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The Development of the Municipal Solid Waste Recycling Dynamic Model at Transfer Station

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Abstract

With the high amount of municipal solid waste (MSW) in Bangkok, Thailand, a number of efforts to reduce and recycle the MSW were performed. However, landfilling is still be the most usual destination for MSW in Bangkok. Landfilling method might lead to a number of environmental problems such as water and air pollution and gas emission. Apart from that, the higher land cost and more restrictive environmental regulations regarding the siting and operation is hard to manage. Some efforts to reduce and recover the MSW were perform in Bangkok, in order to reduce more waste. Householder is one of the factors that help in reducing MSW. Recycling program implemented could lead to reduce more waste by householder, besides that, the other factors such as; private sector and public sector (government) could help in reducing waste also. This paper, therefore, utilizes system dynamic modeling to develop the model based on factors and related relationships that affect the amount of recycled MSW, in order to help decision-makers to assess MSW recycling waste situation in Bangkok. The simulation results could help make the proper recycling plan to reduce the landfill usage.

Keyword

Municipal solid waste, Private sector, Public sector, Recycling, System dynamics modeling

1. Introduction

Municipal solid waste (MSW) is an issue of worldwide concern. It is described as useless or unwanted waste (Tchobanoglous, 1993). In the developing country, the amount of MSW incresed due to the economic development, the urbanization and the better living standard (Glawe et al., 2005; Erdogan *et al.*, 2008). Kansal (2002) mentioned that the quantity of MSW in developing countries has been consistently rising over the years. Thailand, one of the developing countries, also faces with the MSW problem , with around 40 thousand tons of wastes generated per day (Muttamara *et al.*, 2004; Pollution Control Department, 2011). It is found that 20 percent of these wastes come from Bangkok (Pollution Control Department, 2011). These wastes, if not properly manage will be disposed of in landfills (Manomaivibool, 2005; Chiemchaisri *et al.*, 2007). This, in turn, leads a number of environmental impacts, such as land degradation, water and air pollution, and gas emission. (Pohland and Harper, 1985; Qasim and Chiang, 1994; Muttamara *et al.*, 2004; Leao *et al.*, 2001).

According to the Administrative Strategy Division (2009), 60 percent of the MSW can be recycled. Efforts have recently been made to recycle more wastes (Chiemchaisri *et al.*, 2007). (Manomaivibool, 2005) recommended that the recycling program should be implemented with the householder to encourage the recycling activities. (Luanratana and Visanathan, 2006) also mentioned that the government and private sector play an important role in the recycling program implemented.

This paper, therefore, aims to develop a dynamic model of MSW waste recycling using a system dynamic approach. System dynamic (SD) is a methodology and mathematical modeling technique for framing, understanding, and discussing complex issues and problems. A number of MSW related projects were used this technique as methodology such as; Pons et al. (2009) used SD modeling to predict the MSW generation in Andorra and Ahmad (2012) used SD modeling to predict the MSW generated, collected, disposed, recycled and treated capacities, and to estimate the electricity generated from MSW and to predict the fund required for MSWM in Delhi during 2006 and 2024.in Delhi, India. In this paper, the key factors of government and private sector are concerned in the model development. It is expected that the developed model assists in guiding the recycling program implementation overtime.

2. The Development of MSW Recycling Dynamic Model

The collected wastes from householder in Bangkok area are transferred to the three transfer stations before sending them to the landfills (Muttamara *et al.*, 2004, Manomaivibool, 2005). These wastes are then sorted by workers from the private sector that is in charge at the transfer stations, and by the government officers responsible for waste sorting. This leads to two sub-models of the MSW recycling dynamic model, as describe below.

2.1 Private Sector Dynamic Model

Figure 1 shows the private sector dynamic model. The model consists of two stocks: the "Total_Additional_Workers" and the "Total_RA_by_Workers" stocks. The "Total_Additional_Workers" stock is the, total amount of additional private sector workers (see 1). This stock will be accumulated through "Additional_RS" inflow (see 2). At the beginning of the recycling program it is found that the the fulltime workers that work at three transfer stations are 300 people, with the sorting capacity of 900 tons per day (Luanratana, 2003; Noonin, 2004; Manomaivibool, 2005; Puengphum, 2013). The amount of workers are then increase by 10 percent every year as the recycling program continue.

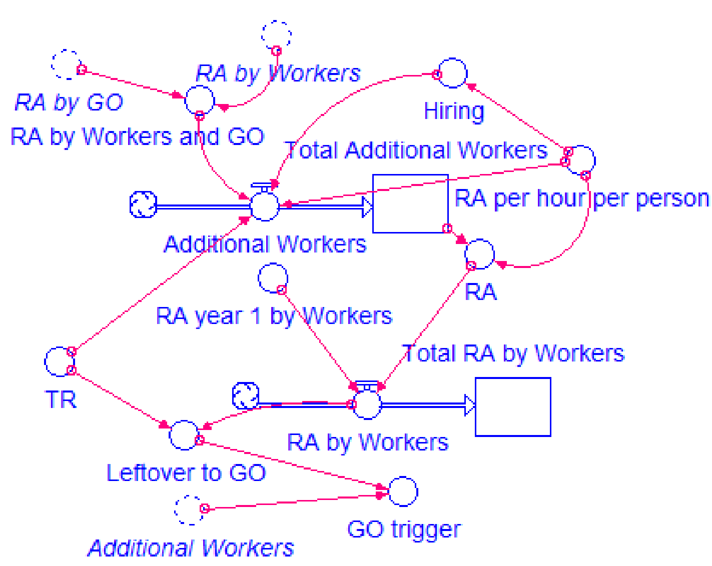

Figure 1: The Private Sector Dynamic Model

Notes: TR=Total Recyclable Waste, RA=Recycled Waste Amount, GO= Government Officers

Total_Additional_Workers(t) = Total_Additional_Workers(t - dt) + (Additional_Workers) * dt (1)

Additional_Workers = if (RA_by_Workers_and_GO<TR) then (If (TR-RA_by_Workers_and_GO>Hiring) then (300) else ((TR-RA_by_Workers_and_GO)/((RA_per_hour_per_person)*8*365))) else (0) (2)

The "Total_RA_by_Workers" stock, on the other hand, is accumulated and accumulate the amount of recycled waste from the private sector. As shown in (3), there would be no hiring fulltime workers if the amount of workers, together with the government officers are enough to recycled the total waste each year. The "RA_by_Workers" flow see (4) combined the current and additional capacities. The leftover waste ,when the current capacity does not match with the waste amount will be managed by the government officers to further recycled (see 5).

Total_RA_by_Workers(t) = Total_RA_by_ Workers (t - dt) + (RA_by_ Workers) * dt (3)

RA_by_ Workers = RA+RA_year_1_by_ Workers (4)

Leftover_to_GO = MAX(TR-RA_by_ Workers,0) (5)

2.2 Government Officers Dynamic Model

The government officers dynamic model, illustrates the capability of the public sector in handling the wastes. Similar to the private sector dynamic model, this model considers hiring more government officers to sort recyclable wastes (see Figure 2). The model consists of two stocks: the "GO_fulltimers" and "Total_RA_by_GO" stocks.

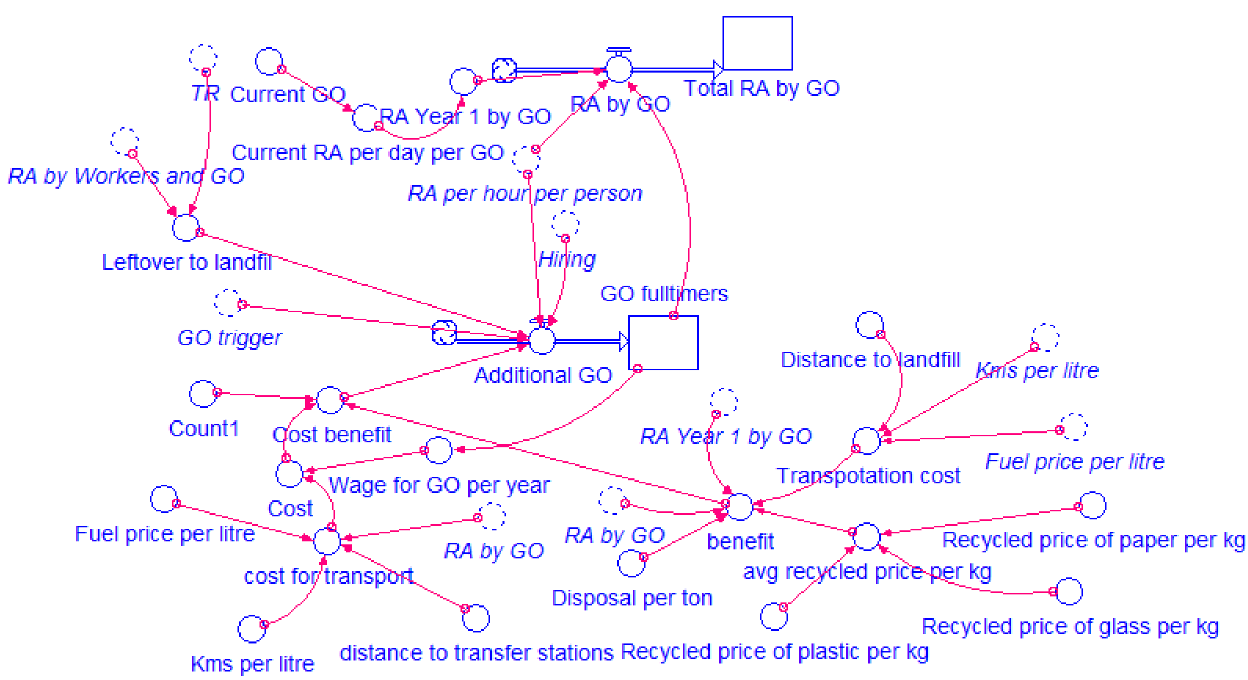

Figure 2: The Government Officers Dynamic Model

Notes: TR=Total Recyclable Waste, RA=Recycled Waste Amount, GO= Government Officers

The "GO_fulltimers" stock, as in (6 and 7) is increased by adding or hiring more fulltime officers. This process continues as long as the benefit of hiring officers, compared to the costs incurred are hire. Benefit refer to the saving in the transportation cost to landfill, the savage value of the recycled wastes and the saving in the disposal cost (Muttamara *et al.*, 2004; Noonin, 2004; Manomaivibool, 2005; Wongpanit 2013). Costs, on the other hand, include the wages of fulltime officers and the transportation cost to the recycled shop (Luanratana, 2003; Muttamara *et al.*, 2004; Manomaivibool, 2005). Based on (Bereau of Budget, 2013) , a maximum of 207 fulltime officers are hired each year. This amount is increased, at a constant rate of 13 percent, of that in previous year based on the increased budget in the last two years (Bereau of Budget, 2013).

GO_fulltimers(t) = GO_fulltimers(t - dt) + (Additional_GO) * dt (6)

Additional_GO = if (GO_trigger=1) then (MIN((Leftover_to_landfil-Hiring)/((RA_per_hour_per_person)*246*8),INT(Cost_benefit))) else (0) (7)

The "Total_RA_by_GO" stock, as in (8), represents the amount of recycled wastes sorted by the government officers see (9). This stock accumulated as more government officers are added in the system.

Total_RA_by_GO(t) = Total_RA_by_GO(t - dt) + (RA_by_GO) * dt (8)

RA_by_GO = ((RA_per_hour_per_person*8*GO_fulltimers*246)+(RA_Year_1_by_GO)) (9)

3. Simulation Results

The dynamic models of MSW recycling is simulated and the results is illustrated in Figure 3 and Table 1. It is clear that the amount of sorted recyclable wastes increase as time increases. This, due to the hiring process of both government officers and private sector workers.

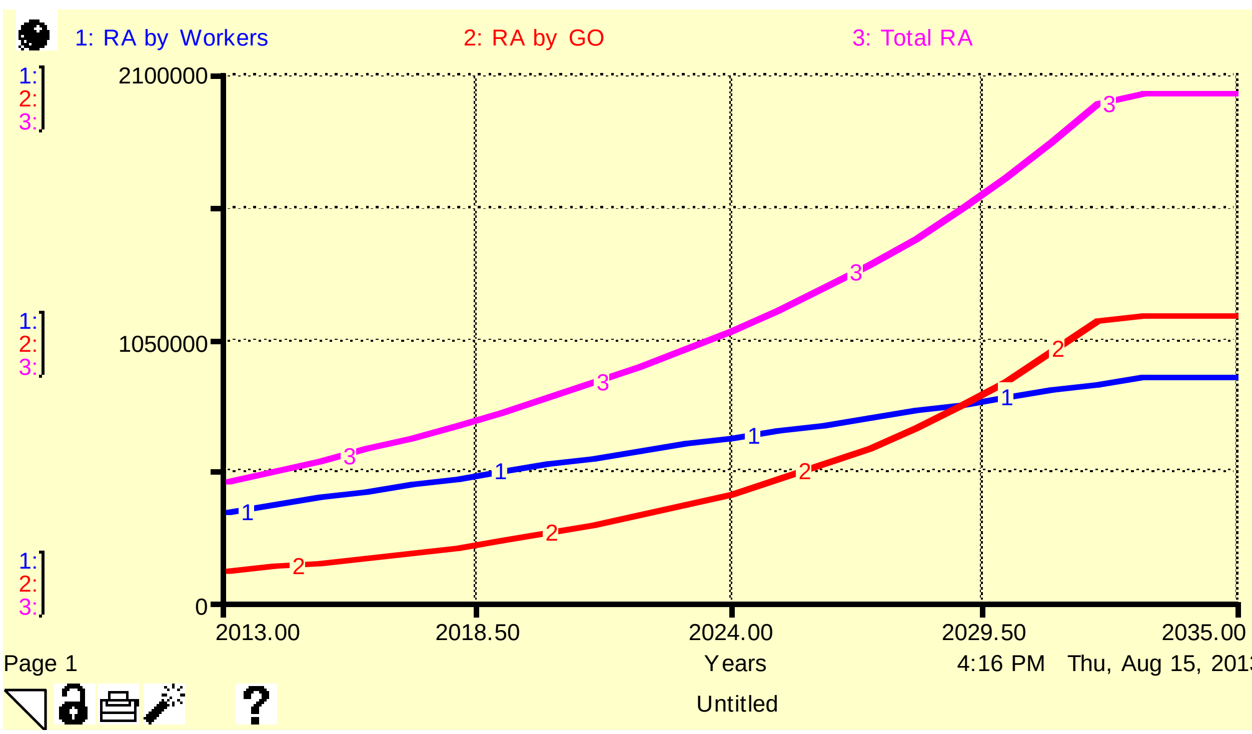

Figure 3: The Graphical Results of MSW Recycling Dynamic Model.

As illustrated in the graphical results above, the amount of recycled wastes achieved from the workers working at the transfer stations dictate those amount achieved from the government officers. This is due to the hiring strategy at a constant rate of 10 percent more workers per year. After 17 periods, however, the number of government officers increase in a sharp rate, as the budget available in recruiting fulltime officers increases. This, in turn, increases the recycled waste amount sorted by the government officers. The model shows that the total recyclable waste (2,033,043.93 tons/year) could all be sorted and recycled in 20 years (2033) using 6,300 workers with 17,097 government officers (see table 1). It is noted that the mentioned workers and officers are located in the three transfer stations.

Table 1: Simulation Results

Year	Number of workers (persons)	Recycled waste amount by workers (tons)	Number of government officers (persons)	Recycled waste amount by government officers (tons)	Total recycled waste amount (tons)
2013	300	355,376.85	207	120,303.03	475,679.88
2014	600	382,253.70	440	134,371.78	516,625.47
2015	900	409,130.55	704	150,312.32	559,447.87
2016	1,200	436,007.40	1,002	168,305.82	604,313.22
2017	1,500	462,884.25	1,339	188,654.18	651,538.42
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2030	5,400	812,283.29	12,767	878,686.73	1,690,970.02
2031	5,700	839,160.14	14,635	991,478.19	1,830,638.33
2032	6,000	866,036.99	16,745	1,118,881.82	1,984,918.81
2033	6,300	892,913.84	17,097	1,140,130.09	2,033,043.93

4. Conclusion

The dynamic model MSW recycling is developed using the system dynamics modeling technique. The simulation results proved that the increase mount of recycled waste over time can decrease the amount of waste to landfills. It is, due to the successful in recycling plan cooperation between the recycle shop and the government.

This MSW recycling dynamic model at transfer station will further be developed with the household recycling dynamic model to investigate the behavior of the recycling program implement in Bangkok, Thailand.

There are limitations in this study. The data that were used in the model come from the Bangkok, Thailand. These will limit the model to simulate only in Bangkok. However, this model can be used in different environments by adjusting data accordingly to the specific situations.

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