LRRC

	1992	1993	1994	1995
Salaries	145,070	247,010	209,910	104,470
Gas/Maintenance for trucks	5,300	25,600	17,980	12,330
Taxes/Insurance for trucks	—	4,660	4,760	3,420
Utilities	420	3,620	3,540	2,320
Site rental	—	—	7,410	6,170
Truck/Machinery depreciation	18,890	56,680	56,680	37,780
Total	169,670	337,580	300,280	166,490

Note: All cost figures in U.S. currency.

Table 5. Cost-Benefit Analysis of Resource Material Recycling

	1992	1993	1994	1995
Total amount of materials sold (kg)	2,257,400	4,708,200	3,436,700	1,463,140
Income from sale (\$)	173,910	407,430	414,700	281,610
Average sale price (cents/kg)	7.704	8.654	12.067	19.240
Total purchase price (\$)	151,370	181,230	162,940	114,160
Operating cost (\$)	169,670	337,570	300,270	166,490
Net income (\$)	-147,130	-111,370	-48,510	+960
Unit cost of recyclable materials (cents/kg)	14.222	11.019	13.478	19.181
Benefit from waste reduction (\$/year)	129,800	270,720	197,610	84,130

Note: All cost (price) figures in U.S. currency.

price was obtained by dividing the income by the total amount of recyclable materials. The total purchase price is that paid to the person in charge of the field collection point. The net income represents the total sale income less the operating cost and the purchase prices. Based on the sum of operating cost and purchase price, the average unit cost of recyclable materials is computed and listed below the net income. The benefit derived from recycling was computed on the basis of \$57.5/ton. The rationale for this benefit is that recycling is equivalent to MSW reduction. Without recycling, the recyclable materials need to be landfilled at a current landfilling cost of \$57.5/ton and such a cost has to be borne by the town or city governments. It is not unreasonable to count the savings from waste reduction as a part of the income of the recycling center.

It is apparent from Table 5 that the recycling center had a sizable operating deficit in the first two years when the waste reduction benefit was excluded. The operating deficit was reduced by more than one half in 1994 and by 1995, a small surplus for the first nine months was realized. Such a drastic financial improvement was due primarily to the rapid price increase of raw material in 1995. By taking into account of the benefit derived from waste reduction, the financial picture of the recycling center looked totally different. With this benefit, the center would still have a small deficit in the first year. This was understandable because at its inception, the organization was not operated smoothly and effectively. It has had a large surplus every year since then. It is emphasized here that incorporation of the monetary benefit of waste reduction as a part of the center's income is legitimate for the reason mentioned earlier. In fact, the annual operating deficit of the recycling center has been regularly made up by a subsidy from the county government since 1992.

According to Table 3, the total amounts of monthly collection decreased steadily from 677.8 tons/month in 1992 to 251.1 tons/month in 1995. These monthly amounts of recyclable material collections were larger than the amounts of monthly sale shown in Table 5 which are 564.4, 392.4, 286.4, and 162.6 tons/month for 1992, 1993, 1994, and 1995, respectively. The difference between them was caused primarily by handling losses, un-salable materials collected and some accumulations of recyclable materials in the storage yard of the recycling center. The handling losses and un-salable materials were estimated to be less than 7 percent of total collections under most circumstances and the rest was accumulation.

Another point worth noticing here is that the recycling center was privately organized and operated under the auspices of county government as a pilot program. This accounts for the relatively small-scale operation of the recycling center and the small amount of daily collection of recyclable materials in comparison to the total MSW generation in the county. In 1994, for example, the amount of collected recyclable materials was less than 297.5 tons/month which represented no more than 1 percent of the monthly MSW generation of the county (about 32,4500 tons/month). However, the pilot program of recyclable material

collection was carefully monitored by the county government and it will be continued for a couple of more years at least. The current operational results look rather promising. If final assessment of the pilot program by the end of 1997 proves satisfactory, the program is expected to be greatly expanded countywide. By that time, the recyclable materials collected and available for resale would be increased by many times. A question raised here is whether the increased supply of recyclable materials would exceed the demand and thus depress their resale values in the market place. The answer to this question is negative primarily because of very large demand for recyclable materials in this country (currently, most is imported).

IMPROVEMENT MEASURES

As mentioned earlier, the LRRC center has eighteen truck routes and arranges daily truck pickup of recyclable materials from the field collection points on each route. A close scrutiny of the pickup schedule and the truck routes reveals some inefficiency. There are several long truck routes with a round-trip distance of over 110 km (70 mi). It would regularly take about a whole day for a truck just to make a trip on those routes. This is due primarily to the low average truck speed about 32 km/hr (20 mi/hr). Hence driving alone takes more than one half day. Furthermore, those long truck routes happen to cover a large number of field collection points in the rural areas. The amount of recyclable materials gathered by those field collection points is much less than those collected in the urban areas. Therefore, from the viewpoint of manpower and equipment utilization, it is rather uneconomic to cover those routes. Instead, it would be a better strategy to delegate the collection duty of those distance field collection points in the rural and thinly populated areas to the local agents. Saving from relinquishing those long truck routes can be better utilized on-site to help sorting duty which is short of manpower at the present time. Such an arrangement will help clean up the recyclable materials which have been slowly piling up over the past years.

Another possible improvement of the operation of the recycling center is the suggestion of converting the center into a central sorting station for the whole county. Eventually, the county government will be gradually enforcing the recycling program countywide. According to the plan, the collection duty of recyclable materials will be delegated to the refuse collection squad of each town or city. The problem stemming from this plan is that nearly all towns and cities lack sufficient space for storage of collected recyclable materials. In addition, most of the refuse collection squads do not have spare manpower, skill and machinery for sorting of the recyclable materials collected. Hence a better alternative is to convert the LRRC center into a central sorting station for the whole county and have all recyclable materials sent to the center for further processing. This arrangement may help solve the problems the LRRC center and the towns and cities are facing. Preliminary surveys of town and city authorities have

encouraged such an alternative. The concept will now be assessed in depth by the county authority. In view of the acute problems of MSW disposal confronting the local government and the sizeable potential benefits of MSW reduction, the concept may receive widespread support.

CONCLUSIONS

The present study examines the operation of a recycling center organized and operated by a private, non-profit environmental protection foundation and subsidized by the county government in Taiwan. The monthly amounts of recyclable materials collected by the center since its inception are reported. According to the data supplied by the recycling center, waste paper constitutes the bulk of the recyclable materials (66%), followed by steel cans (14.2%), PET bottles (13.2%), and other plastics (2.9%). Other recyclable materials represent 3.7 percent. The financial data reveal that the financial health of the recycling center is strongly influenced by the raw material prices in the market place. Cost-benefit analysis of the operation shows that at a period of high raw material prices, the recycling center operates in the black by resale of the sorted recyclable materials alone. At lower raw material prices, the financial health of the recycling center is in worse shape and government subsidy is necessary. However, the monetary benefit derived from the waste reduction due to recycling is found to be rather sizable in comparison to the income from the resale of recyclable materials. The rationale for considering the benefit as a part of income is that recycling is directly related to saving in municipal solid waste disposal by landfill. Considering this monetary benefit as indirect income, the resource material recycling center would be in excellent financial shape except for the first few months after its inception in 1992.

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