Improving The Organization Of Waste Management Sites: An Operational Perspective

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ABSTRACT

Waste management (WM) operations include a broad variety of processes that aim at removing waste from industrial and private facilities. The waste is treated in different ways in waste management sites, which engage in recycling, landfilling and incinerating. The paper examines the effects of the organization of the WM site and its internal work procedures on its productivity and efficiency, measured by the quantity of processed waste and recycled material. The improvement of waste processing is essential from the environmental standpoint, but has also operational and economic aspects that are important for the proper operation of WM sites.

Keywords: Waste Management; Recycling; Productivity; Efficiency; Operation and Organization

1. INTRODUCTION

Waste management (WM) is the sustainable process of the collection, transportation, processing, recycling and monitoring of all types of waste materials that are generally produced by human activities. One of the main focuses of WM is to reduce the impact on the environment and health, while improving the aesthetics of communities, by properly treating the disposed materials. The three major forms of waste are municipal solid waste (MSW), all types of solid waste generated by households and commercial establishments, industrial waste and construction waste. All three of these categories can be sub-classified as hazardous or non-hazardous. Household hazardous waste (HHW) would include dangerous products that are commonly used homes, such as cleaning solutions (McEvoy et al., 1993). Electronic waste (e-waste), another form of hazardous waste, consists of unwanted computers, monitors, televisions and a variety of other electronic devices (Korenstein, 2005). Yard trimmings and landscaping waste (i.e. trimmed branches, leaves, grass, etc.) is another form of non-hazardous waste.

The different types of collected waste cannot be processed in the same manner. For example, used motor oil, which falls into the category of HHW, should be recycled at a proper facility and not landfilled, due to its detrimental effect on the environment. In the U.S., landfill disposal of used motor oil is banned in 20 states out of the 39 respondent states (Simmons et al., 2006).

The various approaches and applications of WM are based on broad and diverse business practices and economic principles that require efficient organization, management, manpower and equipment. Literature on the subject highlights the need to optimize the waste system to reduce environmental burdens and/or economic costs and to improve social acceptance of waste disposal and treatment methods (Woolridge, 2005). Therefore, the need for increased strategic planning of WM resources, work processes and sites has become a critical factor for successful WM.

Economic factors play an important role in successful WM planning and determine the configuration and the organization of each WM site and whether it will be profitable (or, in the least, less costly) to operate in the short and in the long run. The economic costs of operating a WM site may significantly vary due to different organization of the facility and work practices, but also due to different laws and regulations that may vary from region to region. For example, In Shanghai's WM sites, less attention is given to issues such as environmental safety, recycling, or even waste processing methods; the vast majority of waste generated is sent directly to landfills. Conversely, in Connecticut, only 10.9% of the MSW was landfilled, with the remainder being recycled or converted to energy (Simmons et al., 2006). The cost components of operating public WM sites are presented in Table 1.

Table 1: Cost components for public WM entities (McDavid, 2002)

Solid Waste Survey Cost Components	Recycling Cost Components	Landfill Survey Cost Components
• Capital expenditures • Debt retirement • Equipment and vehicle replacement • Vehicle maintenance • Fuel and lubricants • Utilities charges • Building rental • Salaries and wages • Fringe benefits • Administrative overhead • Insurance • Net costs of operating any recycling programs • Net costs of operating any transfer stations	• Capital expenditures • Debt retirement • Equipment and vehicle replacement • Vehicle maintenance • Fuel and lubricants • Utilities charges • Building rental • Salaries and wages • Fringe benefits • Administrative overhead • Insurance	• Capital expenditures • Debt retirement • Equipment and vehicle replacement • Equipment and vehicle maintenance • Fuel and lubricants • Utilities charges • Building rental • Salaries and wages • Fringe benefits • Administrative overhead • Insurance • Legal services • License and permit application fees

The paper presents a methodological framework for improving the efficiency performance of WM sites and reducing their costs of operation. The following section presents the different types of WM operations. Section 3 presents a case study of the Mafat WM site and the improvements carried out in terms of enhancing its internal organization and work practices. Section 4 discusses the fundamental lessons that were derived from our study and highlights the principles for improving WM sites and facilities and their operation costs. Finally, Section 5 concludes and presents new venues for expanding this research.

2. THE DIFFERENT TYPES OF WASTE MANAGEMENT OPERATIONS: OPPORTUNITIES AND SHORTCOMINGS

WM operations usually entail the collection, transportation, processing, recycling, disposal and monitoring of waste (see Fig. 1). While the collection and transportation of waste are relatively simple operations and the means of collecting and transporting waste differ only in treatment of hazardous and non-hazardous waste, the processing of waste requires relatively complex logistics together with production and organization processes. However, waste processing differs between WM facilities, depending on types of waste collected, technological capabilities, financial allocation of resources and the overall planning of each WM facility.

The main methods for waste processing consist of recycling, incineration, composting, landfilling and waste to energy conversion (Eriksson, 2002). Recycling is an important practice of WM that turned into an over 65 billion dollar per annum industry (Childress, 2008).

Recycling does not only prevent unnecessary materials from entering landfills, but it also reduces the need to produce new products from raw materials that require intense manufacturing processes that are harmful to the environment. From the environmental standpoint, materials salvaged from waste via recycling processes are re-used and hence do not require the production of similar quantities of natural resources. Additionally, recycling decreases the consumption of energy necessary to produce raw materials. For example, recycling scrap metal saves 74% or more of the energy required to smelt metal from ore (Childress, 2008). Recycling decreases the volumes of waste and thereby it reduces environmental externalities, such as land and water pollution. From the economic perspective, recycling has become a favorable practice, due to the increasing demand for materials, their rising prices and the lower costs of obtaining resources from waste in comparison to their production costs due to technological advances in the field. To illustrate, in 2004 over 110 million tons of MSW were recycled in the U.S. alone (Simmons et al., 2006). Table 2 presents the distribution of materials salvaged from waste in the U.S. Nonetheless, despite its environmental and economic benefits and the growing concern for the environment, the policy towards recycling is not uniform worldwide and even not nationwide, as only part of the WM facilities practice recycling. For example, in Mississippi, only 1.6% of MSW generated in 2004 was recycled, and the remainder was sent to landfills, while other states in the U.S. implement more active policies towards recycling operations (Simmons et al., 2006).

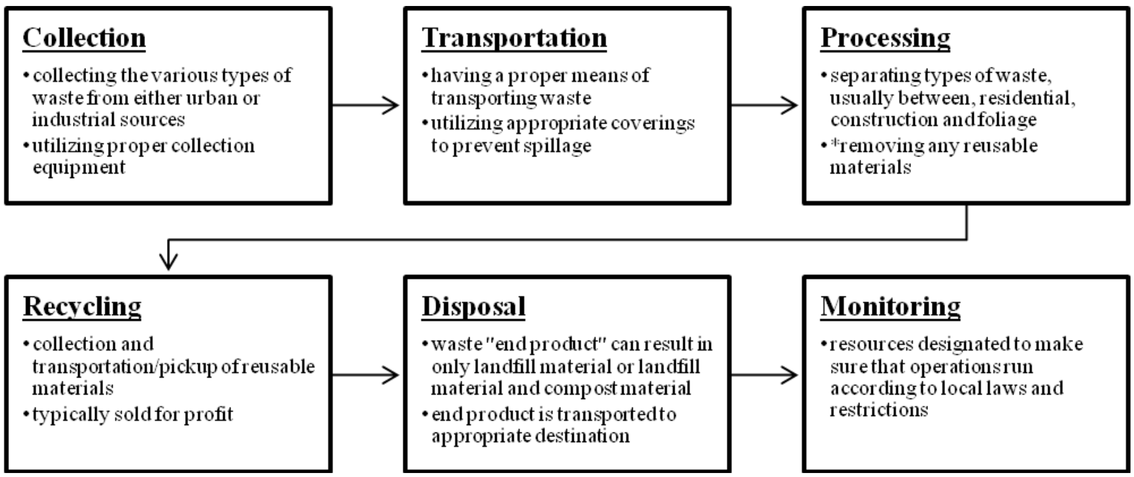

Fig. 1: Description of waste management operations by stage

Table 2: The volumes of recycled materials in the U.S. (Institute of Scrap Recycling Industries Report, 2007)

Quantity In Million Tons	Recycled Material
81.4	Iron, Steel
53.5	Paper
4.5	Aluminum
3.5	Glass
1.8	Copper
1.4	Stainless Steel
1.4	Lead
0.957	Plastic
0.459	Zinc

Incineration is essentially the process of burning waste into ash; however this requires the treatment of cleaning the raw gas generated from combustion before being released back into the environment (Eriksson, 2002). The major critique regarding incineration is that the release of energy, greenhouse gases and toxic materials throughout this process may result in potential environmental damages that surpass the benefits of waste disposal in this method.

Landfilling, which has been practiced in major cities for over 100 years (Walsh et al., 1995), brings about two major concerns. The first is the alarming rate at which landfills all around the world are being exploited. In 2004 in the United States, over 46.6 million tons of waste was imported and over 19.5 million tons were exported (Simmons et al., 2006). The other major concern regarding landfills is leachate. Leachate is the liquid byproduct of landfills. Its composition varies, depending on the contents and age of the landfill, but has high potential to be extremely detrimental to the environment. For example, the Laogang landfill is one of China's largest landfills and is located directly on a beach separated from the sea by an artificial dike. 6.5% to 13.5% of the landfill's leachate seeps directly beneath the landfill into the soil below, thus contaminating groundwater, while the majority of the leachate flows directly into the sea (Ward et al., 1993). Landfilling is typically performed during the disposal stage, however it is considered to be a form of waste treatment when a WM facility does not practice any other form of waste processing. The final process, is waste to energy, which is becoming more popular with increased environmental awareness and advancements in technology. In 2004, 64.9% of MSW generated in Connecticut was converted into energy (Simmons et al., 2006). There are two main methods available for converting waste to energy: thermal gasification, the process of heating compost at high temperatures through controlled amounts of oxygen, and anaerobic digestion, the process of treating organic waste that might otherwise be landfilled or incinerated by utilizing microorganisms to breakdown the organic waste. Both processes result in the production of bio gas and/or methane gas, both have the capability to replace petroleum gas (Eriksson et al., 2002).

Composting is a deliberate biodegradation of organic matter such as food and yard waste. It is a widely accepted method for waste treatment, since the end product (compost) is typically sold for profit to farmers or landscapers. For example, over 20 million tons of MSW was successfully composted in 2004 in the U.S. (Simmons, et al., 2006).

Despite technological and environmental achievements that improve both the safety of waste treatment and its economic value, the organization of WM sites and the work procedures within them largely affect these dimensions. The following case study illustrates the vast potential for improving the performance, the efficiency and the economic returns from reconstructing the work processes of WM sites.

3. DON'T WASTE ANY TIME: IMPROVING THE EFFICIENCY AND THE PERFORMANCE OF THE MAFAT WM SITE

Mafat is a WM site located in the center of Israel. The site serves four cities that are in its vicinity. The core of Mafat's operations is based upon collection, removal, and sorting of MSW. Although the majority of revenues are generated by the sales of recycled materials and not through waste collection contracts, 100% of these materials are salvaged from waste through sorting processes. Mafat receives 1250 tons of waste (excluding landscape waste) on average per day (within a 12 hour time frame) and an average of 650 tons of waste gets processed every day (during a 16 hour time frame). The site utilizes 180 MSW collection trucks, and 65 LW collection trucks. Each MSW truck can carry a maximal load of 9.5 tons and each LW truck can carry a maximal load of four tons. Most trucks have a 4.5 hour route for waste collection and return to the site twice a day. Other trucks have shorter routes and return to the site four to six times a day. In total, 220 to 250 MSW truck arrivals per day were reported.

The sequence of WM operations is carried out as follows: when a waste truck enters the site, it is weighed and then it proceeds towards the waste dump area, where it dumps all of its contents. The truck returns to the scales for a second weighing that indicates the net weight of the waste entering the site by subtracting the truck's weight from the initial weighing.

From the dump area, the waste goes through primary sorting, in which any material not suitable for the sorting machine, such as LW and large items, is removed and transferred to another area on the site. The remaining waste is then transferred to the sorting machine loading area via CAT tractors. The main part of the sorting process is accomplished through the utilization of a large waste sorting machine. Waste is loaded on one end of the machine's conveyor belt, goes through a series of functions, and results in the collection of paper, plastic, and metal for recycling, organic materials for composting and leftover material for landfilling. Within the sorting machine, small waste material falls onto a separate conveyor belt, while the large waste material continues on to paper and plastic removal. Paper and plastic removal is done by hand and the remaining waste moves along to the landfilling pile. Along the path of the small conveyor belt, a large magnet rotates above, removing all metal objects from the waste. The rest of the small waste line continues onward to another cylindrical machine designed to filter out all small organic material. The remains fall off the end of the conveyor belt into a pile of waste destined for landfills (see Fig. 2).

An average of 1250 tons of waste (excluding landscape waste) arrives on site every day (within a 12 hour time frame), but only 650 tons of waste are processed every day (during a 16 hour time frame). Hence, the site operates at a 52% efficiency level. The vehicles operated by the site include 180 MSW collection trucks and 65 LW collection trucks. Each MSW truck can carry a maximal load of 9.5 tons, and each LW truck can carry a maximal load of 4 tons. Most trucks have a 4.5 hour route for waste collection returning to the site twice a day. The others have much shorter routes, returning 4-6 times a day. On average, there are 235 MSW truck arrivals per day. Hence, the calculated use of truck capacity is 56% on average, indicating an inefficient utilization of the site's waste trucks.

A time study of the work procedures carried out in Mafat indicated that by re-arranging the sites and the work processes within it, the complete waste quantity transferred into the site can be processed. Thereby, issues such as untreated waste accumulated on site and bottlenecks in the workflow of waste processing can be fully resolved.

The improvements of the existing work procedures are primarily based on the following principles:

- Reduction of the cycle time – the cycle time is the complete duration of waste treatment from its arrival to the site until its handling begins. At the beginning of our analysis, the cycle time was 5.92 minutes per truck on average. The re-engineering of the site and the work procedures resulted in an average of 3.32 minutes per truck. This improvement represented 78.2% growth of the site's productivity which is reflected by a larger throughput of waste treated by the site.
- Larger frequency of truck handling – in the previous organization of the site, only ten waste trucks per hour on average could be treated in the site. The new structure and organization of the site ensures handling 18 trucks per hour on average, thereby substantially increasing their frequency.
- Relocating the collected waste area;
- Increasing sorting machine speed;

These improvements, fully applied in Mafat, increased the volume of treated waste from 650 to 1323 tons per day, thereby exceeding the amount of daily collected waste by 73 tons per day. This excessive capacity can be allocated to treating the accumulated waste on site, in order to limit its negative environmental impact without having to employ additional resources.

4. DISCUSSION

The physical layout of waste sites is often the key for improving the performance and the productivity of their various waste processing departments and facilities. The major principle in the re-engineering of a site and its internal mechanizations and work procedures lies in reducing the cycle time necessary to process any quantity of waste received by the site. In particular, waste moving processes are time consuming and in many cases unnecessary due to a more efficient planning of the site's layout. By relocating the waste dumping site within the waste loading area, large portion of the cycle time can be saved.

Additionally, possible time reductions can be gained by restructuring on-site weighing procedures. In the case studied, all the trucks had to be weighed in station twice and weights were recorded manually. By installing an extra set of scales and by automating the weighing and recording tasks major time reductions could be obtained, improving the efficiency of the weight recording process. This work procedure can also benefit the sorting department by first eliminating the need for manual weight recording and reallocating personnel to other departments, such as sorting. Second, the automated scales can be connected to the sorting department and data about the entering amounts of waste can immediately be transmitted to it for determining the number of employees and the profile of operating the sorting equipment. In a broader perspective, the data collection can assist management in following the production of the site, controlling its operations and determining whether its daily waste processing objectives are met.

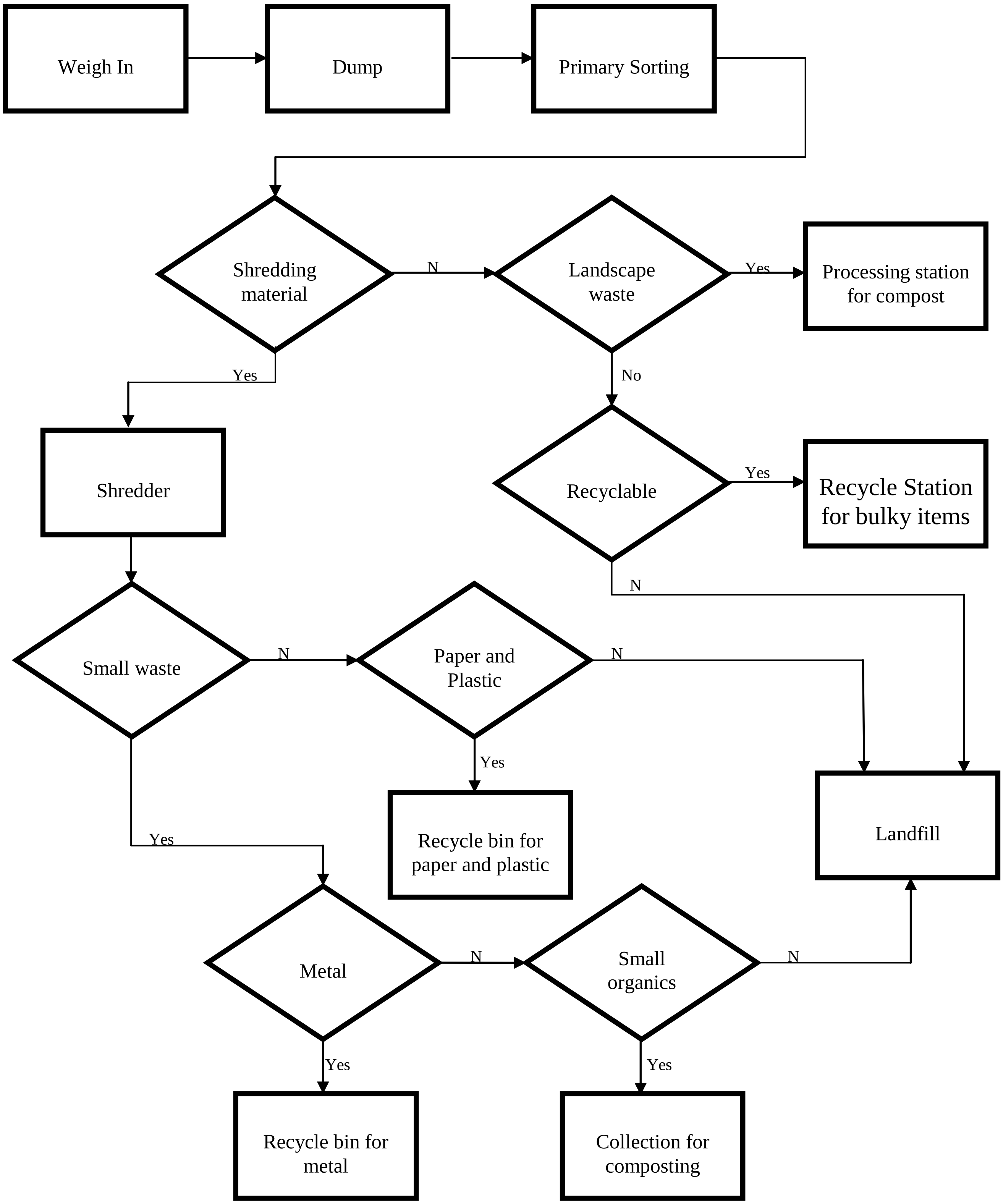

Fig. 2: Flow chart of waste processing.

5. CONCLUSIONS

The growing amounts of waste due to population growth, rapid industrialization, consumption and economic growth worldwide highlights the importance of WM sites and in particular their waste processing and recycling capacities. Despite the use of advanced WM technologies, from the operational and environmental standpoints, sites may fail to “catch up” with the amounts of waste that are daily collected and received due to low degrees of efficiency and productivity that are inherent in their organization and design.

The study analyzes the operation of WM sites as production systems that set production objectives, due to the inputs entering their “production lines.” Though WM sites may be equipped with the best technology available for waste processing, they may suffer from low efficiency rates that may hamper their productivity and, in many cases, may cause negative environmental externalities.

The case study presented hereinabove illustrates how reorganization of the site, its facilities and work procedures can substantially enhance the WM site’s productivity, and even double it, without investing in additional equipment or deploying additional employees. Other aspects that may be relevant to WM sites but are not examined in this paper include planning waste collection routes, operation of vehicle services and the method chosen for waste processing, e.g. incineration, biogas production and landfilling, which can dramatically affect the costs and the efficiency of WM systems and sites.

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