Chapter V

Construction and Demolition Waste Management in Hong Kong

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1 Introduction

The mission of sustainable development has led to a pressure demand for improving environmental performance in the construction process. There is rising concern about the amount of waste generated by construction activities and the consequent disposal of that waste in landfill sites. The construction industry is the major solid waste generator in Hong Kong. Over next five years, it is expected that HK$235 billion will be spent on civil engineering projects (Hong Kong Government, 2000). Any of these construction projects generates an enormous amount of waste. According to the Environment Protection Department (EPD, 2002), a daily average of about 37, 690 tonnes of construction and demolition (C & D) material was generated in 2000, within which 30, 210 tonnes (80%) were delivered to public fill areas and the rest of 7480 tonnes (20%) were disposed of at landfills. Given the small territorial extent and the high population density, it is an urgent task to effectively and efficiently manage the huge amount of solid waste generated from construction and demolition activities. Due to the potential for environmental damage from landfill sites, the decreasing landfill space and the growing public opposition in Hong Kong, reclamation should no longer be the way to accept most of C & D waste (Hao, Liu, and Wu, 2003). The reduction of C & D waste not only yields significant benefit to the environment but also reduces landfill space and cost saving for the project (Graham & Smithers, 1996).

2 Construction and demolition waste management in Hong Kong

Construction and demolition waste

According to the EPD (2004), Construction waste comprises of unwanted materials generated during construction, including rejected structures and materials, materials which have been over ordered or are surplus to requirements, and materials, which have been used and discarded. Waste arises from a number of different activities carried out by the contractor during construction and maintenance. Demolition wastes are generated as a result of site clearance and site formation works.

Depending upon the nature of structures and activities, which have been undertaken, demolition waste may be inert, mixed with putrescible or contaminated. The uncontaminated waste should be reused if found to be suitable, otherwise this material should be delivered to landfills for disposal.

Currently, about 80% of C & D waste is delivered to public filling areas for land reclamation in Hong Kong. Nevertheless, before any land reclamation is carried out at sea for waste disposal purpose, it is necessary to remove the mud from seabed since the marine mud is highly shrinkable. If it is not removed, the claimed land will have stability problems. Since contaminated mud is hazardous to marine life and other negative impact on environment caused by reclamation projects, dumping C & D waste at sea incur intensive public criticism. Approved reclamation projects will only provide outlet for inert materials until 2004.

The rest of 20% C & D waste is going to be landfilling. But land landfilling is a very land intensive way to dispose of waste. As the EPD (2002) mentioned "In recent years, the C & D waste accounts for more than 40% of the total intake at the three strategic landfills. If there are insufficient public filling areas and no waste reduction measures, more public fill will be diverted to landfills and the landfill lives will be shortened." It is estimated that the landfills space will run out until 2004. If the current rate of more 3,500 m^3 /day C & D waste disposed of at landfills cannot be decreased with effective measures. To minimize waste, it is essential to take preventive initiatives by reducing waste before it is generated at the design stage, as it is less difficult and less expensive.

Construction and demolition waste minimization and hierarchy

Waste minimization is defined as any method that reduces the volume or toxicity of a waste that requires disposal (EPA-USA, 2001). In a practical sense, it is any method that reduces the amount of waste. Government regulations, as well as internal cost effectiveness, require that the production and therefore the disposal of all wastes, and particularly hazardous wastes, be kept to a minimum." C & D waste accounts a larger proportion of municipal solid waste, for example, the percentage is 20% in America (Helper, 1994) and 30% in Canada (Kalin, 1991). From these data, it can be seen that C & D waste is an inevitable subject for any waste minimisation program.

According to the technical report of EEA, a waste minimisation plan should consist of the components "Avoidance", "Reduce", "Reuse", "Recycle" and "Bulk waste reduction" in order of priority (Figure 5-1). The first priority is to prevent the generation of wastes in the first place. If wastes must be produced, the quantities should be reduced. The next priority is to select suitable waste materials for reuse and recycle. After the aforementioned measures, the next step is to reduce the bulk volume of waste materials before disposal.

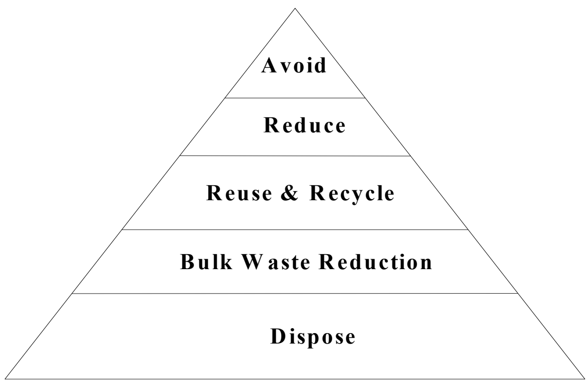

Figure 5-1 Waste Management Hierarchy
(Adapted from Poon and et al, 2001)

McDonald and Smithers (1998) described that there are two distinct procedures in reducing the amount of waste through the construction process, which are to reduce the amount of waste generated though source reduction techniques both on site and during the design and procurement phases of a building project, and to improve the management of that waste that is generated on site.

Strategies and actions for C & D management in Hong Kong

According to the waste reduction framework plan, which was published by EPD in November 1998 to arouse the public's concern on the importance of waste reduction and set targets to achieve an efficient and environmentally friendly waste management plan for the next 10 years, the strategy for C & D material management is to avoid, minimize, reuse, recycle and finally dispose of waste with the desirability decreasing in this order. In accordance with this strategy, three main objectives for C & D material management in Hong Kong are (i) to reduce the generation of C & D material, (ii) to maximize reuse and recycling and (iii) to reduce the intake of mixed C & D waste at landfills. In order to realize these objectives, the key actions identified by EPD (2002) are as follows:

- Provide an adequate number of conveniently located barging points from where the public fill is taken to reclamation.
- Impose charges on C & D material taken to landfills.
- Provide on-site sorting facilities for future public demolition contracts.
- Encourage on-site sorting facilities on private construction sites.
- Develop guidelines and codes of practice to reduce C & D material generation.
- Recycle as much as possible for use in less demanding construction works, for example as aggregates.
- Minimize the use of imported marine sand or other fill for reclamation projects.
- Identify new outlets for the waste materials.

There are some regulations, code of practices, technical circulars from works bureau, guidelines concerning C & D waste management in Hong Kong, including Practice Notes for Authorized Persons and Registered Structural Engineers (PNAP), Practice Notes for Registered Contractors (PNRC), On Site Sorting of Construction Waste on Demolition Sites (No.5/98), Hong Kong Building Environmental Assessment Method, etc. With the directing and supporting of these regulations, codes, circulars and guidelines, it is hoped that the annual waste management costs will be reduced by about $750 million, and extend the life of landfills from 2015 to 2019 through C & D minimization actions.

3 Evaluation of government measures for C & D waste management in Hong Kong

Then need for evaluating government measures for C&D waste management

The issue of waste management is currently on the high priority list of Hong Kong Government. The growth of C & D wastes has driven the need to increase levels of effective C & D waste management. To tackle the increasing C & D waste issue, the government has implemented different measures for C & D waste management in order to reduce, reuse and recycle them more effectively. The application of these measures, however, have had limited effect. This section is based on a study of evaluating Hong Kong Government's measures for C & D waste management (Hao, Hills, and Wai, 2006). The data used for the analysis is from a questionnaire survey sent to professionals in local construction industry.

One hand, with the increasing construction activities and living standards and strongly developing environmental awareness of public, the construction and demolition (C & D) waste becomes an ever growing concern and demand for better planning and management. On the other hand, the Hong Kong Government is aiming to increase the amount of C & D waste that can be reused and recycled as part of its commitment to sustainable development. Teo and Loosemore (2001) stated that construction sectors being predominately profit-oriented, any fiscal measures imposed on the relevant parties would affect their practices toward construction waste management. Since the Government takes a regulatory role in the issue, any relevant public policies and legislations would affect the results of C & D waste management.

To evaluate the government's measures for managing C & D waste in Hong Kong, a questionnaire was developed and sent to 80 construction companies, governmental department, e. g. 36 questionnaires were returned which were fully completed. The response rate is 45%. The questionnaire consists of four parts, which are (1) general information about the company; (2) attitudes toward C & D waste management; (3) Disposal Charging Scheme; and (4) Recycling C & D waste materials. The response to each attitudinal question was measured on a five point Likert scale, under categories of 'strongly disagree', 'disagree', 'neutral', 'agree', 'strongly agree' from 1 to 5. The rest response was used 'yes or no.'

The data was then analyzed by utilizing Relevant Important Index (RII) to determine the importance of the respondents' attributes based on the rating provided by the interviewees. To analyze the data, numerical scores of each identified factors were then transformed to the RII to determine the ranking of the factors. The RII was then evaluated using the following expression.

$$RII = \frac{\Sigma w}{A \times N} \quad (1 > Index > 0)$$

Survey results and discussions

Based on the results shown Figure 5-2, the government's motivation (such as tax relief and government's funding) for the issue of C & D wastes management is the first priority of the respondent's choices as 64% of the respondents agreed with that. The result indicates that the government motivation is the ultimate to support private sectors participation, or create legal and institutional mechanisms to boost sense and awareness of C & D waste management.

By contrast, the respondents perceived a significantly low priority in the item that there are adequate Government advisory services in C & D waste management. It is found that only 22% of respondents agreed with that. It means that government should build enough guideline and technical notes for processing the construction waste. Also, it is suggested that the government should establish waste management advisory committee to provide consultation regarding the C&D waste management. In addition, it is found that there are only 28% of respondents agreed that there are adequate measures covered by environmental related legislation. It is possibly the regulation and legislations related to environmental matters implemented by Hong Kong government are too liberal.

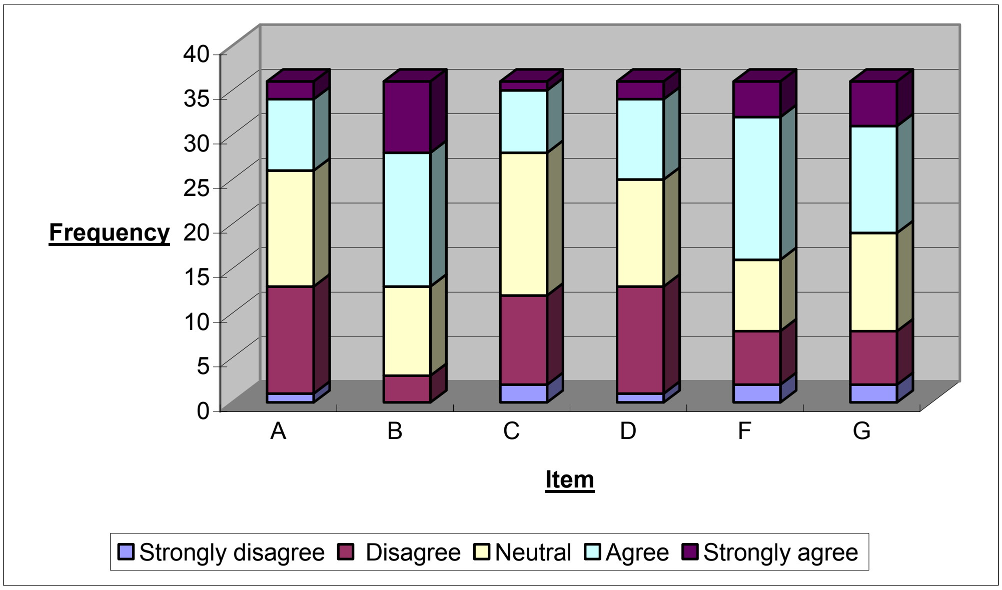

Figure 5-2: Respondent's attitude towards construction waste management

Figure 5-3 and Figure 5-4 show that many people believe that charging scheme is necessary in Hong Kong. 78% of the respondents felt that charges were necessary. Figure 5-4 also indicates that nearly 70% of the respondents thought that they shall take more measures to collect and separate C & D waste due to the enforcement of waste disposal charging scheme.

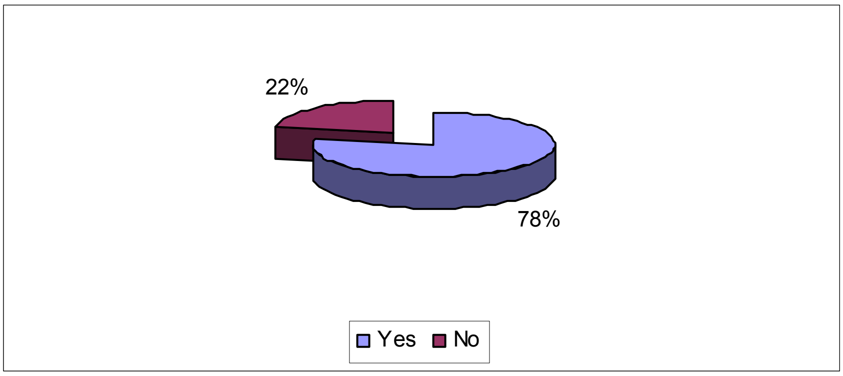

Figure 5-3 Attitude towards necessity of Construction Waste Disposal Charging Scheme

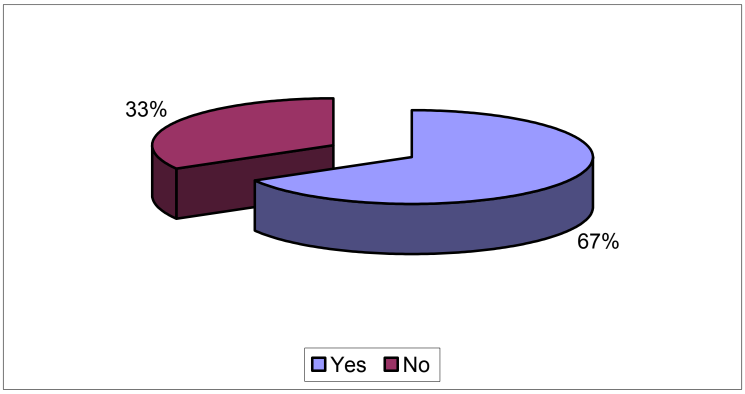

Figure 5-4 More measures after the enforcement of charging scheme

According to Figure 5-5, 25 respondents (nearly 70%) and 21 respondents (nearly 60%) thought $125 per tonne at landfill and $100 per tonne at sorting facilities was high or too high. Only three respondents felt the rate for landfills and public fill and two respondents felt the rate for sorting facilities is low. Moreover, over half of the respondents felt that $27 per tonne at public fill is reasonable. It is also interesting to note that there are none of respondents thought the charge rate at landfills; sorting facilities and public fill are too low.

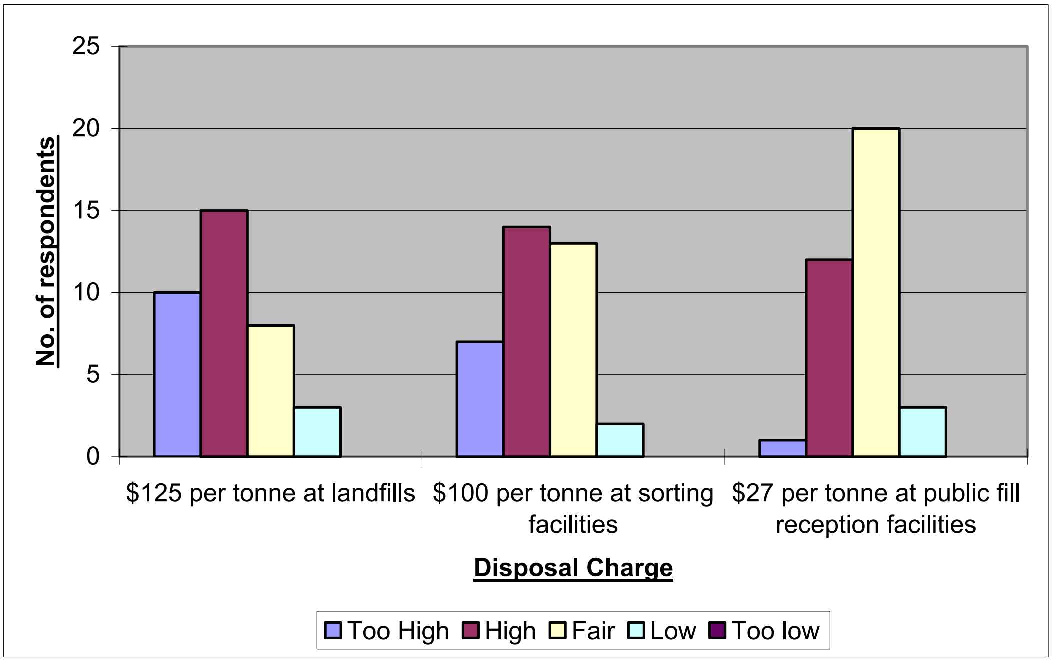

Figure 5-5 Responses regarding the charging rate of the construction waste charging scheme

It can be seen that most of respondents thought that the charging rate at landfill and sorting facilities were too high or high, while the rate at public fill reception facilities was fair. Hong Kong Construction Association (HKCA) is one of parties that strongly objected to the landfill charging of HK $125 per tonne. Although this charge can fully cover the capital and recurrent costs of facilities, this will undoubtedly create additional pressure and financial burden on the construction industry particularly during the down turn of the economy. They suggested that a charge of $60 per tonne, which represents EPD's estimated operating cost of the three existing landfills, should be adopted initially and the charge level is to be reviewed again in 12 months time.

However, in the government and green groups' standpoints, the contractors should have included the waste disposal charges in the construction cost. Such charges should only constitute some 1-2% of the total construction cost and should not financial burden to the construction industry. Also, the actual cost impact should be smaller as the industry would have the economic incentive to adopt waste minimization measures which in turn would reduce the amount of waste to be disposed of at the three facilities. Moreover, the charging level HK$125 per tonne at landfills just represents full recovery of the capital ($56 per tonne) and recurrent ($69 per tonne) costs of the three existing landfills. Since the charging rates just cover the cost of the landfills, it is seen that these fee must be diversionary tactics, as no profit will be made.

For the charging rate at sorting facilities, the sorting charge of $100 per tonne is suitable as it needs to be set and maintained at a good relativity to the landfill charge of $125 per tonne. On the one hand, it has to be lower than the landfill charge thereby providing a financial incentive for waste producers/haulers to go for sorting. On the other hand, the charge cannot be so low as to invite abuse by users. The sorting facilities would provide waste producers, particularly small construction sites with physical constraints and cannot carry out on-site sorting, a "cheaper alternative" to landfills. It is not recommended to provide the sorting facilities free of charge as this goes against the User Pays Principle and would amount to subsidizing the waste producers with taxpayers' money. In addition, this is most likely to invite abuse by users who will be tempted to take mixed with waste with high non-inert content to the sorting facilities instead of landfills.

Therefore, it is suggested that the government should review the charge rate and the charging mechanism regularly to increase the efficiency of the scheme and allay the concerns of the haulers. Also, the government should build a construction waste recycling center in Hong Kong in order to recycle the construction waste. Besides, promoting and educating the concept of recycling in the construction industry is also possible in Hong Kong.

The results of alternative government measures to tackle the problem of C & D waste is indicated in Figure 5-6. The highest score is "Promote the waste management training and education"; the second score is "Landfill Extension / Identification of new waste disposal sites" and the third score is "Exporting C & D waste to Mainland'. Moreover, "Reusing Inert C & D materials in local reclamation projects" and "Incinerator" are considered as the least useful government measures for C & D waste. It is noted that there are none of respondents strongly agree incineration and reusing inert C & D materials in local reclamation projects are useful government measures in tackle the waste problem.

4 Integrated C & D Waste Management by Adopting System Dynamics Methodology

System dynamics in construction and demolition waste management

System dynamics is a discipline originated and developed by Forrester (1958). System dynamics is a system analysis approach that is concerned with creating models or representations of real world systems and studying their

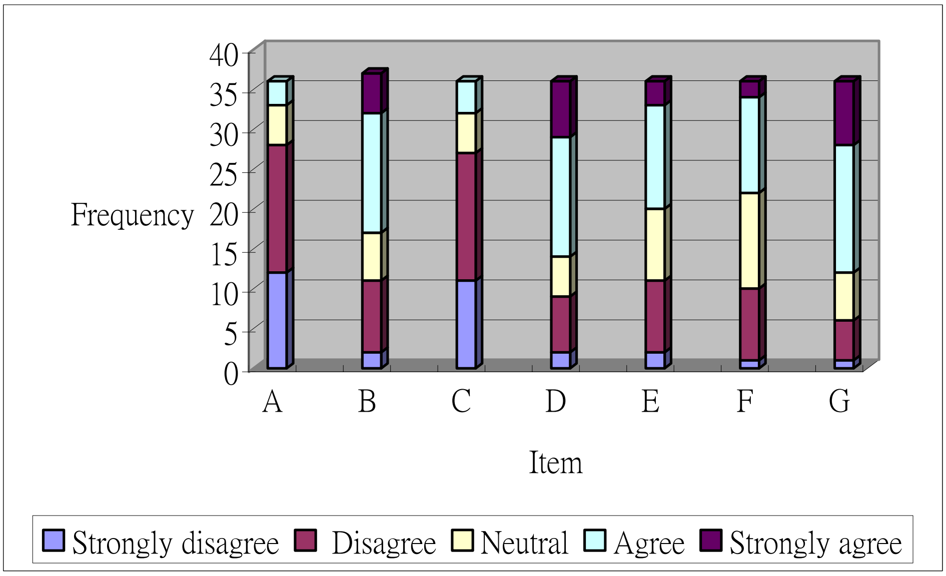

Figure 5-6 The usefulness of alternative government measures for the C & D waste

dynamics. Forrester adapted sophisticated and analytical methods of control engineering for use in social and business fields. Forrester (1994) further advocated the use of modelling and computer simulation as the only way of understanding behaviour that follows from assumptions about parts of a system. Wolstenholme (1997) also provided a good overview of the current state of the art. It can be distinguished from discrete-event simulation in that it is concerned with the state of the system and rates of change. As a result, system dynamics is often used as a methodology for improving the soundness and effectiveness of the decision-making process and, in recent times, has become a popular technique for modelling construction project management (Sterman, 1992; Rodrigues and Bowers, 1996; Li, Love and Drew, 2000; Hao and Scott, 2001).

The composition of waste management can essentially be viewed as a system because it involves different stakeholders, disciplines and activities. A systems thinking approach requires looking at the whole waste management as a system made up of interacting parts instead of analysing isolated events and their causes. In the context of system theory, the focus is upon how sub-systems interrelate to pursue and achieve the goals (Wolstenholme, 1997). With this in mind, waste management can be considered as a system, with the planning, organising, and co-coordinating activities being its inherent characteristics.

The need for such a model in C&D waste management in Hong Kong

While technological barriers to the management of C & D waste management are rapidly being overcome, the effective management of construction waste depends largely upon individuals involved in the construction process minimising waste generation and separating waste for recycling purposes (Lingard, Gilvert and Graham, 2001). Although simulation modelling has been widely used as a management tool in the manufacturing and business fields, there is little evidence that it has been applied to waste management and planning using a system dynamics approach (Chi, 1998). So much so that, based on the volume of publications on each types of model, Wang (2001) opined that simulation is the path less travelled by researchers in the field of waste management modelling around the world.

There are, however, a few studies on the application of system dynamics to solid waste management. Mashayekhi (1993) carried out a comprehensive study which analysed the problems of transition from the landfill method of disposal to other forms of disposal for the city of New York. Mashayekhi's produced a model that incorporated qualitative aspects such as the impact of pollution on waste generation and the separation of recyclable material at source. However, his model is not appropriate for urban solid waste management in developing countries (Sudhir, Srinivasan and Muraleedharan, 1997) where the issues are quite different.

Sudhir et al. (1997) identified that urban solid waste management system in developing countries consists of both formal and informal systems operating at the same time. The formal system consists of a municipal body that is responsible for collection, transportation, and disposal of solid wastes, whilst the informal system of waste pickers, itinerant buyers, scrap dealers, and wholesalers, is responsible for recycling about 10-15% of the solid waste generated in the cities. Planning for sustainable urban solid waste management in developing countries has to address several interdependent issues such as public health, environmental concerns, present and future costs to society, and the livelihood of those involved in the informal recycling sector.

Not withstanding the findings of Sudhir et al, Mashayekhi's model is considered generic enough to be used as a basis for planning for sustainable urban solid waste management in the context of developing countries. However, it does not specify the C & D waste management through the life-cycle of a construction project (Hao, Hills, and Huang, 2006).

Although brief, the foregoing literature review clearly suggests that system dynamics has an important role to play in C & D waste management in Hong Kong; and possibly China. The review also provides compelling evidence to support the use of simulation modelling to analyse the interrelationships of all the disciplines within the C & D waste management process, and to suggest that improvements in the management of C & D waste can be achieved through better management of information. Integration of all these findings results in the use of an integrated simulation model based on system dynamics methodology in order to provide an appropriate decision making tool for C & D waste management in Hong Kong. It is expected that the integrated simulation model would fulfill this need as it has been designed to accommodate enormous amounts of hard and soft data in a complex and dynamic construction environment.

Development of the simulation model

The *stella* software is used to develop the model. The *stella* software is a multi-level, hierarchical environment for constructing and interacting with models (HPS, 1998). The software enables users to visualize interrelationships, which constitute a process, a strategy, or an issue. It also allows the structure of a process or strategy to be rigorously linked to the associated dynamics. The modelling and simulation capabilities of the software are ideally suited for capturing the operational dynamics and complexities of management issues depicting them as a flow chart or schematic. This has been approved by many researchers in the construction industry (Sudhir, Srinivasan and Muraleedharan, 1997; Stanley, 1998; Belt, 2000).

An overview of the model framework is illustrated in Figure 5-7. The model delineates the main stakeholders involved during C & D waste management, depicting the high-level major components. The links between any two components represent the relationships of factors in the modelling layers, which are shown in the following paragraphs.

To make the structure of the model clear, the overall system is divided into five components or sub-systems as follows: (1) On Site Sorting, (2) C & D Waste Generation, (3) Municipal Solid Waste (MSW) Generation, (4) Public Filling, and (5) Landfill. Figure 5-8 shows the structure of the model. To simulate changes to each of the sub-systems, the model includes a total of approximately sixty variables. While the interaction of the sub-systems with each other is illustrated in Figure 5-7, each sub-system, or component is described separately in the following sections accompanied based on Figure 5-8.

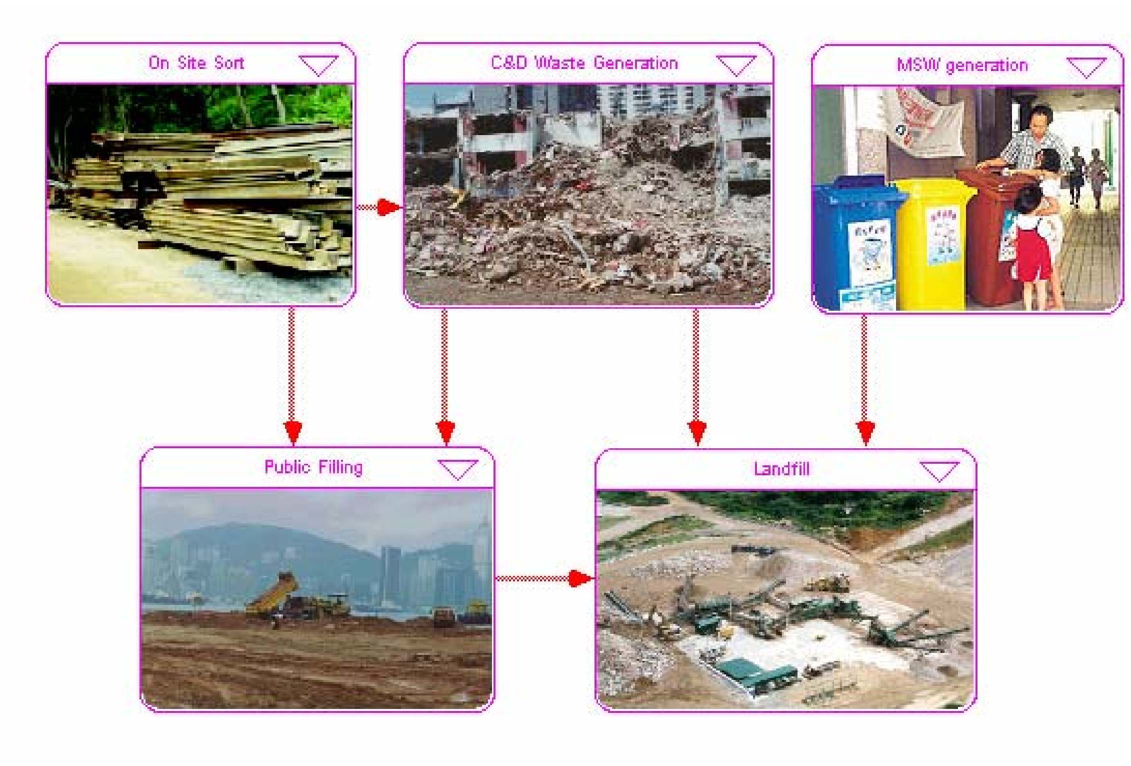

Figure 5-7 An overview of the model framework

The top left component shown in Figure 5-8 is "On-site Sorting" indicating the percentage of C & D material delivered to public filling sites. The top right one shown in Figure 5-8 is "C & D Waste Generation" providing information about the extent to which the following four factors affect the generation of C & D waste: waste management experience, environmental consciousness, site ratio impact, and landfill charges. The middle left one shown in Figure 5-8 is "Municipal Solid Waste (MSW) Generation Component", demonstrating the relationships between C & D waste and MSW as the landfill sites in Hong Kong are for both C & D waste and MSW waste. The middle right of Figure 5-8 is "Public Filling Component" representing public filling sites. The bottom one in Figure 5-8 is "Landfill Component" processing MSW and C & D waste as well as surplus inert C & D materials. The landfill areas are consumed by these three parts and are recruited by new ones.

Simulation Process and Results

The data to be used for this model's simulation is based on MSW and C & D waste generated over a period from 1986 to 2020. According to data from the Environmental Protection Department (EPD, 2003), there were about 2 million tons of MSW in 1986, which has been increased by 4% every year. The Government published a Waste Reduction Framework Plan (WRFP) in 1998,

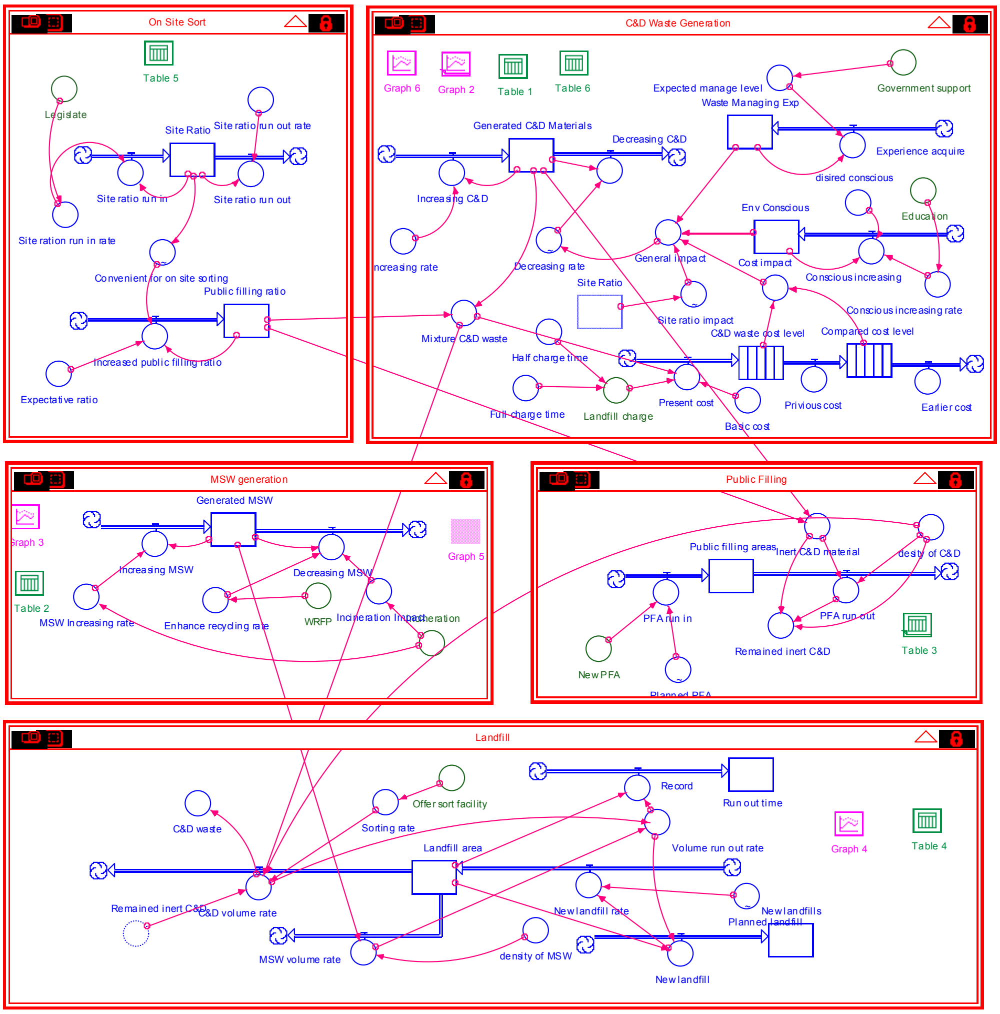

Figure 5-8 The structure of the model

with the intention of achieving a 58% reduction in the total amount of MSW by 2007. The model divides the plan into two stages. The first stage is to show the decreases MSW by 5% each year for 5 years by enhancing the recycling rate, and the second stage is to show the decrease in MSW by 10% each year for 3 years after the Government's incineration facility is operational. After the WRFP has achieved its goal in 2007, the rate of increase in MSW is estimated to decrease about 2.5% a year.

In 1994, only 35% of total C & D material was delivered to public filling sites. After the gradual implementation of the C & D material management strategy in early 1998, a considerable improvement was made by diverting 80% of the total C & D material produced to public filling sites. One of the targets of the WRFP was to deliver 84% of C & D material to public filling sites. Major reclamation and earth filling projects currently being planned will provide about 35 million m^3 over the next 10 years. The average density of C & D material is 1.8ton/m^3 while MSW is 0.7ton/m^3. The three strategic landfills with a total disposal capacity of 140 million m^3 had been depleted by about 30 million m^3 by the end of 2000. There was a surplus of inert C & D material in the early 1990's and in the year 2002. Total C & D waste is increased by about 6% each year. The four factors that affect the generation of this waste (waste management experience, environmental consciousness, site ratio impact, and landfill charges) have different impact patterns.

After all the variables are determined, which means the parameters and the start values are specified based on the imported data above, simulation can then be processed and performed (details can be seen in the Appendix). Figure 5-9 shows the results of the MSW Generation Component having simulated achievement of the municipal solid waste reduction targets. The model indicates that the quantities of MSW requiring disposal by 2007 will be reduced from 4.57 to 2.75 million tones.

Figure 5-10 and Figure 5-11 show the behaviour of the model from 1986 to 2020 without implementation of the Government's C & D waste management polices. The model shows that if MSW reduction targets are achieved, the life of the existing strategic landfills will be extended by 4 years to 2019, and that the capacity of the new landfills needed by 2050 will be reduced from 580 million m^3 to 335 million m^3.

The impact of the four factors that affect the generation of waste is depicted in Figure 5-12. It can be seen that environmental consciousness and waste management experience increase very slowly due to a lack of government support; site ratio decreases continually if no legislation is introduced to regulate on-site sorting, while the cost impact is negligible if waste charges are not implemented. These conditions are regarded as the model's benchmark to which the 'what if' scenarios are compared. Table 5-1 shows the results of these comparisons.

If all the suggested measures are implemented, the life of existing strategic landfills can be extended by up to 16 months, and the new landfills that are needed up to the year 2050 will be reduced by about 50 million m^3. Figure 8 show the behaviour of the model from 1986 to 2020 with all C & D waste management measures implemented: environmental consciousness and waste management experience increases more quickly as a result of government support; although waste charges and on-site sorting legislation have little impact on the life of landfills, they have a significant economic impact on

Table 5-1 Comparative Result in Different Conditions

	Worst	Base Run	Support &Education	Landfill Charge	Legislate Require	Offer Sorting Facility
Enhance MSW recycling rate	N/A	1998	1998	1998	1998	1998
Employ incineration facilities	N/A	1998	1998	1998	1998	1998
Government support	N/A	N/A	1998	1998	1998	1998
Environment education	N/A	N/A	1998	1998	1998	1998
Legislate about on-site sort	N/A	N/A	N/A	N/A	2004	2004
Offer sort facility	N/A	N/A	N/A	N/A	N/A	2004
Half landfill charge	N/A	N/A	N/A	2004	2004	2004
Full landfill charge	N/A	N/A	N/A	2010	2010	2010
Landfill Run Out Time	2015	2019.4	2019.10	2020	2020.2	2020.8
New Landfills Needed	583,000	335,000	314,000	302,000	296,000	288,000

contractors and the Government; and if Government can offer sort facilities at landfill sites and consequently recycle 10% of the C & D waste, the life of existing landfills can be extended by about six months.

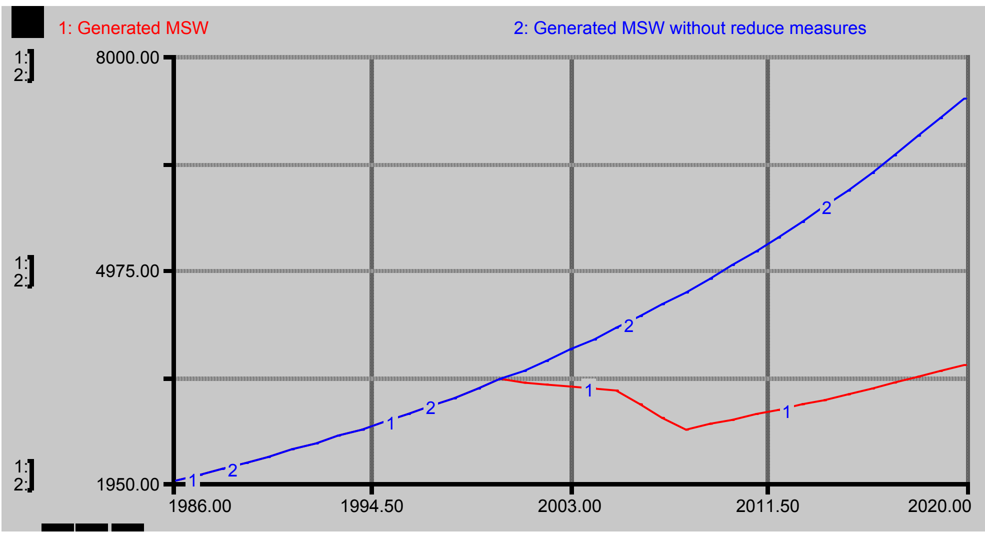

Figure 5-9 Simulation in MSW Generation

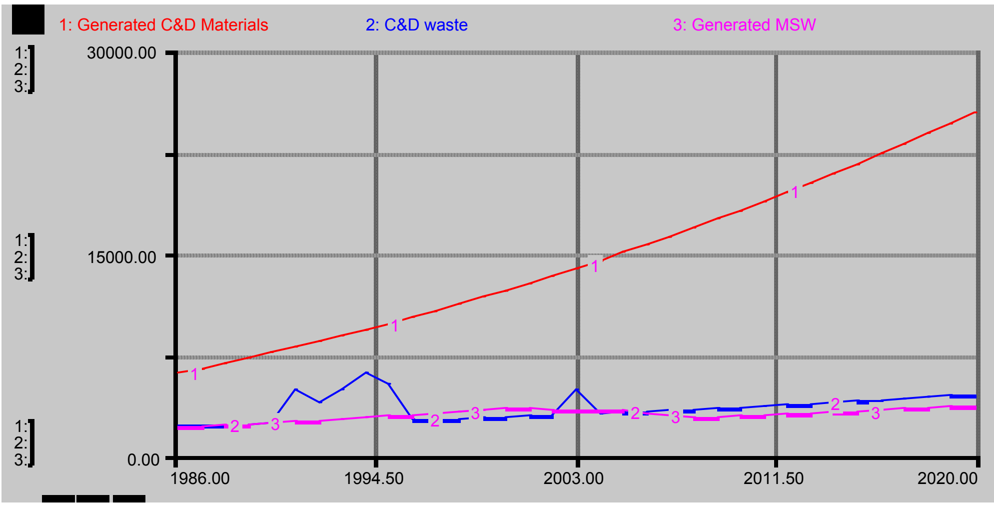

Figure 5-10 Simulation in C&D Waste Generation in Base Run

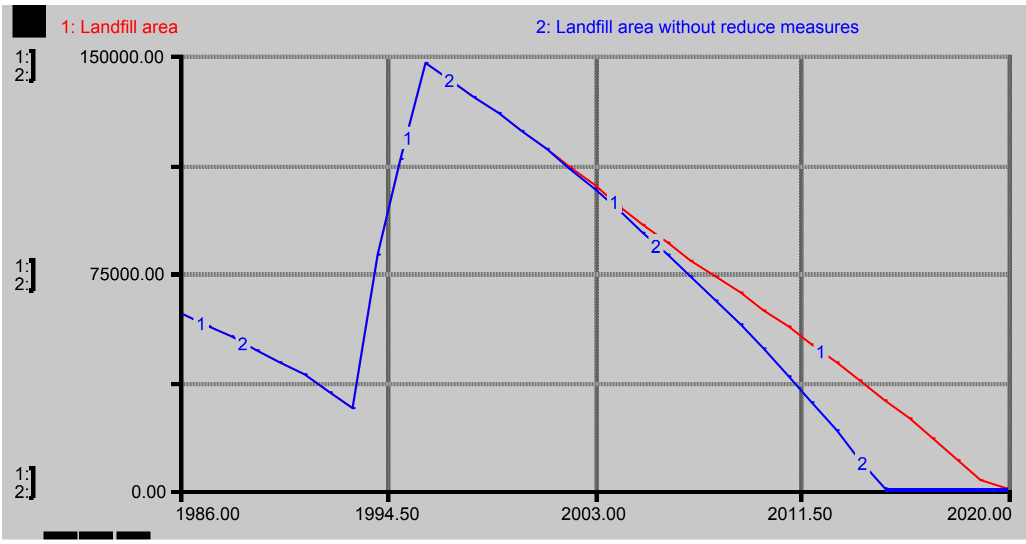

Figure 5-11 Simulation in Landfill Running Out

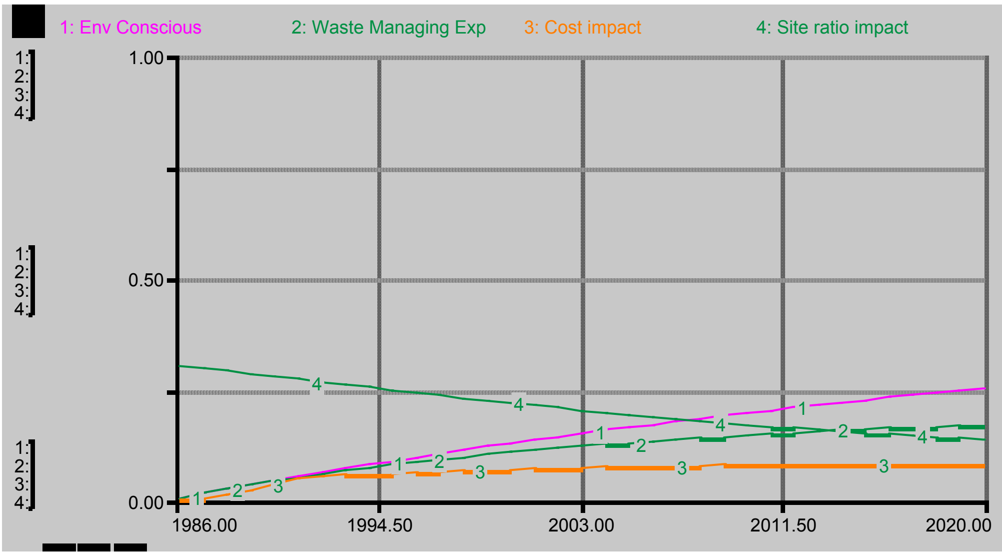

Figure 5-12 Simulation of Four Factors Impact in Base Run

The simulation indicates that the life of existing landfills can be extended to 2020 with appropriate C & D waste management measures. However, it is based on the assumption that enough public filling sites will be found. In 2002, the high percentage of C & D waste was attributed to the closure of one of the Public Filling Areas (PFA), which caused more C & D material to be disposed of at landfill sites. To ensure that inert waste material is not sent to landfills again, it will be necessary to prepare some large stockpiling sites as a contingency measure.

In the long term, the construction industry cannot depend only on public filling sites and importing raw materials from neighbouring areas. Other outlets should be found for inert materials and other sources for raw materials. The ideal solution would be to reproduce raw materials from inert waste materials. To this end, it is recommended that the Hong Kong Government should commit itself to the further use of recycled materials and to the development of a market for recycled materials.

When the complexity of C & D waste management increases, system dynamics can help decision makers to handle the complexity. However, as shown in the literature review, that there are currently very few system dynamics models addressing the complexity and integration of C & D waste (Hao, Hills, and Huang, 2006). The study on which this section is based provides a systematic approach to C & D waste management in Hong Kong by using a simulation model, adopting system dynamics methodology to fill this gap. Further studies will concentrate on the empirical validation and verification of the model. In addition, modifications and extension of the model will focus on its simulation capability to support explorative learning, qualitatively and quantitatively, about the environmental impact of C & D waste.

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