Solid Waste Management in Lima Considering Recycling

Ygor JIMENEZ[1],
○Xuepeng QIAN[2]
Junzo TACHIBANA[3]
Mamoru HARUNA[4]

Effective waste management is taking more importance around the world, especially among industrialized countries attending to the necessity of their growing people whom, as they grow, generate more waste. Same problem is for developing countries with the financial issue included. The objective of this work is to develop a General System for the Management of General Waste Treatment; it is by the concepts of "reducing" amount of waste to landfill and "recycling" the disposed materials. It aims to raise the level of efficiency for the waste collection systems and the development of an effective treatment process by the construction of treatment facilities.

【Keyword】 Solid waste, recycling, landfill

1. Background

This research is conducted to the districts in Lima province, which also forms the Metropolitan city of Lima. Metropolitan Lima consists of 48 district municipalities belonging to 2 Provincial municipalities: Callao (7 districts) and Lima (43 districts).

On the Fig. 1.1, the diagram for household solid waste system is shown.

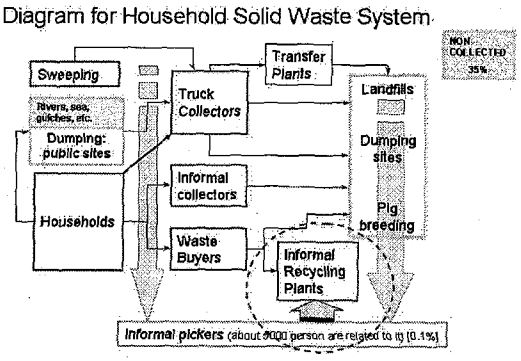

Fig. 1.1 Diagram for Solid Waste

There are some informal collectors who collect and/or buy recyclable materials like: pet bottles, glass, semi-broken articles, etc. also some people pick organic waste in order to use it for feeding animals like pigs. Final disposals in most of the times are dumping sites (60%) which do not respect the technical norms for according to a proper sanitary landfill. Inside those informal dumping sites, pig breeding and feeding are also done.

Figure 1.2 show us different kinds of waste. There, we can see that organic waste (42%) and paper (23%) are the most predominant types. Even though all of them could have different treatments (see middle boxes), now they all finishes at landfills, dumping sites, open burning, or animal breeding.

However, at present, those potential recyclable materials end to the final disposals where a kind of informal recycling is done. Such informal recycling is, in most of cases, used for reusing products containers to do products falsification.

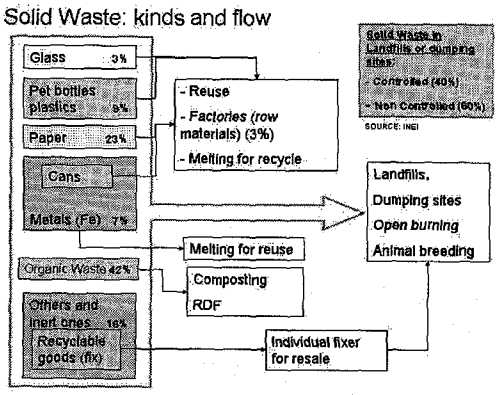

Fig. 1.2 Kinds and flow of solid waste

2. MAIN PROBLEMS

The most critical problems in solid waste management in Lima are:

- No formal recycling program (informal is done and about 3% is recycled)
- Luck of complete and accurate data and deficient collection system: routs, frequencies
- Lack of waste management facilities: few proper landfills and no control in dumping sites provoked by increasing disposed waste to landfills

3. NECESSITY OF THE RESEARCH

[1] Master Course student at Ritsumeikan University
[2] Master Course student at Ritsumeikan University
[3] Doctor Course student at Ritsumeikan University
[4] Professor at Ritsumeikan University

- Soil pollution: landfills, dumping sites
- Air pollution: open burning of waste
- Diseases: informal pickers, animals, reusing
- Institutional: improve the quality and cover services
- Encourage of more research to have actual and complete data
- Formalize recycling and reusing: stable markets

4. OBJECTIVES OF THE RESEARCH

1. Minimize of the total cost of the construction facilities during a certain planned period
2. Reduce amount of generated waste
3. Increase amount of recycled waste
4. Reduce amount of waste to landfill

5. PLAN

The aim of this study is to make an Integrated Waste Management (IWM) in Lima. IWM is the selection and application of suitable techniques, technologies, and management programs to achieve specific waste management objectives and goals. For the proposed system in the present research, it has been identified four basic management options (strategies) for IWM: (1) source reduction, (2) recycling and composting, (3) combustion (waste-to-energy facilities), and (4) landfills [Tchobanoglous, 2002].

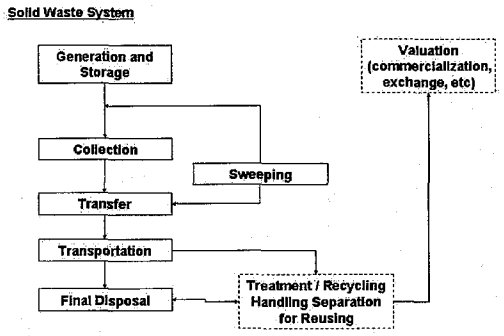

Fig. 5.1 Actual Solid Waste System

Fig. 5.1 shows the actual solid waste flow. Fig. 5.2 shows the planned solid waste flow recommended by this paper for an effective system. It is divided into 2 parts depending on how well urbanized are the zones and what is the situation or availability from municipalities to collect waste separated on the source.

Collection is divided into 2 groups: source-separated waste, including yard waste, and commingled (mix) waste collection. Commingled waste is collected from curbside and then transported to one materials recovery facility or transfer station to separate some recyclable products and non recyclable products can end directly to landfill but the goal is to dispose them for waste transformation before final disposal.

When the waste is source-separated, waste can be collected from curbside or disposed directly by inhabitants into drop-off and/or redemption centers.

The waste collected by local governments, goes directly to the materials recovery facilities.

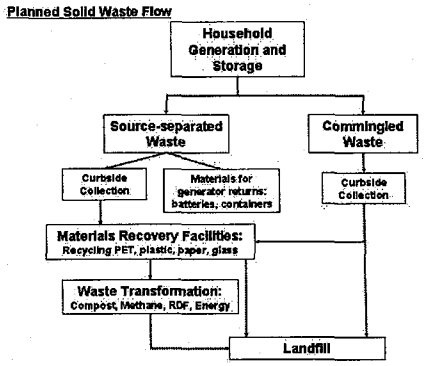

Fig. 5.2 Planned solid waste flow

Waste Transformation involves facilities for compost, RDF (burning), energy, methane (from landfills), and so on. These facilities are an important part of the system because here more of the waste reduction is done.

Landfill will be used only for dispose the ashes from incinerating facilities and for materials that can not be burned. Basically, the first years, the landfills will continue receiving garbage but gradually and according to the construction time of the facilities, the waste disposed at landfill will be decreased.

On Fig. 5.1 is shown the life cycle of waste management and taking it as basis for a right management, actual situation and deficiencies will be analyzed. See the ones with dotted line are a total informal part in the whole system.

6. MATHEMATICAL ANALYSIS

This paper has as an objective function to determine a model for solid waste management that determinates the minimizing of the total cost of the construction facilities during a certain planned period, which is 'T' in this case. The determination will be done when the process of the household waste starts at the disposal of the waste. It is assumed during a period 'T', and it should be considered: the type of processing facilities, the time, the scale of the facility and the administration during this period 'T.' This type of problems can be handled as a control mathematics problem of the discrete variables in the dispersal time.

By this, the objectives can be reached as follows: establish a recycling system by construction and proper management of facilities which will allows us also to have more controlled and accurate data; by recycling, treatment and burning of the waste, the amount of waste to landfill will be reduced. It was considered the reduction of cost for facilities as an objective function considering the

economical conditions as a priority to waste management and you can realize later as not all the facilities will be constructed because of the income that municipalities have. Of course it can be considered the reduction of waste to landfill as the second objective function or status function.

This type of problems can be handled as a control mathematics problem of the discrete variables in the dispersal time.

This is all the formularization regarding the objective function, project variable and the state space. Including each boundary condition, to bring a conclusion of this formularization of model, it will be as following:

Objective Function

$$V(T) \rightarrow \min$$

Status function

$$P(t) = p(t) + P(t-1)$$

$$V(t) = v(t) + V(t-1)$$

Plan variable

$$\$(t) = \{s_1(t), s_2(t), \cdots s_j(t), \cdots s_n(t)\}$$

Boundary conditions

$$P(0) = 0$$

$$V(0) = 0$$

$$\$(0) = \{0,1,0,\cdots,0\}$$

$$V(t) \leq 0$$

$$P(T) : \text{FREE}$$

Where *i: type of general waste, j: type of processing facilities, V(T): C (Costs) – M (incomes), P(t): amount of waste to landfill until period t,* $\$(t)$ *vector showing 1= facility exists 0= does not exists*

7. CONSIDERATIONS

In order to manage the whole province of Metropolitan Lima, it was divided into seven (7) zones.

As the input for the program needs a different distribution, so final rates were considered as follows:

Pet bottle	0,50%
Aluminum, glass, steel	9,20%
Plastic	8,40%
Organic waste	42,40%
Flammable waste	28,60%
Inflammable waste	10,90%

The study was done for a plan of 20 years.

Based on the necessity of fresh income, 3 patterns have been considered to analyze the system considering additional revenues and applied in the program: (1 oku yen = 100 000 000 ≅ 1 million dollar)

Pattern 1: 30 oku yen of additional revenue

Pattern 2: 20 oku yen of additional revenue

Pattern 3: 10 oku yen of additional revenue

Those amounts of money were considered because they can provoke a significant change in revenues and costs to invest on construction of new facilities.

Among the facilities to be constructed, it was considered to analyze their effectiveness: Recycling facility of PET bottles, Recycling Center, Composting facility, Melting and Solidification facility (produces slug), Incineration facility (produces ashes).

Last 2 similar facilities will never be considered to construct both at the same zone. In case of burning facility will be constructed, program chooses the most effective one.

8. RESULTS

The purpose is to manage the construction of most facilities by using some financial resources and consequently, the amount of waste to landfill will be decreased. So the output of the computing program to analyze solid waste management system is:

Money's situation for 20 years, in order to show the profitability of a system or pattern used. It can be analyzed from the refund graph (refund = total cost – revenue)

The results of the analysis are shown into figures of expenses, which includes graphs for: Construction expense, Conveyance (transport) expense, Management expense, Refund trajectory. 21 figures where got and her one example:

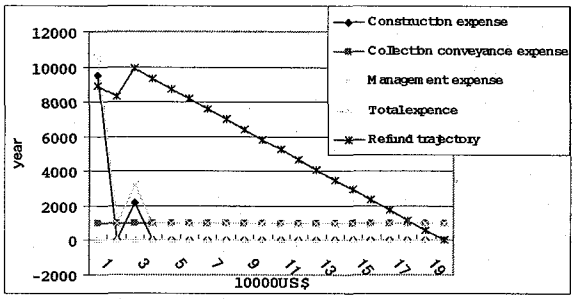

Fig 8.1 Expenses with Pattern 1 for Zone 4

In all patterns, all zones will invest for construction of facilities mainly in the 1st year where construction graph has its highest value. Later investment situation can be seeing also in few zones; this raises the construction expenses and affects the refund trajectory.

The expenses for collection and transport is kept fix due service will be continually offered, same as for the management expenses.

Total expenses graph (sum all expenses involved: construction, collection and management) tends to decrease, also, after investments. Then, it keeps the position of collection and conveyance expense's graph.

Here also, the refund trajectory starts having red numbers then it gradually decreases until be located in blue numbers where municipalities can manage the facilities without doing other investments. All the zones are

expected to be recovered in refunds since the 10th until 18th (depend on revenues).

The computing analysis and figures will show us that it is not necessary to build for sure some facilities, only cheap and effective ones will be constructed. It builds from the most effective institution. It can be seeing on Table 8.1

PATTERN		TABLE 8.1 FACILITIES CONSTRUCTION IN EACH ZONE						
		1	2	3	4	5	6	7
1	PET				√			
	Recycling		√	√	√	√	√	
	Plastic							
	Composting		√		√	√		
	Incineration	√	√	√	√	√	√	√
2	PET							
	Recycling		√		√	√		
	Plastic							
	Composting				√			
	Incineration	√	√	√	√	√	√	√
3	PET							
	Recycling	√	√		√			
	Plastic							
	Composting							
	Incineration		√	√	√	√	√	√

The forecast of solid waste with the actual system in Lima is also been calculated by the program.

From these data, comparisons have been done.

Results and figures will show us the amount of waste to landfill for 20 years (Figures 8.2 8.3 8.4).

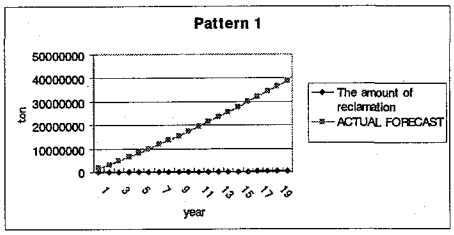

Fig 8.2

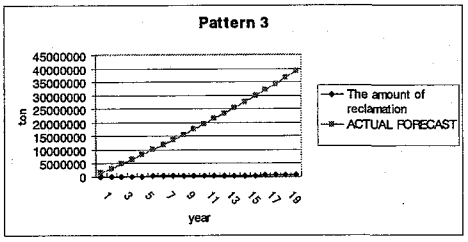

Fig 8.3

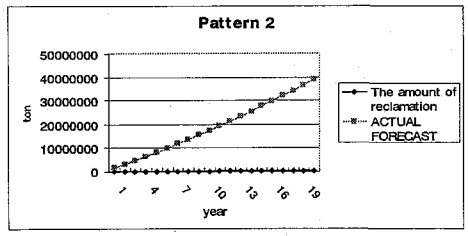

Fig 8.4

So the effectiveness of the system in waste reduction is shown with great results.

9. CONCLUSIONS

This paper describes a system that can be taken into consideration to the analysis of solid waste management considering recycling in a metropolitan area under a local government in developing countries. It includes choosing of most suitable selection of facilities, system and establishment of process for waste treatment. Also the financial management for a proper validity and capacity of reclaimed land is done. This system is to establish the management of waste considering reducing and recycling, choosing the finance resources for each zone, determine kinds of facilities to be constructed, and the amount of reduce waste to landfill.

Data found and used are old and not complete. For a more accurate result, more accurate data are needed, however this study is reliable and data used has a good approximation to reality.

Even though the investment for this plan is high at the beginning (30, 20 or 10 million dollars), it will decrease by improving the tax collection (30% procrastination) and increasing it gradually according to the services offered (now it is around 50 million dollars).

According to analysis, Pattern 1 is best because reduction of waste is minimum value and we can have more facilities to waste management.

Through mathematical analysis was found that the best system to manage the wastes and reducing reclamation in Lima is using burning facilities as main strategy to reduce waste.

Further planning is necessary in order to achieve a complete system with all facilities required.

REFERENCES

[1] Alegre Marcos, "Situación Actual y una Mirada al Futuro del Ambiente Urbano en el Perú," *El Medio Ambiente en el Perú, year 2001,* CD version (Lima: Cuánto Institute, 2002), pp. 115-154

[2] Amar, Jorge, De que Hablamos Cuando nos Referimos a un Municipio Sustentable? : primera aproximación, (Buenos Aires, 1999)

[3] Cointreau – Levine, Sandra; Private Sector Participation in Municipal Solid Waste Services in Developing Countries, 1st Edition (Washington DC: Urban Management Programme by the World Bank, 1994.)

[4] Municipalidad Metropolitana de Lima, Plan de Emergencia Ambiental para el Manejo de Residuos Sólidos a Nivel Provincial, (Lima: Metropolitan Municipality, January 2002)

[5] Tachibana Junzo, A Study on Development of Model on Derirable Waste Disposal System in Regions, Thesis, Ritsumeikan University (Japan)