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MODELLING WASTE FLOW PRACTICE ON CONSTRUCTION SITE

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ABSTRACT
The increasing awareness of environmental impacts from construction wastes has led to the development of waste management as an important function of construction project. Various approaches and methods for managing construction wastes have been developed in the existing research works and practice, and these works can be grouped largely into three areas: waste classification, waste management strategies (avoiding waste, reducing waste, reusing waste, recycling waste, and disposing waste), and waste disposal technologies. This paper extends the existing approaches to examining the waste flow during construction on site with support from four cases selected in Hong Kong construction industry. The examination was conducted by mapping the waste management flows (WMF) is developed in those four cases. WMFs provide tools assisting in examining the adequacy and effectiveness of flow processes of dealing with various construction wastes, from the sources generating it to the destination of disposal. WMFs can serve as a vehicle to compare the waste management practice between construction sites, thus both good practice and weak areas in managing wastes can be presented. The key stages and areas of processing construction wastes can be identified, thus effective waste control methods can be developed for application to these areas. An effective waste management flow model on construction sites will be developed in further research.

KEYWORDS
Environmental Management, Construction Waste, Waste Management, Waste Management Flow (WMF)

1. INTRODUCTION

Waste management in construction activities has been promoted for the aim of protecting the environment in line with the recognition that waste from construction and demolition works contributes significantly to the polluted environment. Craven et al. (1994) reported that construction activity is approximately to generate 20-30% of all waste deposited in Australian landfills. Cotton et al. (1999) suggested that uncollected solid waste such as the construction wastes have become a major health hazard, yet municipal waste is still the dominating wastes to health hazard as only about 25 per cent of the total refuse produced is collected. Ferguson et al. (1995) found that more than 50% of the waste deposited in a typical landfill in UK comes from construction waste. According to Rogoff & Williams (1994), 29% of the solid-waste stream in the USA is construction waste. Poon (2000) showed that the daily generation of construction waste in Hong Kong has been increasing significantly, and suggested the government to set up intermediate waste sorting plants and on-site sorting of waste for the minimization of demolition waste generation. All these investigations demonstrate that construction business is a large contributor to waste generation and that there is significant potential of protecting the environment through managing construction waste properly.

Furthermore, existing works have also identified and analyzed the sources resulting in construction wastes. Faniran & Caban (1998) conducted a comprehensive survey in examining the construction waste sources, and they identified five most significant sources of construction waste, namely, design changes, leftover material scraps, wastes from packaging and non-reclaimable consumables, design/detailing errors, and poor weather. Their findings indicate that many construction companies did not have specific policies or methods for eliminating the sources of waste. Gavilan & Bernold (1994) grouped construction waste sources into design error; procurement or shipping error; materials handling; machine operation error and residual or leftover scraps. Rounce (1998) examined the major wastage sources at design stage, including the variability in managerial skills; the variability in numbers of drawings required for project, the variability in scale of drawings and the level of design details, and the variability in organizing jobs. Rounce's assumption is to maximize profit by minimizing the cost through achieving quality and minimizing the sources of wastage at design stage.

Significant research works have also been devoted to investigating methods for managing wastes generated from construction and demolition works. Spivey (1974) suggested that proper sorting on waste is an important procedure of properly managing wastes, and he classified construction waste as demolition materials/ packaging materials, wood, waste concrete and asphalt, garbage and sanitary waste, scrap metal products, rubber, plastic and glass, and pesticides and pesticide containers. By sorting out wastes, different techniques can be identified and effectively adopted to deal with various wastages. Bossink & Brouwers (1996) found that construction waste is mainly from the application of various building materials and classified wastes according to the nature and the technology of using the materials, including stone tablets; piles; concrete; sand-lime elements; roof-tiles; mortar; packing; sand-lime bricks and other small fractions of metal and wood. These classifications provide good basis for employing practical methods in controlling wastes on construction site. Other research works have presented various methods of controlling wastes. Chun et al. (1997) discussed the benefits of waste recycling operation over the traditional landfills method in Hong Kong, and proposed the mechanism of changing construction and demolition landfills into construction and demolition recycling operations. Petts (1995) demonstrated the good effectiveness of a more proactive community involvement programme for waste management, and suggested the strategy of consensus building among the public. Sing (2001) investigated the potential of controlling construction wastes by applying environmentally friendly construction methods. And, some typical construction methods are found effective for reducing the waste generation during construction stage, such as using large panel system, applying bamboo scaffolding, and reducing the application of wet trade. These practical methods are also suggested to be able to result in better construction quality and higher productivity. Coffey (1999) suggested that the implementation of waste management system as part of project management functions thus could bring a significant reduction in the generation of construction waste. Lingard et al. (2000) presented the benefits of involving employees' participation in implementing waste management. But he pointed out that employees' participation could only be effective if genius support can be obtained from senior management within the business. Shen & Tam (2001) conducted a comprehensive survey on the implementation of environmental management in construction and found that the issues of waste and environmental management are generally considered less important than construction cost and time in construction industry.

Among various existing methodologies for implementing waste management in construction activities, waste management hierarchy is promoted as a typically effective tool. Waste management hierarchy classifies and prioritizes waste management options in sequential order into reducing wastes; re-using wastes; recycling wastes; and disposing waste where the first three options are not possible (Faniran & Caban, 1998). Nevertheless this approach has been criticized of giving little attention for eliminating the generation of waste (Shen & Tam, 2001). In fact, the minimization of waste at its source is most important and should be given the highest priority. This is considered logical, management methods can be more effective when they are applied to the areas where the problems occur. The construction process is a systematic and sequential process, along which various types of construction wastes can be generated at any stage. Therefore, the identification to the waste resources during whole construction process can lead to the adoption of proper management methods. As an alternative approach for understanding such identification, McDonald et al. (1998) proposed to implement waste management plan during the whole construction process. The evidence from their survey suggested that a proper waste management plan across the whole construction process could result in up to 50% cost savings for waste handling charges, 15% volume reduction of the waste generated prior to recycling on site, and 43% waste reduction for landfill.

Existing studies present the importance of properly understood waste management process in order to identify effective methods for controlling wastes. This paper examines the waste management process by using a waste flow technique. This extends the previous waste classifications (Spivey, 1974; Bossink & Brouwers, 1996; Gavilan & Bernold, 1994) to examining waste handling process. The methodology of waste management hierarchy developed in previous studies (Faniran & Canan, 1998) forms the basis in identifying the proper application of various waste management methods at different stages in the whole process of waste handling. Examination on waste flow process is supported with six practical cases.

2. TYPICAL METHODS IN DEALING WITH CONSTRUCTION WASTES IN HONG KONG

Construction wastes are normally classified to various groups, which carry different characteristics. The understanding on waste characteristics helps to adopt proper management methods for handling different types of wastes. Spivey (1974) categorized construction waste into direct and indirect waste. Direct waste mainly concerns the materials wastage described as the loss of materials, which are lost during the building process or damaged and cannot be repaired for further use. Indirect construction waste is defined as a monetary loss for damaged or lost materials. This study focuses on direct construction waste. Previous studies have developed various classifications on construction wastes (Spivey, 1974; Bossink & Brouwers, 1996; EPD, 2001). A typical classification presents five categories, municipal solid waste, construction and demolition waste, chemical waste, special waste and other solid waste.

In general, municipal solid waste covers a wide range including plastic, paper, paperboard, textile, rubber type, organic, aluminum, ferrous metals, non ferrous metals, glass, wood, etc. Considering generating sources, municipal solid waste is divided into domestic waste, commercial waste and industrial waste. Domestic municipal solid waste refers to household waste generated from daily activities in institutional premises and refuse collected from public cleaning services. Public cleaning services are normally provided by governmental departments, for example, in Hong Kong, collection of dirt and litter by the Food, Environmental and Hygiene Department (FEHD), collection of marine refuse by the Marine Department and collection of country parks wastes by the Agriculture and Fisheries Department. Commercial waste is the waste arising from commercial activities taking place in markets, shops, restaurants, hotels and offices etc, and this kind of waste is normally collected by private waste collectors. However, certain amounts of commercial waste are mixed with domestic wastes and collected by the FEHD in Hong Kong case. Furthermore, industrial waste generally refers to that from industrial activities other than construction and demolition, usually collected by private waste collectors except that some industrial sectors may deliver their industrial wastes directly to landfills for disposal. Of these various municipal solid wastes there are bulky waste items like furniture and domestic appliances, which may come from residential premises, commercial and industrial activities. These bulky wastes are usually collected separately.

Wastage from construction and demolition activities are usually handled differently from those municipal solid waste. Construction and demolition wastes (C&D–w) include waste arising from all construction related activities such as land excavation or formation, civil and building construction, site clearance, demolition activities, roadwork and building renovation. C&D-w is in the form of various types of building debris, rubble, earth, concrete, timber and mixed site clearance materials. In Hong Kong, C&D-w is divided into two groups according to the level of the inclusion of inert waste. Type I C&D-w, as stated in the landfill contracts between environmental protection department (EPD) and the constructor concerned, is defined as containing no more than 20% by volume, or 30% by weight, of inert materials (EPD, 2001). Inert materials comprise dirt, soil or mud, concrete, reinforced concrete, asphalt, brick or sand, cement plaster or mortar, aggregate, inert building debris, and rock or rubble (EPD, 2001). Type II C&D-w consists of more than 20% by volume, or 30% by weight, of inert material content and is not normally accepted by landfills, and can be used for proper site formation.

Furthermore, chemical waste and other special waste from construction activities are strictly regulated for special treatment in Waste Disposal Ordinance (WDO, 2001). Chemical waste contains chemical or similar kind of contents, which can cause pollution to the environment or become a risk to health. In WDO (2001) special waste is described including abattoir waste, animal carcasses, asbestos, clinical waste, condemned goods, livestock waste, sewage treatment and waterworks treatment sludge, sewage works screenings and stabilized residues from Chemical

Waste Treatment Centre. The separation of the chemical and special wastes helps the adoption of special methods for dealing with them before going to dumping areas. There are other types of solid waste that have not been covered in the above classifications, such as coal ash, dredged mud and excavated materials, they are also normally disposed of at dumping areas. Based on the above discussion, the overall profile of construction wastes and typical methods of dealing with them can be presented in a table format, as shown in Table 1.

Table 1 Construction Wastes And Typical Methods Of Dealing With Them

Type of waste	Specific description	Typical handling method
Municipal solid waste	Timber & paper, concrete & stone, chemical substances, plastic waste, wood, glass, water, metal, aluminum, mild steel, stand steel, copper/bronze, etc.	Recycle, reuse, dumping areas or incineration
Construction & demolition waste	Demolition materials, packaging materials, waste concrete and asphalt, garbage and sanitary waste, scrap metal products, rubber plastic and glass, pesticide containers, etc.	Recycle, reuse, dumping areas or incineration
Chemical waste	Oil, chemical liquid, etc.	Special treatments to recycle
Special waste	Special chemical wastes, etc.	Special treatment before go to dumping areas
Other solid waste	Abattoir waste, animal carcasses, asbestos, clinical waste, condemned goods, livestock waste, sewage treatment and waterworks treatment sludge, sewage works screenings and stabilized residues, etc.	Special treatment before go to dumping areas

3. INVESTIGATION TO THE WASTE FLOW PRACTICE ON CONSTRUCTION SITE

The discussion in the previous sections identified the classifications of construction wastes and the typical methods of dealing with them. This section is to investigate the way that construction wastes flow on construction site. This research team has examined four construction projects in the Hong Kong construction industry and mapped out the flow processes in managing the construction wastes in these projects. The major information presented in each mapping includes four key elements, namely, waste source, waste facilitator, waste processing, and wastes destination. In order to conduct comparative analysis between different waste management practices, the following symbols are designed for representing the four elements:

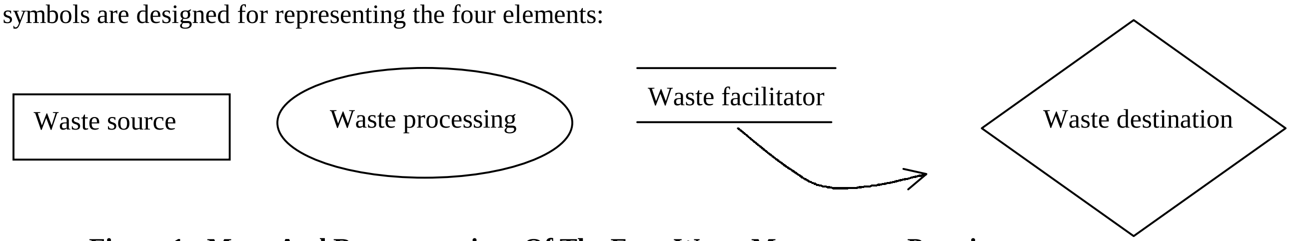

Figure 1: Maps And Representations Of The Four Waste Management Practices

By using the above symbols, the four waste management practices are mapped and presented in figure 1, 2, 3 and 4 separately. It is considered that mapping presentations have the advantages of being easily understood. These mappings are constructed based on the observations and discussions with the site management staff, who were operating the projects concerned. The evaluation on the advantages and weaknesses of each waste management practice is given in the following discussions used in mappings.

3.1 Case Study I

This was a high rise residential building project at superstructure construction stage and the mapping of waste management practice for this project is shown in Figure 1. The typical weaknesses observed in this waste management practice include: (1) No recycle consideration about waste materials; (2) Serious dusty and air pollution from uncovered handcart in delivery; (3) Intensive labour works was involved in waste handling; (4) Adopting less mechanical waste handling system and more time consumption on waste handling; (5) No packing or container for waste collection thus double waste handling; and (6) Not an environmentally friendly handling method due to using plastic bag for waste collection.

Nevertheless, the advantages in this waste management practice are considered as: (1) The simple process for waste management, namely, fewer processes for handling wastes on site; (2) Less investment on setting up waste handling / disposal device on site as less energy consumption device was used; (3) Generation of income from the sale of waste materials; and (4) Effective waste reusing as waste materials were properly sorted out.

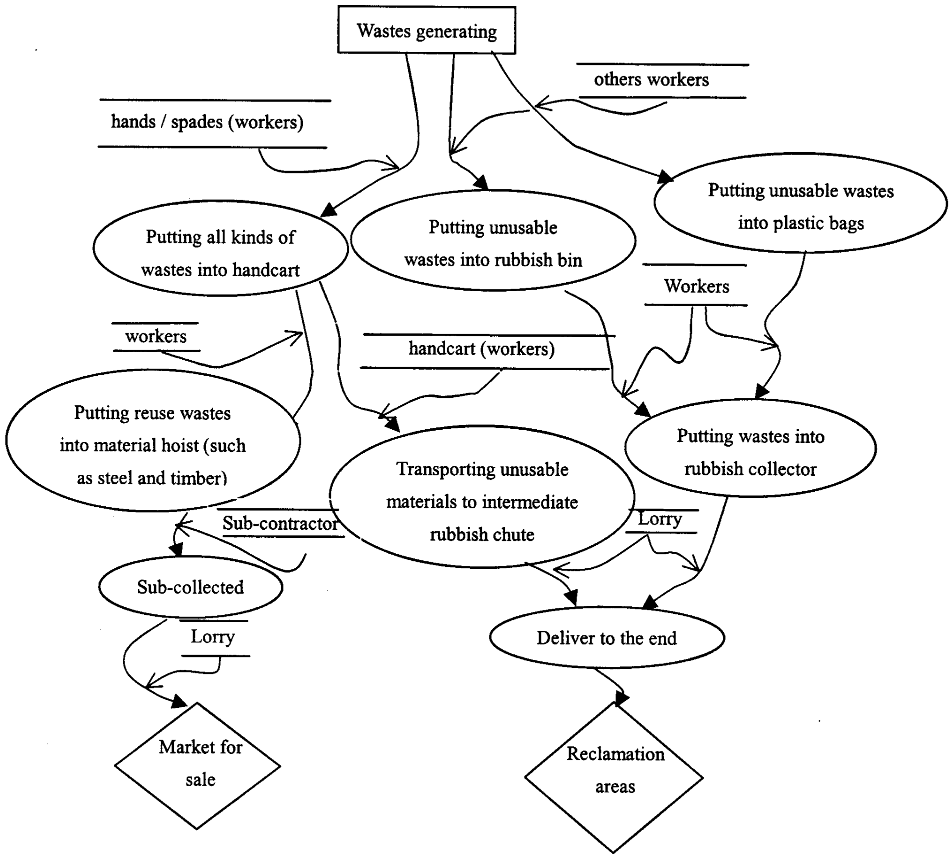

Figure 2: Mapping of Waste Management Practice for Ngau Tau Kok Estate

3.2 Case Study II

Case study II concerns a three-block private housing estate at finishing stage. The mapping of this waste management practice is shown in Figure 2. The problems observed in this practice include: (1) Highly involving intensive labour works thus expensive in waste handling; (2) Using plastic bag for waste collection thus not an environmentally friendly handling method; (3) No sorting out and no recognition to the benefits of waste recycling and reuse; (4) Involving more resource input including manpower, lorry, hoist, rubbish chute; (5) Scattered locations for collecting wastes requiring more manpower thus more costly for waste handling; (6) Engaging higher chance of safety accident by allowing more people collect waste materials within the construction site; and (7) Requiring more coordination works for all waste handling activities on the whole construction site, thus increasing the project overheads.

The advantages in this practice were suggested by the project manager concerned, as: (1) Use of energy saving device for waste disposal such as rubbish chute; (2) Less air pollution by using plastic bag and rubbish bin reducing dust dispread; and (3) Packing of waste material increasing the efficiency of waste handling than dealing with pieces of waste materials.

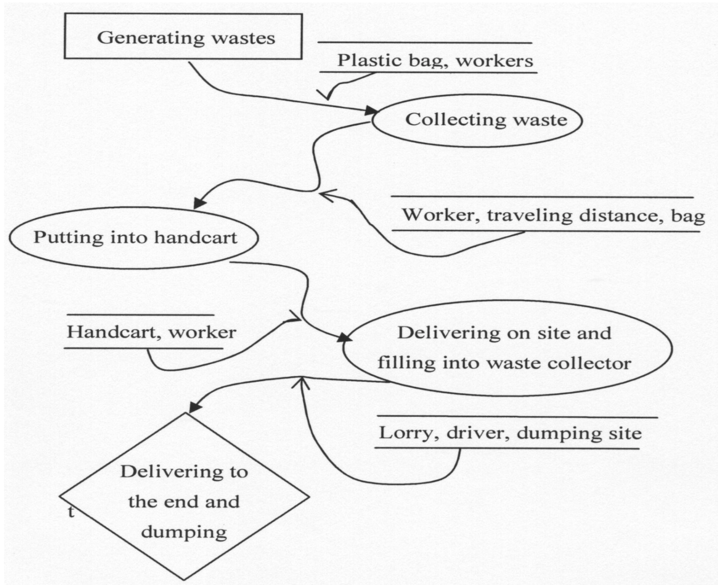

Figure 3: Mapping of waste management practice for project of finishing stage

3.3 Case Study III

The mapping of waste management practice in case study III is shown in Figure 3. Typical problems involved in this practice include: (1) No proper sorting out for waste materials and little recognition to the benefits of waste recycling; (2) No packing or container for waste collection, thus involving double handling in waste collection; (3) Dispose of large size waste materials presenting the chance of blockage inside the refuse chute; (4) The disposal of large-size waste material by refuse chute causing noise pollution; (5) Involving higher dumping charges due to the increase of the volume of waste materials without proper sorting; and (6) Investing more resources on constructing the special refuse chute and the use of waste-delivering lorry.

Some advantages observed in this practice include: (1) Efficiency and time saving in handling waste materials through refuse chute and handcart; (2) Involving less labour works in waste material handling; (3) Dusty and air pollution under control by use of refuse chute with running water; and (4) Reusing the usable materials thus engaging an environmentally friendly waste management practice.

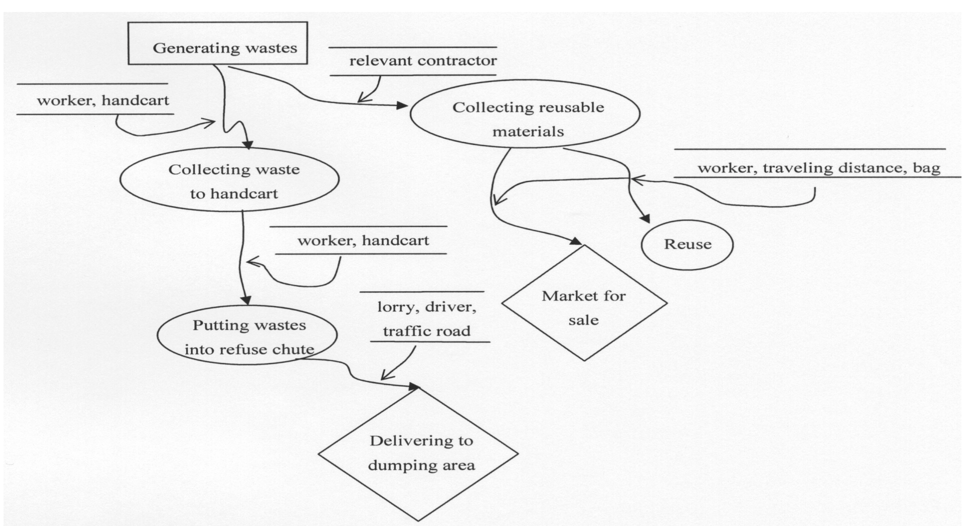

Figure 4: Mapping Of Waste Management Practice for Canton Road Project (Construction Stage: RC Structural Works)

3.4 Case Study IV

Figure 4 shows the mapping of waste management practice in case study IV, which was a large housing estate at finishing stage. The problems discussed in this case include: (1) Involving intensive labour work for waste materials handling; (2) Long traveling distance for delivering waste materials to rubbish collector thus increasing time consumption for waste handling; (3) Lack of using mechanical device such as refuse chute, thus low efficiency in waste handling; (4) No consideration for recycling waste materials; and (5) Serious problem with dusty and air pollution due to uncovered waste in handcart during delivery.

Advantages in this practice were suggested as (1) The use of top-open rubbish collector reducing double handling of wastes (as it was connected directly to the lorry delivering wastes to dumping areas); (2) Logic and simple handling processes of waste materials, easily identifiable waste collection locations, thus better efficiency of waste handling; and (3) Clean construction site as wastes were properly collected and stored in rubbish collectors, and reusable waste materials were tidily placed.

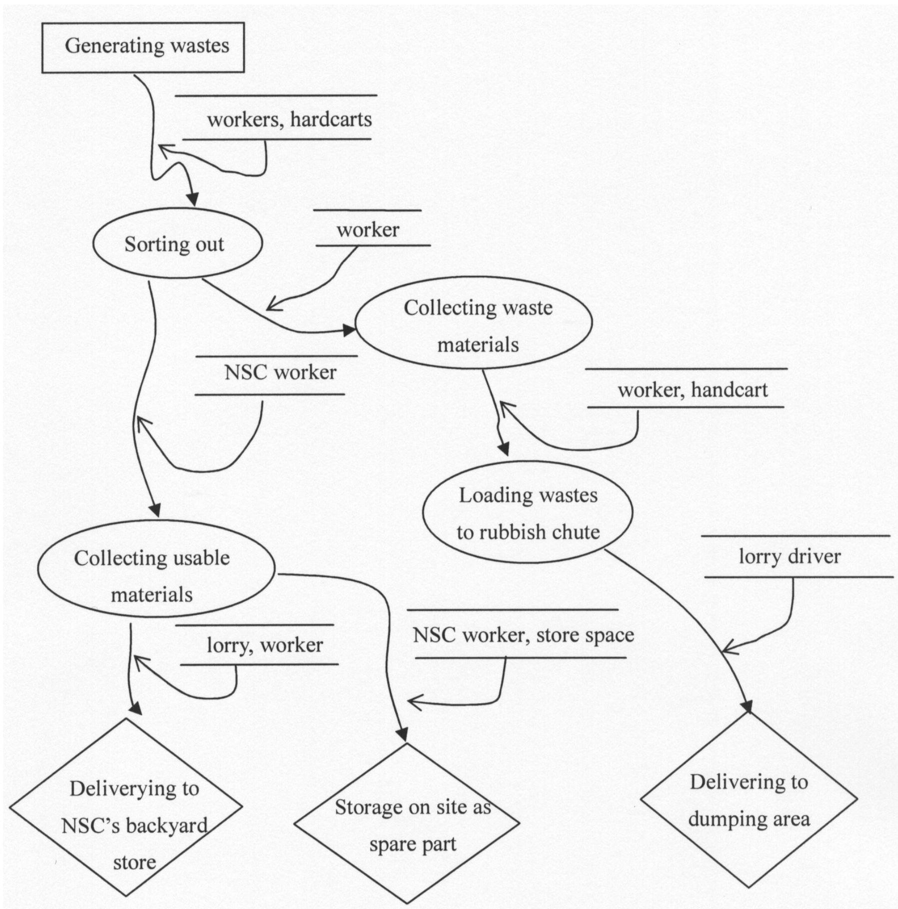

Figure 5: Mapping Waste Management Practice for Metropolis Project (Construction Stage: Finishing Works)

4. DISCUSSIONS AND CONCLUSIONS

The benefits of implementing waste management are multiple. McDonald et al. (1998) suggested that the main advantage of engaging waste management is cost saving, 50% of handling cost could be saved in their case studies. However, the cost reduction by controlling wastes is difficult to achieve in short term. Shen & Tam (2001) found that one of the most serious barriers to constructors in Hong Kong construction industry in implementing waste management is cost increase due to additional investment on staffing, technologies and facilities. Furthermore, in the current waste management practice, governmental enforcement seems being the driving force that pushes most contractors to implement proper waste management. Contractors normally seek for a way that can satisfy the minimum requirement imposed by governmental restriction. This waste management practice is considered of limited effectiveness from long term's viewpoint if there is a lack of contractors' initiative and the public awareness. Contractors' active contributions are essential for the successful implementation of waste control and environmental management mission. The investigation on four case studies in this paper demonstrates that different site management practice engages a different waste management model presented in a mapping or WMF. The identification of their weaknesses and advantages provide valuable references for further research in developing a more effective and standard waste management flow model. Whilst such a standard model should be able to incorporate the advantages embodied in the practice, the guidelines for constructing such model must be established, and this is the immediate future study to be undertaken by this research group.

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