A Strategy for Planning Solid Waste Sanitary Landfills to be Constructed in Taiwan Region by the Systems Analysis Method

Control #185

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ABSTRACT

Systems analysis is applied to plan the construction of solid waste sanitary landfills in the Taiwan region. This study focuses on the analysis and definition of the solid waste problem in Taiwan, and the establishment of sanitary landfills, the making of variable policies and the constraints. The factors governing the various feasible plans are in put to a simulation and eventually an evaluated optimal plan is out-put which can be executed and subjected to a control audit. The various features that need to be considered in the system include the total amount of solid waste generated, the total amount of solid waste recovered, the available landfill, the financial budget, manpower resources, and organization assets. The limiting factors include keeping sites away from water resources, to avoid secondary environmental pollution, to dispose of hazardous industrial waste separately, to have an active life of more than 5 years, and to have a recovery ratio that

increases by at least 1% per year, etc. In this study, the well-known systems model can be applied not only to optimally plan the landfill construction, but also provide the functions of forecasting and modification, to be used in the practical day to day operation of the landfill.

INTRODUCTION

Taiwan's population is growing year by year and its metropolitan areas continue to expand. This means that the total amount of solid waste generated per day, per capita, cannot be effectively reduced, meaning that the total amount of solid waste generated increases in all areas. The available capacity of existing landfills decreases day by day in every county/town/city. Given the continuous increase in the amount of solid waste generated, existing landfills will soon be full. In Taiwan solid waste treatment methods include minimization, recycling, recovery, combustion, composting, landfills, and others. The demand for sanitary landfill construction has became unavoidable to effectively manage the solid waste that needs do be treated. In the past, landfill planning has been executed in a somewhat haphazard manner, which has resulted in sites that are often inappropriate, that are insufficient to meet the demands of the integrated system concept. It has been difficult to integrate all items regarding useful resources necessary for the effective treatment and disposal of solid waste.[1] Thus, it is essential to utilize a systems concept framework to intellectualize sanitary landfill building problems, to more effectively solve solid waste disposal problems. Thus, the aims of this study are to focus on the analysis and definition of the solid waste problem in Taiwan, and the establishment of sanitary landfills, that conform to variable policy and constraint conditions.

Systems analysis is used to eliminate any inherent prejudice and to integrate the various types of useful resources. The system models can be used to consolidate the various factors that have an impact on planning, to engage in outputting a model and to evaluate this model. One of the strengths of the output model is that we can forecast the impact in order to reach a higher standard prior to the construction of new sanitary landfills in the

Taiwan Area.

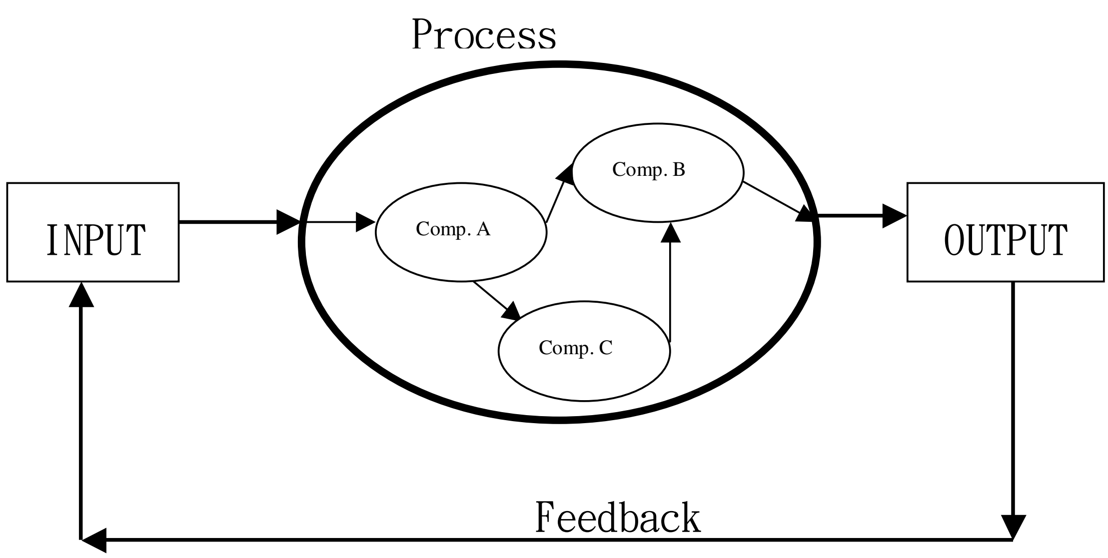
METHODOLOGY

Systems Theory

Fig. 1 shows the numerous and verifiable components of the system, including individual elements, members, sub-systems, components, etc. Correlations exist among these components, and these correlations form linkages, giving the system its structure. The looping knots of these components are interdependent and interrelated. These linkages achieve certain functions. Inputs and outputs are on-going within the systems boundary, that is inputs enter from the boundary, and outputs go out of the boundary, to interact with the system environment. The inputs are clear, with well-defined interaction, and the outputs are authoritative. Meanwhile, there are outputs that occur after the inputs happen, and outputs that affect the inputs by feedback action, to form a route in this way.[2]

Within the closed scope of the system, each system is a sub-system within a bigger system, having its own built-in limit and independent of the environment. On this time scale, systems often show dynamic behavior to achieve system objectives.

Figure 1: Systems Analysis Concept Chart

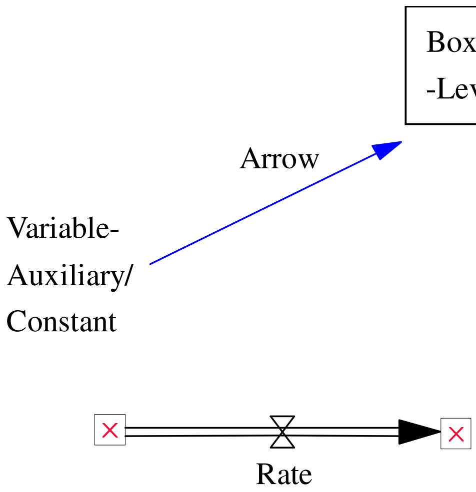


Systems Analysis Tool – the VENSIM Software was Used for the Modeling

Schematic Graph

There are only four icons needed in VENSIM to set up the system. These four icons include the stock or level, the flow rate, the converter or arrows and the auxiliary. The four icons are shown in Fig. 2.

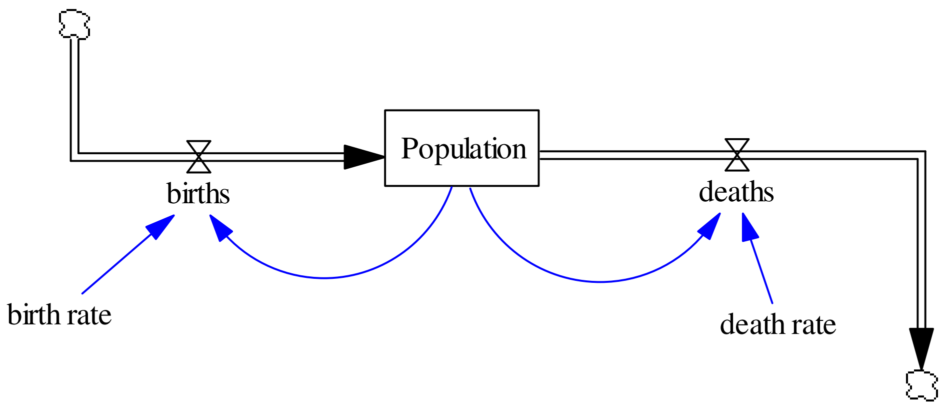
Figure 2: Systems Analysis Coins



Building the Model

In VENSIM, these four icons can be used to build a correlation graph and a cause-effect graph to display the observed modeled behavior. In this model, all the observed variables can be increased or decreased; computer software can be used to program the modifications an efficient and accurate way. One modeled population example is shown in Fig. 3. Systems models can be used to build a simulation to test by theory, to obtain observation results, to make assumptions, and then to make modifications to let the system function even better.

Figure 3: Example of a Systems Analysis Model



System Analysis

Some components in the same system, but with different input conditions, can be utilized to analyze and determine which variable is major, and which variable is minor or even irrelevant. All these results can serve as policy-making reference guides.

PROBLEM IDENTIFICATION AND DEFINITION

The first step to build the model is to thoroughly understand the problems, the persons and to know how to communicate with them. Therefore, it is necessary to verify the scope of the system and to identify and define the problem, to build a systems model. The following problems occur in sanitary landfills in Taiwan. These problems must be considered during construction planning.

Sanitary Landfills are the Final Solid Waste Disposal Method

The primary method for the disposal of solid waste in Taiwan is incineration, but the sanitary landfill is the final solid waste disposal method. Fly ashes/cinders, generated by incineration equivalent to 20% of the total solid waste, and solid waste generated in those areas (county/town) without incinerators, must all be disposed at in sanitary landfills.

The Disposal Capacity of Existing Landfills is being Reduced Day by Day

The landfill capacity of the existing landfills in Taiwan is decreasing, but the generation of solid waste, per person, per day, is increasing. Eventually the available space will not be sufficient.

Difficulty of Finding Locations for the Construction of New Solid Waste Sanitary Landfills

Sites are limited, especially in densely populated regions. It is thus difficult to locate places for new solid waste sanitary landfills.[3, 4] Over the past few decades, city development plans in the Taiwan region have not included locations for solid waste sanitary landfills, thus there are no sites for reserved this purpose.

Unsystematic Operation and Maintenance of the Solid Waste Sanitary Landfills

No deliberate operation and maintenance of the solid waste sanitary landfills can easily lead to sewage leaking, running surface sewage, air pollution, and the proliferation of mosquito breeding grounds.[5] The leaching of toxic materials poses a tremendous threat to drinking water resources. Moreover, the construction of landfills can increase traffic volume, neighborhood noise levels, and vibration damage to areas nearby the landfills, all of which will have a great impact on the quality of life of people living nearby.

Non-joint Establishment of Regional Solid Waste Sanitary Landfills

Adjoining counties/towns/cities, should, but have not established regional solid waste sanitary landfills, which would reduce the time for obtaining sites, and simplify the establishment process. When confronted with new problems, they are often unable to support and solve such problems mutually.

Budget Deficiencies

Most municipal areas in Taiwan are unable to arrange an establishment budget in advance. Therefore, the establishment and operation of solid waste sanitary landfills must be completed with whatever resources may be available. Inadequate resources can lead to poor planning an ultimately secondary environmental pollution.

Political Intervention in the Establishment Process

People often feel that waste disposal site should “NIMBY-not be in my back yard”. Politicians are tempted to improperly interrupt with the political force to serve their own interests. In Taiwan, they have encouraged the local people to oppose and to ask for compensation for the construction of such sites in their area which raises the costs and hinders the construction process.[6]

Relevant Legislation needs to be Revised

The legislation governing waste management is nearly complete, but without prompt revision, necessary to comply with the actual current situation, there will be a gap between execution and planning,[7] such as resource recovery allocation problems from sale income.

Solid Waste Minimization and Resource Recovery are the Most Important Factors Upon which Sustainable Development is Based

Solid waste minimization, resource recovery, recycling, reuse, and decreasing the toxicity are the main basis for sustainable the development. At present, the ratios of resource recovery, recycling and reuse are growing slowly.[7] The effectiveness of the relevant policy is not evident. The establishment of sanitary landfills must be preceded by policies that encourage solid waste minimization and resource recovery.[8]

Other Relevant Issues

There are many relevant problems encountered during the establishment of landfills in many places in Taiwan. For example, the arbitrary dumping of an enormous quantity of construction waste, although sufficient disposal space is lacking. Solid waste landfills, that have originally been located near riverbanks cannot be relocated. The selling price of recovered resources is under-valued, or fluctuate greatly. All these are problems that need to be effectively and quickly solved.

PLANNING OBJECTIVES AND MAJOR POLICY-MAKING FACTORS

The simulated solid waste sanitary landfill model for the Taiwan region is shown in Fig. 4. A step by step explanation follows.

Planning Objective

The most the important requirements for solid waste sanitary landfills in the Taiwan region are mainly listed as follows:

(1) To safeguard the health of the surrounding population, to preserve the ecosystem and to avoid the generation of secondary environmental pollution.

(2) The proper final disposal of solid waste that can enhance the environmental living quality.

(3) Given the insufficient space allocated for future solid waste sanitary landfills, it is necessary to select new solid waste sanitary landfill sites to provide enough space

for future solid waste sanitary landfill needs.

(4) To safely operate, maintain, manage, and follow the best step-by-step procedures for the management, operation, maintenance, environmental monitoring, and auditing of the sites.

(5) To effectively utilize the land made available at land fills after they are covered over.

(6) To develop a things-to-do list for planning and for the relevant legislation. There are investigation data, the arrangement of land use change notices, the arrangement of environmental impact assessments, the arrangement of public hearings, and so on.

(7) Optimal plans for different locations need to be reevaluated.

Major Policy-making Variables

Policy-making variables are determined at the moment, at which they have meaningful definitions. In accordance with aforementioned planning objective, the major policy-making variables for the establishment and planning of solid waste sanitary landfills in Taiwan are as follows:

Total Solid Waste Generation

Solid waste generated per site per day.

Total Solid Waste Recovery

Total solid waste recovery includes not only waste recovery and landfill recovery.

Available Capacity

The current landfill space capacity is subtracted from the landfills space already used up.

Financial Budget

Mechanical operating and maintenance expenses, the expense of purchasing landfill cover clay, personnel expenses, and so on.

Manpower Resources

The organization needs to consider, personnel management strategy, as people control in-coming and out-going control, and other landfill operation processes.

Organization Assets

This includes equipment, pollution control facilities, sorting facilities, resource recovery facilities, entrance and exit roadways, monitoring facilities, etc.

Restraints

The biggest restraint on the construction of solid waste sanitary landfills is to keep the landfill confined to certain areas in order to avert heavy pollution and to secure the safety of the life and property of the neighboring population. This means not being next to water resources to prevent secondary environmental pollution, such as the generation of sewage, air pollution, toxic substances, disease mediums, or noise and vibration. All these would have an adverse impact on the environment and living quality of the people nearby. The restraints are listed in detail as follows:

(1) Ground water: to avert the pollution of underground water resources.

(2) To protect water resources, to maintain water quality and water volume: to avoid the pollution of drinking water resources.

(3) Surface water: to avert polluting near by rivers.

(4) Natural and protected ecologically sensitive areas: to avoid damaging existing natural environments and local ecology.

(5) Faulted or unstable areas: to avoid the imperilment of human health or damage to the environment in geologically unstable areas.

(6) Flood plains: to avoid damage to human health or the environment by construction on a flood plain.

(7) Drainage slopes: to avoid draining that could cause washouts or contamination from the landfills.

(8) Cultural relics in protected areas: to retain the completeness of existing cultural relics.

(9) National parks: to avoid the destruction of existing features in the park.

(10) Roadway accessibility: should be located near the existing roadway system in order to reduce the cost of development.

(11) Slopes: areas with steep slopes that could cause construction or engineering difficulties or increase the cost of development should be avoided.

(12) Avoid being near airport facilities or runways.

(13) Toxic industrial waste should be disposed of separately.

(14) The active life of the site should be more than 5 years.

(15) The recovery ratio should be increased by at least more than 1% per year.

(16) Compliance with the relevant legislation.

Presentation of Various Feasible Plans

Feasibility analysis does not contradict the restrictions, but it is also not likely to lead to the maximization or minimization of the objective functions. A plan of action is the best possible way for decision-makers to achieve this objective. Systems analysis provides many possible alternate plans of action, which can also be regarded as alternatives or optional plans for the decision-maker.

Evaluation of the Most Optimal Plan

Based on the feasible alternatives, resource conditions, the principles or standards that need to be met by an optimal plan and the execution criteria, are evaluated in general terms. Three or four feasible plans can be selected then evaluated to find the most optimal among these. In order to evaluate the optimal plan by means of systems analysis, the most common evaluation criteria is cost-effectiveness analysis.

Execution and Control Audit

When the plan is executed, there are two kinds of risks that need to be considered, one is the environmental risk, also called the risk of input/output conditional changes, the other is the system risk, which is caused by the process of correlation within the system itself. These risks come from uncertainties in the factors of execution.

CASE STUDY

Keelung, located in northern Taiwan, is a harbor city. The population of the city was 392,242 at the end of 2002. It is located near a mountainous area and every year has high precipitation especially in spring and summer. Systems analysis is used to estimate the increase in population, the solid waste generation rate, the remaining capacity of landfill space, the available services, and so on. The model built for this study is shown in Fig. 4. The initial conditions for the respective variables are as follows: the population in 2002 is 392,242, the birth rate is 1.2%, the death rate is 0.8%, the solid waste recovery rate is 40%, the solid waste generation rate is 0.9 kg/day, the solid waste density 0.3 ton/m^3, and the initial available landfill capacity is 2,000,000 m^3. No relevant data is available for the financial budget, manpower resources, or organization assets. In effect the weighting was assumed to be irrelevant. Once the relations of concern come out; the simulation follows the steps of the systems analysis method.

In the model simulation monthly values are used for, population growth (Fig. 5), solid waste generation (Fig. 6), total solid waste generation (Fig. 7), total solid waste generated m^3 (Fig. 8) and available remaining landfill space (Fig, 9). The results of the simulation are shown in Table 1. From Figs. 8 and 9, and Table 1 of this case study, we see that the landfill site is expected to be filled up, and outburst, after being in operation for 93 months, i.e. a duration of 7 years and 9 months. It is thus necessary to plan and complete setting up of a new landfill site before this time.

Figure 4: Model for the establishment of solid waste sanitary landfills in Taiwan region

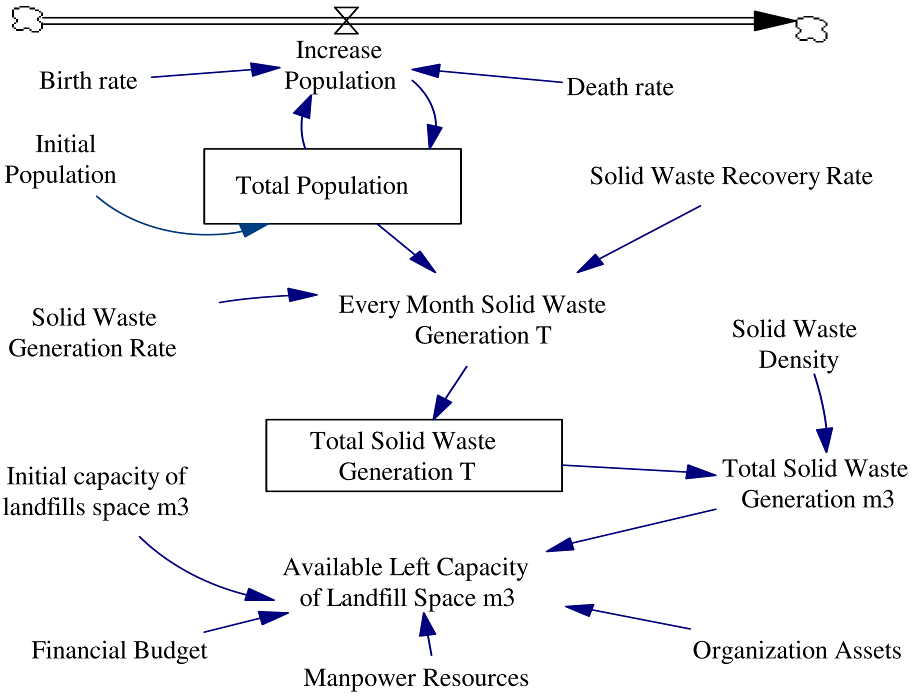


Figure 5: Prediction of the Population of Keelung City

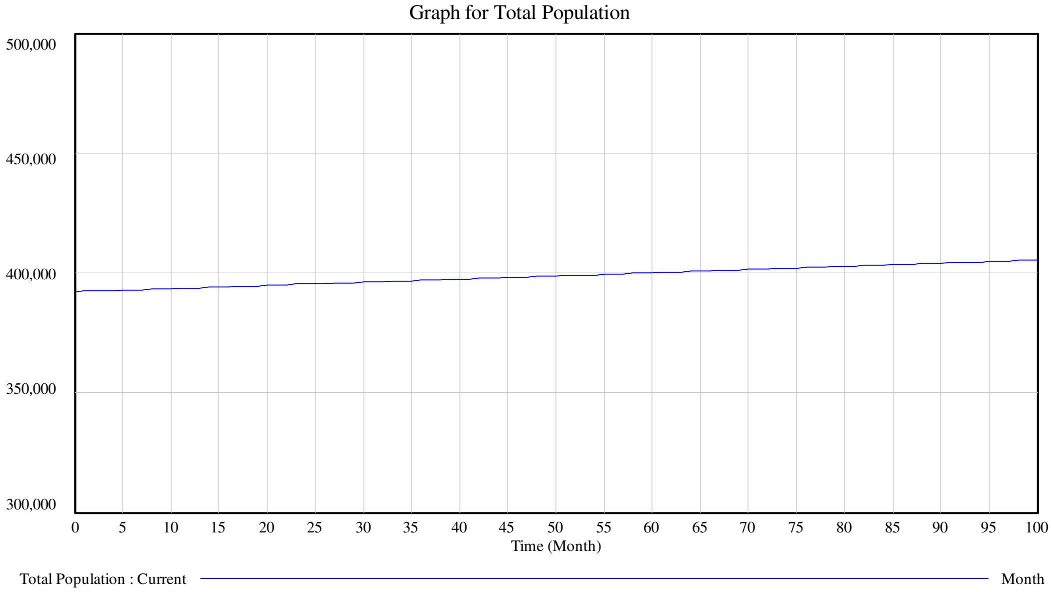


Figure 6: Monthly Solid Waste Generation.

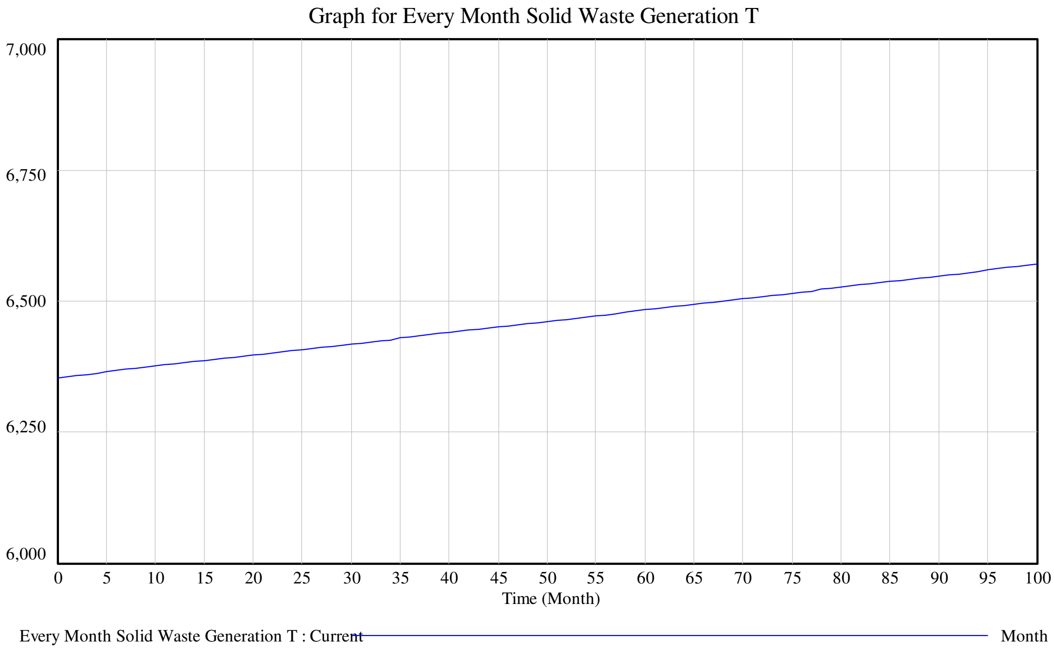


Figure 7: Total solid waste generated

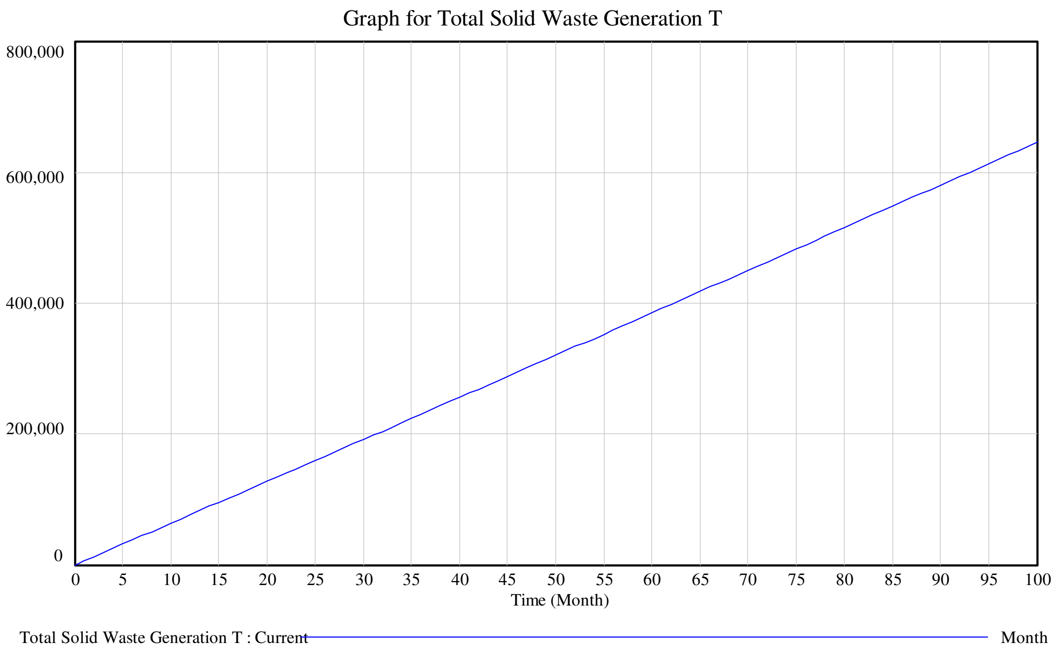


Figure 8: Total Solid Waste Generated

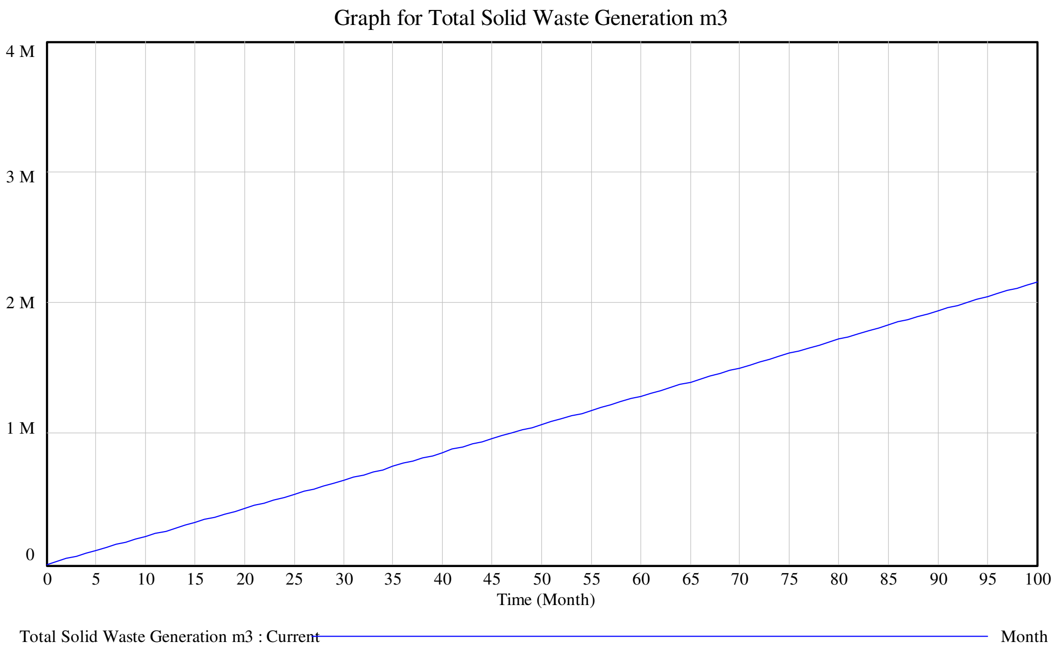


Figure 9: Available Remaining Landfill Capacity

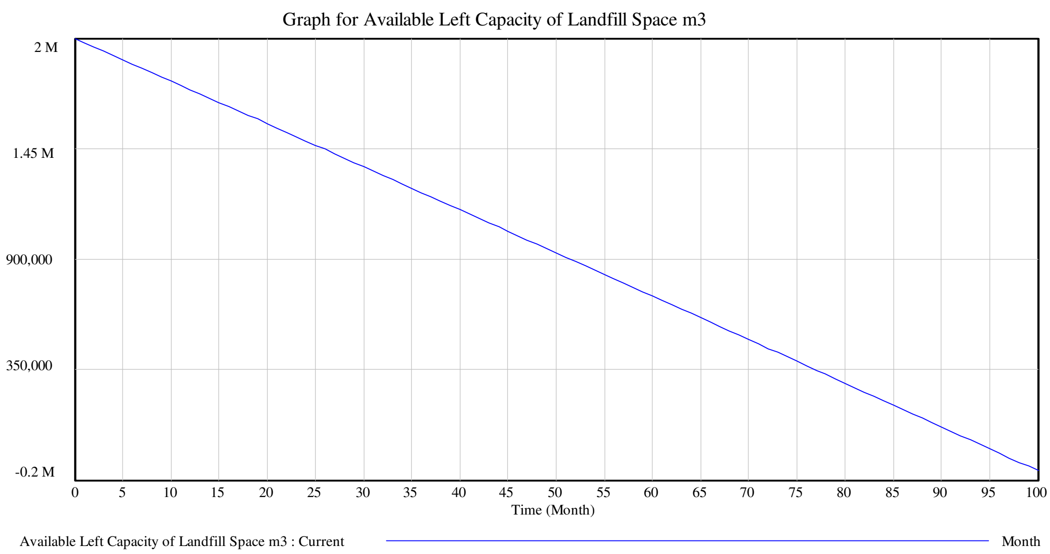


Table 1. Results of the Simulation.

Time (Month)	Total Population	Monthly Solid Waste Generated (tons)	Total Solid Waste Generated (tons)	Total Solid Waste Generated (m^3)	Remaining Available Landfill Capacity (m^3)
0	392,242	6354	0	0	2000000
1	392,372	6356	6,354	21,181	1978000
5	392,896	6364	31,792	105,975	1894000
10	393,551	6375	63,638	212,128	1787000
15	394,207	6386	95,537	318,458	1681000
20	394,865	6396	127,489	424,965	1575000
25	395,523	6407	159,495	531,650	1468000
30	396,183	6418	191,553	638,512	1361000
35	396,844	6428	223,666	745,553	1254000
40	397,506	6439	255,831	852,773	1147000
45	398,168	6450	288,051	960,171	1039000
50	398,833	6461	320,324	1067000	932,251
55	399,498	6471	352,651	1175000	824,494
60	400,164	6482	385,032	1283000	716,558
65	400,831	6493	417,467	1391000	608,441
70	401,500	6504	449,956	1499000	500,145
75	402,169	6515	482,499	1608000	391,667
80	402,840	6526	515,097	1716000	283,009
85	403,512	6536	547,749	1825000	174,169
90	404,185	6547	580,455	1934000	65,148
93	404,589	6554	600,105	2000000	-351
95	404,859	6558	613,216	2044000	-44,054
100	405,534	6569	646,031	2153000	-153400

CONCLUSIONS AND RECOMMENDATIONS

1. System dynamic models can be easily modified for timely new changes.
2. In this model, besides fore-casting the output given the input conditions, the output results can conversely be used to estimate what kind of input conditions are needed. With output to requests for the minimization of cost, what input conditions are

needed.

3. In order to build a systems model, we must understand the operating mechanism, forecast future performance and evaluate future policy options.
4. Over the past few decades, it is observed that the scope must always be considered first when the model is developed. The development of the model can be either from small to large or vice versa.
5. A system analysis model has the capacity to be gradually expanded in scale, which includes increasing the policy-making variables, and the correlation set-up, as well as accepting new input and generating new output.
6. In this new economic era, our environment changes rapidly, input condition change quickly, as does the correlation between the components; models can meet the actual requirements only by being constantly modified. Although the environmental connection keeps on changing, there is order among these changes. Systems analysis can help to find this kind of order.

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Key words

1. Construction Planning; 2. Landfill; 3. Model; 4. Operational Execution