A System Dynamic Approach for Financial Planning in Solid Waste Management: A Case Study in Phnom Penh city

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Abstract

Financial planning in solid waste management (SWM) is a very important issue that needs to be carefully considered. The failure to insure an adequate budget for operational expenses may have negative impact on the whole SWM system. However, the dynamics of solid waste make decision making difficult for preparing financial planning.

This paper presents a model that is based on the system dynamic (SD) approach to serve as a decision support tool for financial planning in community-based solid waste management (CBSWM) system. A case study of the CBSWM system in Boeng Keng Kang (BKK) district illustrates the application of the model.

Keywords: Community-based solid waste management, Financial planning, System dynamics, Cambodia.

1. Introduction

Least-developed countries such as Cambodia have weak economic bases and hence, insufficient funds for sustainable development of a solid waste management system. In general, the SWM sector is given a low priority in the country (MOP, 2002), especially in some blocks in the city where people who live there are considered squatters. The Municipality of Phnom Penh (MPP) which is responsible for SWM in the city hesitates to provide people in those areas with solid waste service because the introduction of such services would recognize their existence officially. However, the unavailability of the solid waste service results in the poor scattering their waste and large areas becoming flooded because the drainage systems are blocked by waste. As a result, the Municipality is burdened with an expensive cleanup system for streets and drains.

Seeing that the solid waste service should be brought to the urban poor areas, the capital-short MPP tried to seek financial support from donor agencies. With financial aid from the Norwegian Agency for Development (NORAD) and the Asian Development Bank (ADB), a pilot project of the SWM has been implemented. However, the SWM system in the project area, Boeng Keng Kang (BKK) district, is a community-based system that is different from the one that has been operated in the city by the present private corporation.

A community-based organization model has been well known and widely recommended as a strategy for effective solid waste management in urban poor communities in many Asian cities (Kum et al., 2003). However, most of the projects in this type have generally been carried out in collaboration with external support. The pilot project being implemented in BKK district is in this type. Hence, a question remains whether the pilot project being implemented in the project area can support itself or expand further when the external agencies discontinue their support.

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2. CBSWM system of the Municipality of Phnom Penh

MPP assigned Phnom Penh Waste Management (PPWM) to manage the solid waste service in the project area and PPWM has a mandate to collect the service fee from its clients as well. PPWM contracts out primary collection to the so-called Self-Help Groups (SHGs). The groups use pushcarts with a volume of 0.8 m^3 operated by two operators.

The waste is collected door to door from the households in the project area and brought to the Waste Recycling Development Center (WRDC) for sorting. Waste with a market value will be sorted for sale and compostable waste will be separated for composting at the WRDC. PPWM provides a secondary collection with a 16m^3 compactor vehicle procured through the project. Secondary collection involves the transporting to the dumpsite of all residual waste that remains after sorting and removal of compostable and recyclable materials.

At the WRDC, recyclable materials sorted from waste are not processed locally but the sorted recyclables are sold directly to the local buyers at the end of the month. These middlemen add value to the recovered material by further sorting, classifying, shredding, baling and other processing before it is sold to specialized junk shops or traders who transport the waste to recycling facilities (mostly in Vietnam). The revenue from recyclable sales goes to the SHGs. The compostable waste such as food and vegetable waste is sorted out from the mixed waste and transported to the WRDC for composting. Some carbonous material like sugar cane and coconut is first fed into a locally fabricated shredder. The shredded material is then mixed with the compostable material and stacked in bins with aeration tubes for three to four months. When the waste is fully decomposed, it is fed into another machine that sorts it by particle size. The final product (compost) is sacked and stocked for sale. The revenue from the compost sales also goes to the SHGs.

3. Model conceptualization

Overall concept of the model development

The waste authority, PPWM runs the collection service in the low-income area by depending completely on the revenue from the collection service fee of its clients, with no additional financial aid from the government. The poor can afford only a partial service tariff, thus, it may be not enough for the operating expenses; and the collection service may not be able to sustain itself due to the financial crisis of inadequate funds. As a result, the waste authority will collect only a portion of waste at source that it can manage to transport to the dumpsite with the funds available. If the collection coverage is not enough, waste at source to be collected will exponentially increase and the pollution index will also increase. It is very difficult to quantitatively estimate the impact of pollution from the uncollected waste in terms of economic loss, public health or degradation of urban environment, though it is believed the uncollected waste can result in such problems. The pollution index in the model is a variable that represents the *pollution level* corresponding to the uncollected waste and it is assumed that the willingness of the poor to pay the collection service increases when the pollution index increases. The causal loop diagram of the model is shown in figure 1.

- *Waste at source to be collected* (WASTBC)

Waste at source to be collected is a state variable that shows the amount of waste at source that needs collecting.

- *Waste at WRDC to be transported* (WAWTBT)

Waste at WRDC to be transported is a state variable that shows the amount of waste at WRDC that needs transporting to the dumpsite.

- Pollution index (PI)

Pollution index is the ratio between WASTBC and AWAS. In the model, fee collection effectiveness starts increasing when the PI approaches one, i.e. the WASTBC approaches AWAS.

- Fee collection effectiveness (FCE)

Fee collection effectiveness is the efficiency of collecting the service fee. The FCE is assumed to be a dependent variable as a function of the PI and it is dimensionless (Dmnl).

- Admissible waste at source (AWAS)

AWAS in the model is assumed to be the highest amount of waste left at source uncollected beyond which the poor start to respond to waste issues, i.e., they increase their

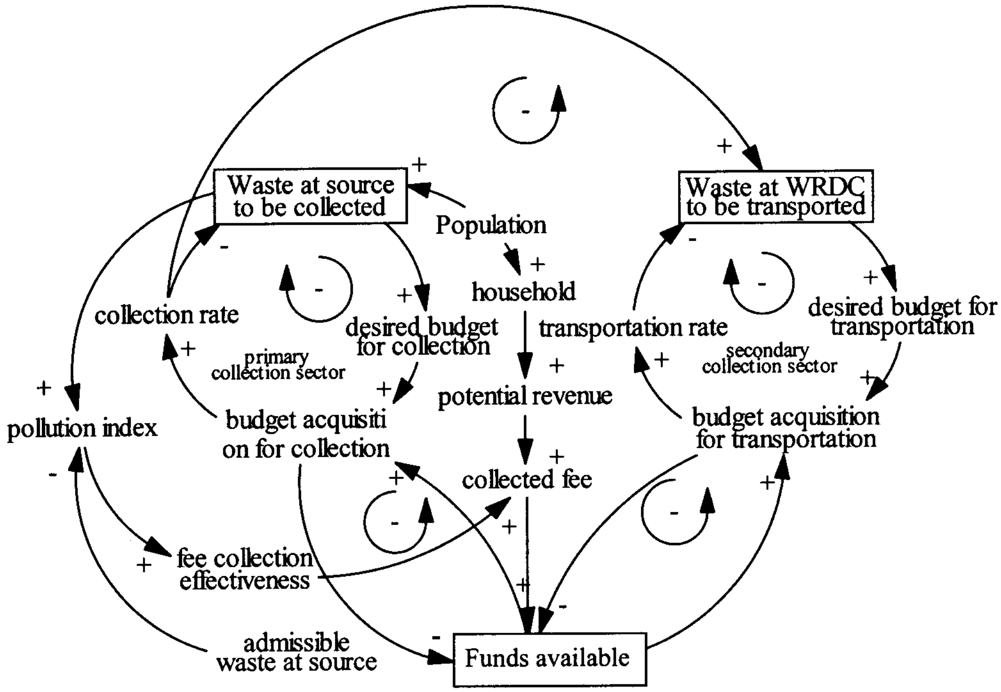

Figure 1. Causal loop diagram of the model

payment to collection fee. The above-mentioned assumption is based on the fact that there has been no previous research for explicit determination of AWAS, though it is believed that people want to live in a clean environment and being poor does not necessarily mean being dirty.

AWAS in the model is a constant calculated based on some assumptions on certain parameters: population density, admissible period of unavailable service; and the assumptions may be suitable to only the local poor area. For example, if the density of population can reach the assumed admissible highest density, 29,500 persons/km^2, the accumulated period of unavailable service is allowed up to one month. We adopted the very high population density to take into account crowding factor and a long accumulation period to take into account the possibly strong tolerance of the poor to waste appearance and bad smell during unavailable collection service. Such a long duration of unavailable service may not be acceptable to the higher income public. AWAS is calculated as follows:

AWAS = NWGPC*AAP*AHD*LA

Where:

NWGPC: Nominal waste generation per capita

AAP: Admissible accumulated period (i.e. period of unavailable collection service)

AHD: Admissible highest density

LA: Land area

Model formulation

Model formulation in SD is the process of translating model structure into mathematical equations. In other words, it is the transformation from an informal conceptual view to a formal, quantitative representation (Richardson et al., 1981). The stock and flow diagram of the model is shown in figure 2.

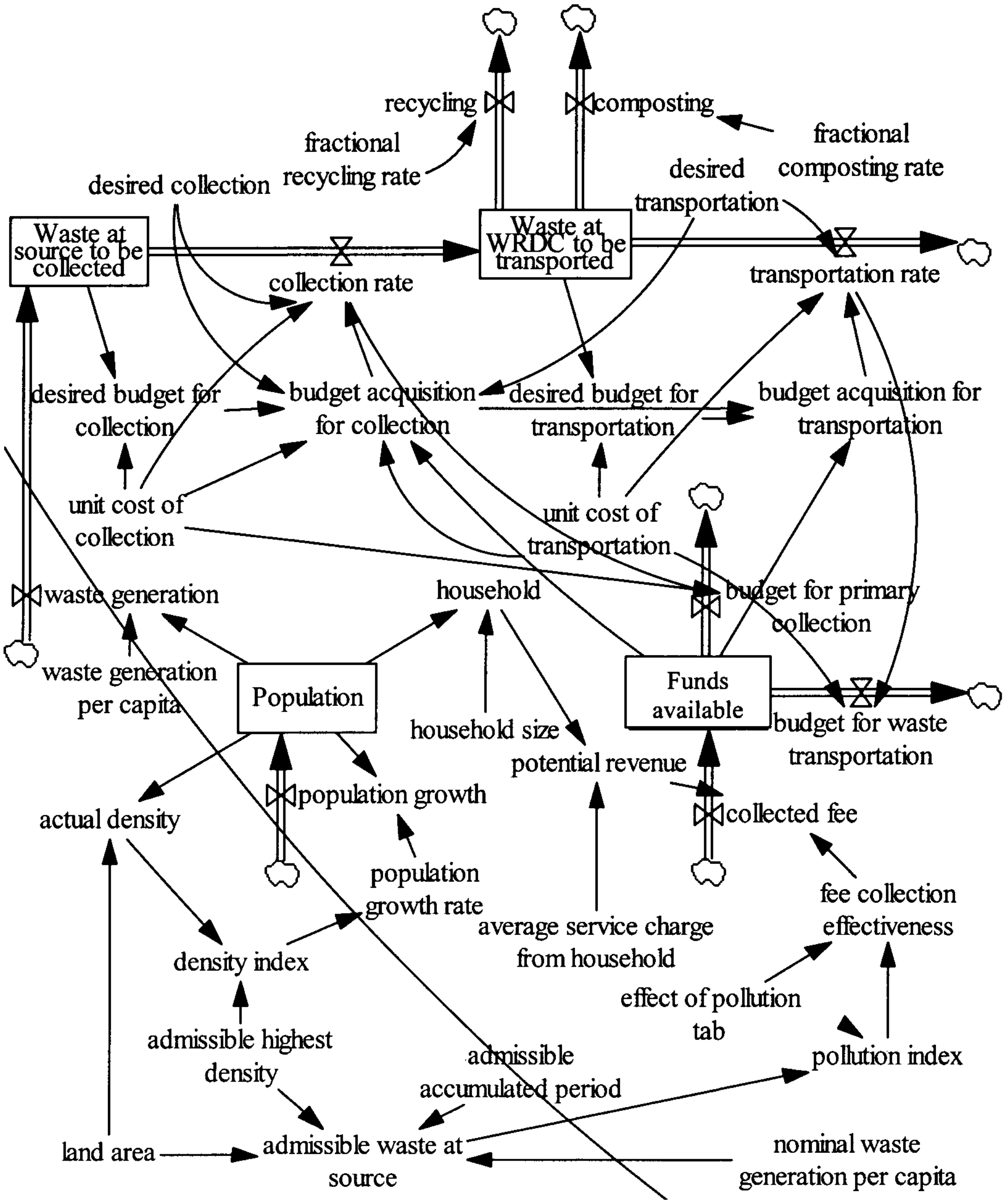

Figure 2. Stock and flow diagram of the model

4. Model simulation and testing

Vensim is a visual software to help conceptualize, build, and test system dynamics models (Ventana systems, 2003). The model to be used for the policy experiment in this paper is developed using the software package.

The desired behavior of the model, when policy experiments are conducted, is considered as one that results in the equilibrium of or increase in the stock 'Fund available' while waste at source and waste at WRDC have to all be collected and transported to the dumpsite. However, such a desired behavior does not require the stocks "Waste at source to be collected", WASTBC, and "Waste at WRDC to be transported", WAWTBT, to be in equilibrium because the waste generation rate is not constant but increasing and thus, the stocks will generate growth patterns. The funds available are enough for collection and transport of all waste at source and at WRDC to the dumpsite. This can be confusing because the WASTBC can also generate a growth pattern when the funds for waste management service are inadequate. So, the growth pattern of WASTBC and WAWTBT should be seriously considered before any judgments on each simulation run can be made. If the WASTBC and WAWTBT increase slowly, there may be no financial problem in the waste system but if one or both of these stocks increase sharply, the waste management system may be in financial crisis.

The values of parameters and initial values of stocks are presented in Table 1.

Table 1. Specific values used in the model

Variable	Name	Unit	Initial value(Constant)
Stock	WAWTBT	Tonne	0
Stock	Population	Person	29580
Stock	Funds available	$	25323
Time step	dt	Month	0.25
Constant	Admissible highest density	Person/Km^2	29500
Constant	Average service charge	$/House/Month	1.23
Constant	Desired collection	Fraction/Month	1
Constant	Desired transportation	Fraction/Month	1
Constant	Household size	Person/House	5.8
Constant	Nominal waste generation per capita	Tonne/Person/Month	0.021
Constant	Unit cost of collection	$/Tonne	2.93
Constant	Unit cost of transportation	$/Tonne	4.8
Constant	Fractional composting rate	Fraction/Month	0.014
Constant	Fractional recycling rate	Fraction/Month	0.086
Constant	Land area	Km^2	1.16

Remark: All constant values are adapted from an unpublished report prepared by Inter-Consult. (2002) under the title: Assessment report on the community-based solid waste collection system in Phnom Penh.

Simulation run with current policy

In this simulation, the external support discontinues and the financial arrangements of the local waste authority depend totally on the revenue charged to a user. Resource recovery that may contribute to the financial benefits is not even seriously considered (fractional recycling rate and composting rate are very low). This is assumed to be the current policy of the local waste authority in managing the present waste system in the poor areas.

Simulation results are shown in Figure 3 and display the behavior of the model under the current policies. The figure shows that with an initial allocated fund of around US$ 25,323, financial crisis may occur around 27 months after the operation starts. The financial crisis results in the exponential increase in WASTBC, which grows and continues to grow to the end of simulation.

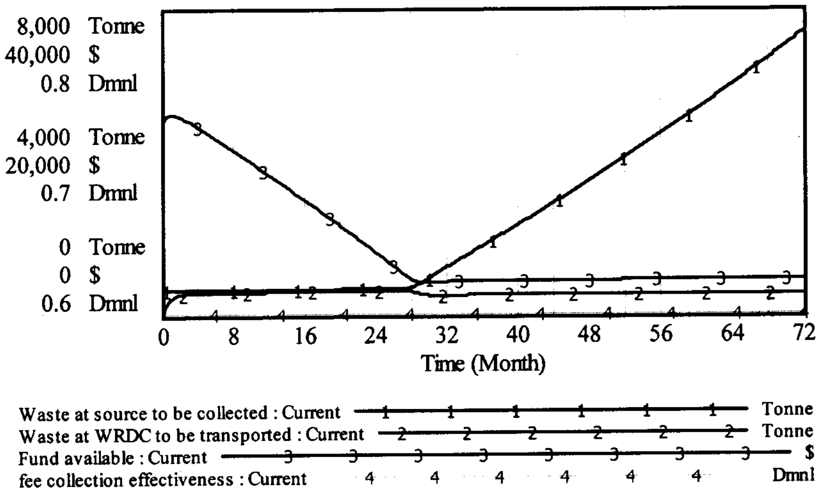

Figure 3. Simulation run with current fractional recycling rate 1.4% and fractional composting rate 8.6% and with the current fee collection effectiveness 60%

Alternative policy N1

Simulation under the current policies shows that the financial crisis occurs around month 27. It is interesting to learn about a situation where fee collection effectiveness increases but the benefits of resource recovery from waste is ignored. Figure 4 shows the simulation of such a policy. A remark can also be made about Figure 4. Though FCE increases up to 80%, i.e. real collected fees are increased up to 80% of potential revenue, the behavior of the model shows that the system may still face a crisis at around month 52. This is shown in the graph by the start of the exponential increase in WASTBC.

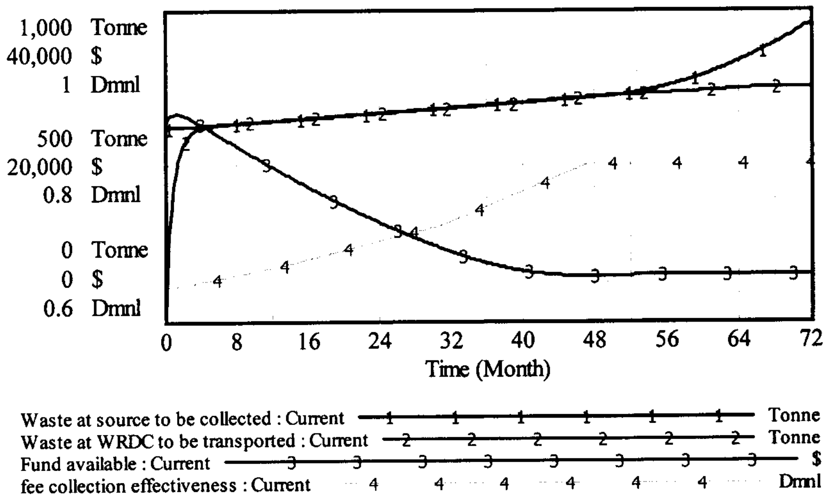

Figure 4. Simulation run without recycling and composting and with the influence of the increase in fee collection effectiveness

Alternative policy N2

In this section, the benefit of resource recovery and the increase in fee collection effectiveness are considered. It should be noted that the fee collection effectiveness in this section is increased up to only 70%, but the fractional composting and recycling rates increase three times higher than the current composting and recycling rate. Figure 5 shows the simulation of such a policy. The simulation results show the desired behavior that has been searched for: the fund available is enough for collecting all waste at source and transporting all waste at WRDC to the dumpsite. This means that the implications of the synthesis of the policies could save the financial shortage problem of the local waste authority.

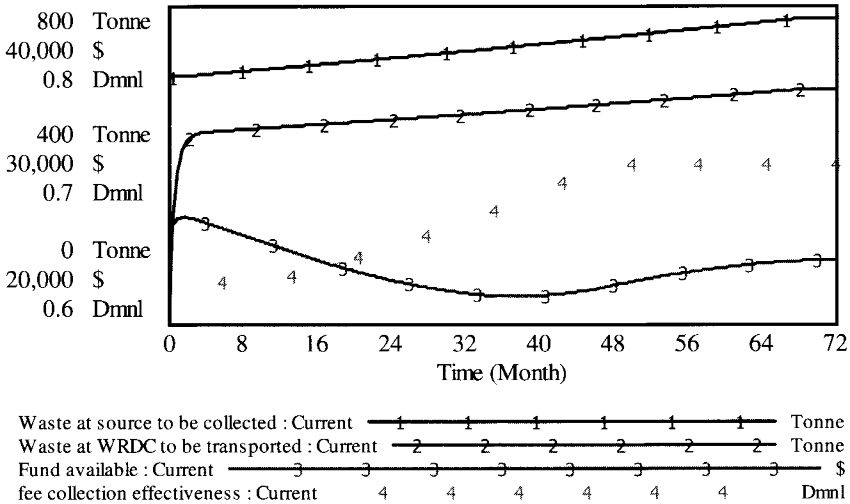

Figure 5. Simulation run with the increase in recycling and composting and with the influence of the increase in fee collection effectiveness

5. Conclusion

Financial planning for the community-based solid waste management can be facilitated by means of system dynamics. The SD model in the paper was simulated within a six-year time frame and the initial time is the year 2003.

The model presented is simple and an aggregate representation. It can serve as a platform for a free and fair discussion about the impact of waste recovery policies on financial arrangements in CBSWM systems. The model demonstrates that increases in composting and recycling does have a positive impact on the financial shortage problem of the local waste authority.

Though the concept of the model is generalized, the values used for simulation were estimated with specific assumptions that reflect mostly the local conditions, for example the estimate of an AWAS value. The authors strongly recommend that potential users of the model should re-estimate an AWAS value using the available local data so that the model can better reflect the real situation.

6. References

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