Web-based DSS for Economic Evaluation of Municipal Solid Waste Management

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Abstract: - The rapidly increasing generation of municipal solid waste leads to the complexity of large scale urban management projects. In this age of stringent fiscal policy, the application of a new broad-based management approach that takes full advantage of benefits afforded by a cost-effective alternative is required. To assess effectiveness and profitability of any technological process and to find a cost effective model solution in municipal solid waste management (MSW), it is useful to prepare an evaluation model. In this paper, Net Present Value (NPV) is proposed to evaluate and select the best solution for such economical evaluation among alternative options. This paper presents the development of a Decision Support System (DSS), which elaborates on the construction of databases, the evaluation model using NPV, and the development of system. The system via standard Web Browser can query the database or use the decision models to achieve the objective of economic evaluation.

Key words: - Decision Support System, Net Present Value, municipal solid waste management

1 Introcduction

In 1999, the total quantity of municipal solid waste in the whole of China reached 150 million tons, which occupy a great deal of land (Han Guangfu et al., 2001). Over the past ten years in China, the annual average increased rate of municipal solid waste is about 7% to 9% (Sun Jiyin et al, 2003). In the same period in Europe the total amount of municipal solid waste generated increased from 517 kg per person in 1999 to 537 kg per person in 2004. The amount of generated waste varied significantly in different countries, i.e. in Ireland – 869 kg per person in 2004, whereas in Slovakia – 274 kg per person.

The rapidly increasing generation of municipal solid waste has made a great impact on the environment of cities, so various processes for waste management are developed by researchers. It is necessary to select both environmental friendly and economically viable methods for waste management. In this paper, an evaluation model is developed to assist the economic calculation in municipal solid waste management, which uses Net Present Value (NPV) to compare alternatives and select the best solution. In this field, many researchers (Kunsch P et al., 2002) have done a great deal of work generating a lot of outcomes. But at present, few of outcomes concerning evaluation are developed to be based on computer technology. As information technology develops, various applications using computer databases or computer-aided systems for municipal solid management have been established over many years. Over the last several years, DSS has been developed and successfully implemented in many subjects. On the other hand, the rapid increase of internet application and rapid advances of internet technologies have opened new opportunities for enhancing traditional decision support systems. There is thus a possibility for the development of financial management techniques, correctly supported by scientific tools, which help to find cost-effective solutions in municipal solid waste management systems.

In this paper, the Decision Support System is meant primarily for economic evaluation of considered alternatives and is applied to select and evaluate different options for waste management.

The organization of the paper is as follows. In section 2, the system data is presented for average management of municipal solid waste, associated with the classification of costs by type for every process. Section 3 describes the detailed design of evaluation model on which the DSS is based, and the followings are system flow and interface.

2 System Data

Decision support for the municipal waste disposal economic evaluation involves various types of data, some of which are based on the process of waste disposal. The process of waste disposal is divided into three stages: (1) *operating* (2) *closure* (3) *post-closure*. Every stage involved consists of different type of costs, which will be stored in the database. There is also some data involving general information about the project. See Table.1

Table 1. Data Structure

Data Structure
1.General discount rate; working hours/day; working days/year; projected life of disposal; recovery; condensation ratio; volume of waste; capacity; size;
2.By type Exploitation; Energy; Fuel; Parts; Wages; Maintenance; External services; Other; Amortization
3.By process
Opening: waste collection; waste selection; waste storage; maintenance; on-site transport; dust suppression; chemical compounds reduction; water management; (bio)gas management; monitoring; emergency alarm system; ecological fees for storage; construction of disposal facility; amortization #1
Closure: gas management; soil stockpile and inventory; regrading; demolition; construction work; final cover and cap; amortisation2; monitoring; security and fencing; engineering plans and permits; stormwater and leachate management
Post-closure: stabilization of solid waste; stabilization of other waste; contamination release control; final cover; cap maintenance; gas management; hydrological control; control of seepage; prevention of acid generation; erosion control; landscape integration; revegetation; monitoring; reduction of infiltration amortisatoin2;

3.Evaluation Model

3.1 Calculation for basic data

1. For some basic data, such as costs by process, costs by type, for the model in the life cycle of the project, they are changing values in time because of two reasons:

(1)changes resulted from passing time (change in real value);

(2)changes resulted from projected, specified cost level in every single year (change in nominal value).

The first aspect is covered by discount rate. The second one is solved by variability ratio (*VR*). This is to cover expectations for increase/decrease in annual costs of every single item, during the period of analysis, to be shown as a trend (e.g. if VR is 110%, 100€ in year #1 become 110€ in year #2, 121€ in year #3, 133.1€ in year #4). This change can be made once or twice, if required (or even more frequently, but this has to be strongly justified as causes in technical implications for modeling). It is important to remember that changes should be expressed as difference from 100%, so 5% change makes *VR* equal to 95% or 105%, but not 5%.

2. In the life-cycle of the project, for every stage, only items "covered" by "Project schedule" (General Information) can be fulfilled. In both specified stages and specified type, annual and total costs are obviously the same. Annual variations became an effect of using Variability Ratio (*VR*). After passing logical tests for project schedule, the formula is taking the following shape:

$$C_{ppy} = AVoI \times VR \quad (2)$$

In this formula, C_{ppy} represents cost by process per year, *AVoI* is annual value of item, and *VR* represents the variability ratio.

Annual value of item is taken for items specified in the "input user-interface"; VR is changing values increasingly, every year.

3. In the life-cycle of the project, annual costs for different types in every stage are calculated based on the annual costs of the corresponding stage.

Costs types are distinguished as mentioned above: exploitation, energy, fuel, parts, wages, maintenance, external services, other, amortization.

Percentage distribution in specified stages and specified type needs to be given by the User and amounts totally to 100% (for every stage separately), excluding amortisation, which consequently remains subject of separate calculation. In the case of amortisation, its total value per stage is input through interface, and then proportionally recalculated:

$$A_{pp} = \frac{C_{tpp}}{C_{tps}} \times A_{ps} \quad (3)$$

A_{pp} represents amortisation per process, C_{tpp} is costs by type per process, C_{tps} is costs by type per stage, A_{ps} represents amortisation per stage

The rest of "Costs by type" as mentioned above can be calculated as a result of following formula:

$$C_{tpy} = AVoI \times D_t \quad (4)$$

In this formula, C_{tpy} represents cost by type per year, *AVoI* represents annual value of item, D_t distribution of accurate cost by type, which is generally a percent. Annual value of item is taken for items specified in the "input user-interface".

3.2 Main model

Municipal solid waste management is a complex, multidisciplinary problem involving economics and informatics technology, mathematical, normative constraints about the minimum requirements for recycling and sustainable development issues. Most industrialized countries have adopted many urban waste management strategies.

In the last two decades, considerable research efforts have been directed towards the development of economic-based optimization models for urban waste management. Several examples of mathematical programming models have been developed for urban waste management planning. A model based on the minimization of overall cost, taking into account energy and material recovery requirement, formulated as a constrained non-linear optimization problem, has been presented (Chang et al, 1998) In this model, the cost function includes transportation treatment, maintenance and recycling costs, and possible benefits for electric energy sales. Decision variables are continuous and represent the material flows to the various plants (Fiorucci et al, 2003)

The waste management problem requires the integrated use of a series of modeling techniques tosolve a full-scale problem, because it is complex, and is a field currently lacking in decision support (Barlishen et al, 1996). Especially in financial aspect, the decision support system is scarce.

In this paper an evaluation model, based on economics was developed to find a cost effective model solutions in municipal solid waste management system, in which net present values (*NPV*) are presented. In economics, *NPV* is usually defined as the sum of the present values of a project's cash flow, with the present values found by discounting all flows – both costs or outflows, and inflows – at the project's cost of capital (Brown and Kwansa, 1999). In some cases, IRR (Internal Rate of Return) is also used.

The generic formulas from finance theory for these investment decision tools are as follows:

Net Present Value:

$$NPV = \sum_{t=0}^{n} \frac{CF_t}{(1+i)^t} \tag{5}$$

NPV represents the net present value; *n* represents the calculation period, which is equal to the life-cycle of project; *t* is the number of years modeled (from *0* to *n*) CF_t is the cash-flows after *t* years when the project was carried out, expressed in Yuan□*i* is the discount rate (Adeoti et al., 2000)

Internal Rate of Return

$$\sum_{t=0}^{n} \frac{CF_t}{(1+IRR)^t} = 0 \tag{6}$$

IRR represents the Internal Rate of Return, *n* represents the calculation period, which is equal to the life-cycle of project; *t* is the number of years modeled (from *0* to *n*) CF_t is the cash-flows after *t* years when the project was carried out, expressed in Yuan.

$$AC_t = OC_t + CC_t + PC_t \tag{7}$$

$$CF_t = AC_t +/- \text{Amortisation} \tag{8}$$

In the formulas, AC_t is annual costs after *t* years when the project was carried out; OC_t represents the costs for the process of operating after *t* years when the project was carried out; CC_t represents the costs of the process of closure after *t* years when the project was carried out and PC_t represents the costs for the process of post-closure after *t* years when the project was carried out. CF_t is the cash-flows after *t* years when the project was carried out.

In this model, amortisatin is the only exception, for this item the way of calculation is also different.

Annual Rate of Return

$$RoR_t = \frac{AC_t}{CC} \tag{9}$$

In this formula, RoR_t represents the annual Rate of Return after *t* years when the project was carried out; AC_t is annual costs, *CC* is the capital cost, which is decided in the early date of the project and is input into the model through the user-interface.

4 System Flow and System Interface

4.1 System Flow

Fig1 shows the data flow between the user interface and decision-maker, which illustrates the sequence of steps and the decision process that the decision maker can utilize for effective design and operation for urban waste treatment.

4.2 user interface

In this DSS, the main screen is shown in Fig 2, with a button on it. Once the user clicks on the button, he can enter the evaluation interface, seeing Fig 3, into which required information and data, related with three categories, including information about the operating stage, the closure stage, and the post-closure stage are input. Percentage distribution needs to be given by the user and can be input by interface "Percentage distribution", presented in Fig 4. According to the *VR* input in Fig. 3, and the model calculation, the annual costs by process can be attained, which are shown in Fig. 4. The annual costs by type are shown in Fig. 4.

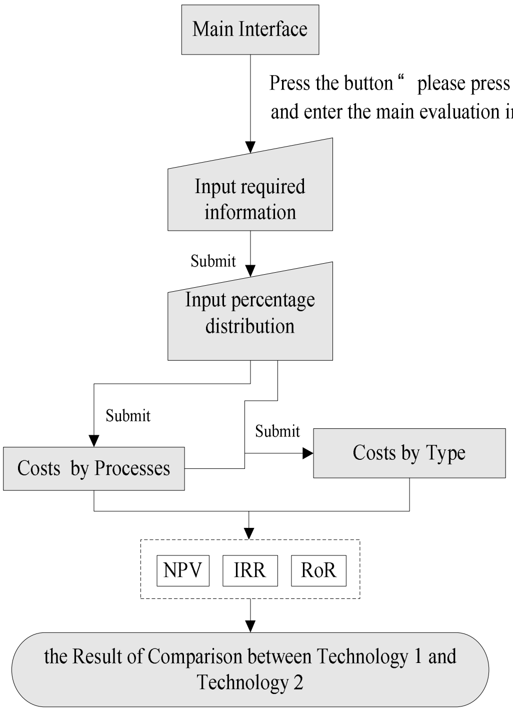

Fig.1.The system flow chart

As the interface of percentage distribution, costs by process, costs by type are similar, they are integrated into one.

Execution of the model is initiated via "submit" buttons in an HTML form, launching the DSS's model management agent. After the execution of the model, many results, such as *NPV*, annual cash-flow, *IRR* (Internal Rate of Return), *RoR* (annual rate of return) and so on, are derived from the calculation of the model

built in the computer program. See Fig. 5 following.

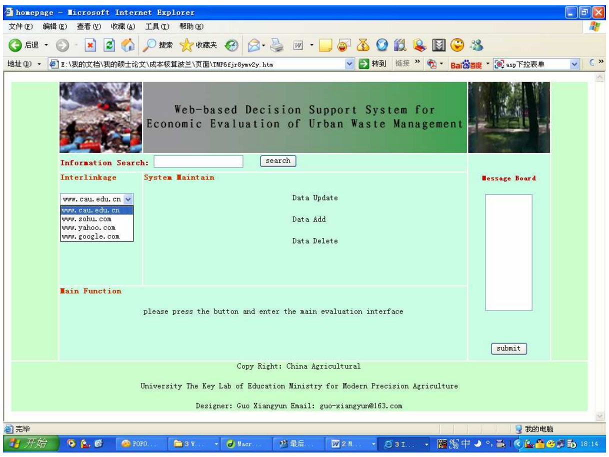

Fig.2 The main interface for economic evaluation

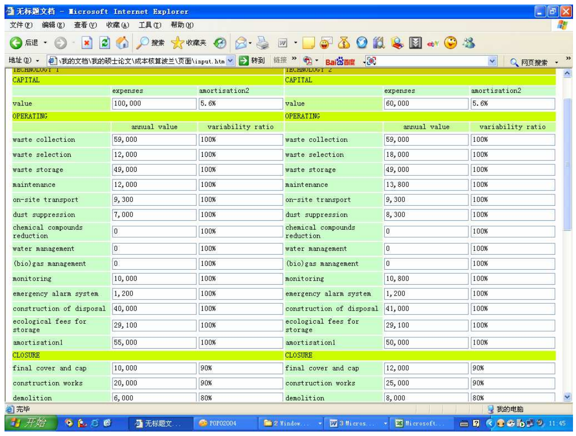

Fig.3 The information about technology 1 and technology 2

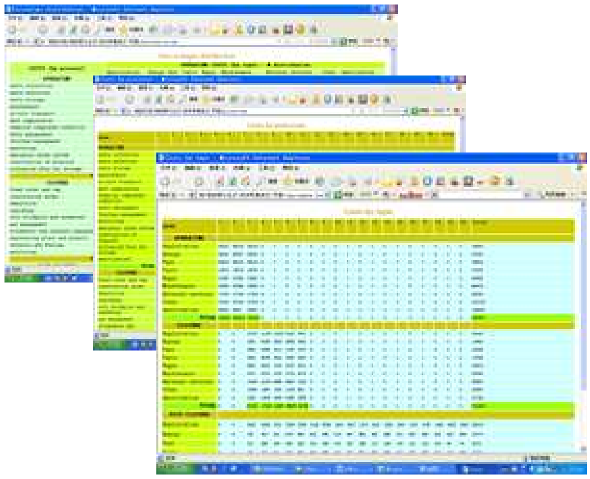

Fig.4 The interface of analyzed costs

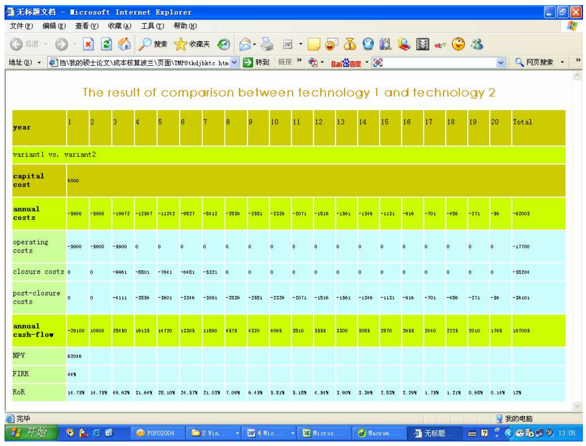

Fig.5 The result of comparison between technology 1 and technology 2

5 Conclusion

In this paper presented is an economic model, which helps decision-makers search for a cost-effective treatment and choose between different alternatives. Regarding the research, the following results can be concluded:

(1) In order to make a comparison between different alternatives, a great deal of data, which concerns the cost during treatment disposal, should be input into the system for the calculation.

(2) At present, there are many ways of waste treatments available for municipal solid waste management. In this DSS, it doesn't clearly distinguish different treatments, so further research should pay much attention to this.

(3) A good DSS requires tight collaboration among users, field experts and system developers. The final complete system is the result of the close cooperation among all parties concerned in the system.

Considering the above results, in the field of municipal solid waste management, a great deal of further work should be done. With the rapid development of the Internet technology, the benefit of DSS has been greatly enhanced. However, it also brings a number of challenges from the methodological and technological point of view.

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