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Feasibility Of Automatic Food Waste Collection For A University Catering Complex

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ABSTRACT

Hong Kong is facing an increasing challenge on food waste management due to limited landfill capacity and delayed construction of incineration facilities. Despite efforts have been made to promote the reduction and recycling of food waste, less than 1% of the waste is currently recovered and recycled. The green policy to enhance recycling capacity, efficiency and cost-effectiveness of food waste treatment plants is hindered by less effective collection practices. This study presents the feasibility of the adaptation of a centralized food waste collection facility for university canteens, and evaluates the benefits of employing such collection system. The system is implemented in a university catering complex that houses 3 canteens with about 1,000 seats. Food waste is collected from disposal inlets, which is then automatically fragmented, de-watered and transported to a centralized storage tank for collection by waste trucks. The system is believed to streamline food waste handling processes in kitchen areas as it would require less space and manpower for operation as compared with existing manual collection practices. On-site monitoring and usage data collection of food waste will be carried out to evaluate system performance. Life-cycle costing analysis will also be performed to quantify total cost and to assess the cost-effectiveness and environmental benefits of the system. User behaviour prior and after system installation will also be surveyed and analysed. Implications of the food waste collection system on the development of food waste recycling industry will be discussed.

Keywords: Food waste, waste collection, behavioural change, life-cycle cost analysis

1. INTRODUCTION

Hong Kong is facing a huge challenge on waste disposal as the city is expected to run out of the existing landfill space by 2019, while its waste disposal rate and population are on the rise (Environment Bureau, 2013). According to the Environmental Protection Department (EPD), the average Municipal Solid Waste (MSW) disposed at landfills was 10,345 tonnes per day in 2016, which has increased by about 15% compared to 8,996 tonnes per day in 2011 (EPD, 2013; 2018). Among all MSW produced in Hong Kong, food waste is the largest contributor, which accounted for around 35% (3,600 tonnes per day) of the total MSW disposed in 2016. Despite the high rate of generation and disposal of food waste, recycling rate remained low at under 1%, and the commercial and industrial (C&I) sector was responsible for 32% (1,137 tonnes per day) of the daily food waste produced (EPD, 2018).

In response to the mounting food waste challenge, the Hong Kong government has published the Food Waste & Yard Waste Plan for Hong Kong 2014-2022 with a target to reduce the quantity of food waste delivered to landfills by 40% in 2022 compared to 2011 (Environment Bureau, 2014). In particular, Organic Resources Recovery Centres (ORRCs) are being developed in phases to recover energy from food waste through anaerobic digestion (EPD, 2017). In order to fully utilise the facilities, an efficient and cost-effective food waste collection system should be put in place to facilitate source separation and collection of the waste.

However, recycling behaviour depends largely on attitudes towards the environment, the investment of personal efforts and the inconvenience arose from recycling (Oskamp et al., 1991). Current food waste recycling practices within the Hong Kong C&I industry are inadequate to support development and expansion of the food waste recycling industry. Therefore, an increase in collection rate and hence total food waste delivered to ORRCs is crucial to the achievement of the waste diversion target as set by the government.

The MSW charging scheme to be implemented in the latter half of 2019 (HKGov, 2017) will further push demand for food waste collection systems to enable cost-effective separation and recycling of food waste, given that food waste and other recyclables are exempted from waste charges. Thus, a need to enhance the efficacy and effectiveness of food waste collection process, such that recycling practice can be in line with prospective policy development.

As a pioneer study in Hong Kong, this project studies the effectiveness of implementing the food waste collection system as a replacement of the conventional waste handling process, and investigates the feasibility of implementing the system in Hong Kong as an integral part of regional food waste management plan to maximise the recycling rate of food waste. In this study, we aim to evaluate the outcomes and the benefits resulted from the adaptation of a centralized food waste collection facility through lifecycle costing analysis, as well as to analyse behavioural changes of users due to implementation of the system. The implementation of the system in catering facilities in Hong Kong may be feasible and achievable if the study yields promising outcomes, in which food waste collection rate will be enhanced and manpower and cost will be reduced. As a result, food waste recycling practices can be facilitated and promoted among C&I sector and the public.

2. FOOD WASTE COLLECTION SYSTEM

The experimental food waste collection system is implemented in 3 canteens within a university catering complex that has a total capacity of around 1,000 people. A schematic diagram of the system is shown in Figure 1(a). The system collects food waste from three inlet benches I_1, I_2, I_3 on third and fourth floors of the complex. The collected food waste will then be transported through pipes via a vacuum pump unit P to the dewatering unit D on ground floor. The food waste is fragmented and dewatered before being emptied to a temporary storage tank S for collection by trucks. Operation of the system will be monitored for twelve consecutive months to gather relevant data for the study.

Food waste collected at inlet benches I_1, I_2, I_3 will be measured for its volume V_i (L); electricity consumption E_p, E_d (kWh) of the vacuum pump and dewatering unit will be measured; water consumption V_w (L) and amount of wastewater discharge V_d (L) are to be recorded; and the weight M_s (kg) and volume V_s (L) of dewatered food waste collected at temporary storage tank will also be recorded. The system process diagram is shown in Figure 1(b). The collected data will be used to quantify and compare the handling costs of food waste before and after installation of the collection system. The unit handling cost before system implementation $\overline{C}_b$ (HK$ kg^{-1}) is shown in eq. (1), which includes labour C_l (HK$) and waste contractor C_w (HK$) costs:

$$\overline{C}_b = \frac{C_l + C_w}{M_s} \quad (1)$$

Similarly, eq. (2) shows the unit handling cost after system implementation $\overline{C}_a$ (HK\$ kg^{-1}), which comprises of the production, installation, maintenance, operation and waste contractor costs C_p, C_i, C_m, C_o, C_w (HK\$):

$$\overline{C}_a = \frac{C_p + C_i + C_m + C_o + C_w}{M_s} \quad (2)$$

The operation cost C_o of the system will consist of labour C_l, electricity E_p, E_d and water V_w costs, and can be calculated in eq. (3), where P_e (HK\$ kWh^{-1}) and P_w (HK\$ L^{-1}) are the unit prices of electricity and water:

$$C_o = C_l + (E_p + E_d) \times P_e + V_w \times P_w \quad (3)$$

The system is expected to simplify food waste collection procedures in the canteens as the entire collection process is operated automatically. We will quantify the anticipated impacts to labour and transportation costs, as well as cost-effectiveness of the system. As a result of the study, users and businesses could get more information on food waste recycling practices.

2.1.Food Waste Unit Cost

A number of studies have attempted to quantify the unit cost of food waste in terms of avoidable waste and management practices, such as composting and anaerobic digestion. Chen (2016) has carried out a cost and benefit analysis on turning food waste into compost in Taiwan, which showed that the automation of treatment processes may enhance cost effectiveness as they reduce operation costs. Takata et al. (2012) studied the environmental and economic efficiency of various food waste treatment methods in Japan, including composting, feed production and bio-gasification. The results showed that bio-gasification and dry feed productions emitted the least greenhouse gases, and integration of machines could increase the cost effectiveness of composting systems (Takata et al, 2012). Another study conducted in the UK has looked at the cost of food waste within the Hospitality and Food Service sector, such as restaurants, pubs and hotels, by determining the costs related to food purchase, labour, transport, etc. (Lee, Parfitt and Fryer, 2013). The study showed that about 90% of the cost of food waste was associated with food purchase and labour, and food waste was estimated to cost the sector £2.5 billion in 2011 (Lee, Parfitt and Fryer, 2013). In Hong Kong, Lam et al. (2018) has studied the net costs of food waste management using Hong Kong International Airport as the case and Life-Cycle Cost-Benefit Analysis as the framework. Of the six studied management scenarios, it was found that onsite incineration treatment of food waste has the lowest life-cycle cost and the highest energy recovery, while offsite anaerobic digestion of food waste has the highest cost (Lam et al., 2018). The accounted unit costs of food waste are presented in Table 1.

Currently, Hong Kong lacks comprehensive data on the cost of source separation, collection and transportation of food waste, and the data available are from large-scale management practices. Thus, this study will attempt to quantify the unit cost of small-scale food waste collection system by taking production, installation, operation, maintenance and waste contractor costs of the system into account.

2.2.Life-cycle Cost Analysis

Life-cycle cost analysis (LCCA) will be carried out to quantify the total cost of the system throughout its life-cycle. Total cost associated to a product or service can be categorised into acquisition, ownership and disposal costs. Acquisition cost accounts for installation, training and shipping costs of a product; operation and maintenance expenses are included in ownership cost; disposal cost may be incurred for the proper recycling, recovery or disposal of the product (Asiedu and Gu, 1998). The total cost will be evaluated and compared with the estimated overall benefits generated from improvements in the rates and processes of food waste collection. The LCC (HK\$ kg^{-1} $year^{-1}$) of the food waste collection system is calculated in eq. (4) as total cost $\overline{C}_a$ from eq. (2) over the period of lifecycle years T:

$$LCC = \frac{\overline{C}_a}{T} \tag{4}$$

For this study, LCCA will be conducted to evaluated the benefits of reduced labour input, transport distance and costs due to the adoption of an automatic food waste collection system. The costs of manual source separation and delivery of food waste to waste collector will be compared with the costs required to collect and deliver dewatered food waste to the ORRC with the system. Expected benefits of the system include reduced number of trips for staff to move food waste to collection points, as well as reduced number of collection trucks required to collect the dewatered food waste. System benefits B (HK\$ kg^{-1}) as shown in eq. (5) is calculated as the difference of unit handling cost before and after system implementation ($\overline{C}_a$ and $\overline{C}_b$):

$$B = \overline{C}_a - \overline{C}_b \tag{5}$$

Reduced staff trips will be calculated as the difference in time and labour cost required to sort and transport waste to collection points with and without the system. The reduction in waste volume and hence collection truck required will be calculated as the difference in waste contractor cost prior and after implementation of the collection and dewatering system.

3. USER BEHAVIOUR

Changes in user behaviour towards the system will be monitored, surveyed and analysed prior to and following system commission. Personal experience, attitude and comment of direct system users and managers towards the collection system will be collected through personal interviews, so as to analyse whether the project can successfully improve food waste collection practices.

Survey interviewees will be canteen staff affected by the implementation of the system, including direct system users and managers. The direct system users will be interviewed on system usability, their attitudes towards the system and changes in waste collection behaviour, as well as health and safety. Canteen managers will be interviewed on the impact of the system on operation cost, workflow, and health and safety conditions. The interviews aim to gather data on user attitudes and behaviours through self-reporting on the experience of interviewees with food waste separation and collection with the system. Descriptive analysis will be performed on the interview transcripts. Keywords will be identified through coding and categorisation to record and present issues addressed in the interviews.

Prior to system implementation, direct system users and canteen managers will be interviewed on their attitudes towards current food waste management practices at the catering complex, opinions on whether an automated food waste collection system will facilitate their jobs, and comments on existing hygiene conditions and availability of space at their work places. The following are some questions to be asked:

- What are the specific issues regarding the management practice that you would like to improve?
- What problems do you belief the system will solve/ bring?
- How would you describe the hygiene and odour conditions of your workplace?

Similarly, interviews will be conducted to the interviewees twelve months following system operation to gather their user experiences of the system and attitudes towards the new food waste management practice, including opinions on system usability, training and technical support provided, and whether the system has enabled staff to perform food waste sorting and collection more efficiently. The following are some examples:

- Did you find the system easy to operate and user-friendly?
- How satisfied are you with the training and technical support provided?
- How has the system helped you to perform sorting and collection of food waste?

In addition, interviewees will be asked about their overall satisfaction towards the system and willingness to use the system in the future.

4. EXPECTED BENEFITS

This study is expected to identify the amount of food waste collected from typical food service providers and compare the quality of food waste collected by recyclers with and without the use of the system. Findings from the study could also facilitate education and technology transfer on food waste separation and collection among the C&I sector, as well as implementation of the system to improve overall performance on food waste collection in Hong Kong. The study is also anticipated to bring environmental, social and economic benefits. On the environmental aspect, the system is believed to raise the percentage of food waste collected and diverted from landfills for recovery. Socially, the adaptation of an automatic collection system would strengthen the willingness of system users to sort and recycle food waste and their understanding on the importance of food waste recycling. Economic benefits associated to the system includes an increase in cost-effectiveness of the food waste recycling process due to reduced labour, storage and transportation costs and greater capacity and efficiency in the handling of food waste.

5. CONCLUSION

Hong Kong is facing a mounting waste problem and there is an urgent need for improving the collection rate and management practices of food waste in the city. Current food waste recycling projects are focusing on the reduction of food waste at source and expansion of food waste handling capacity of the recycling industry. However, improvements in the waste collection process has not been thoroughly investigated. Thus, this study fills the gap by looking at how the overall effectiveness and performance of food waste separation and collection processes can be enhanced. If the adoption of the system is shown to be feasible, food waste collection will be more manageable and cost-effective, and the government may consider this as one of the tools to manage food waste sustainably in Hong Kong.

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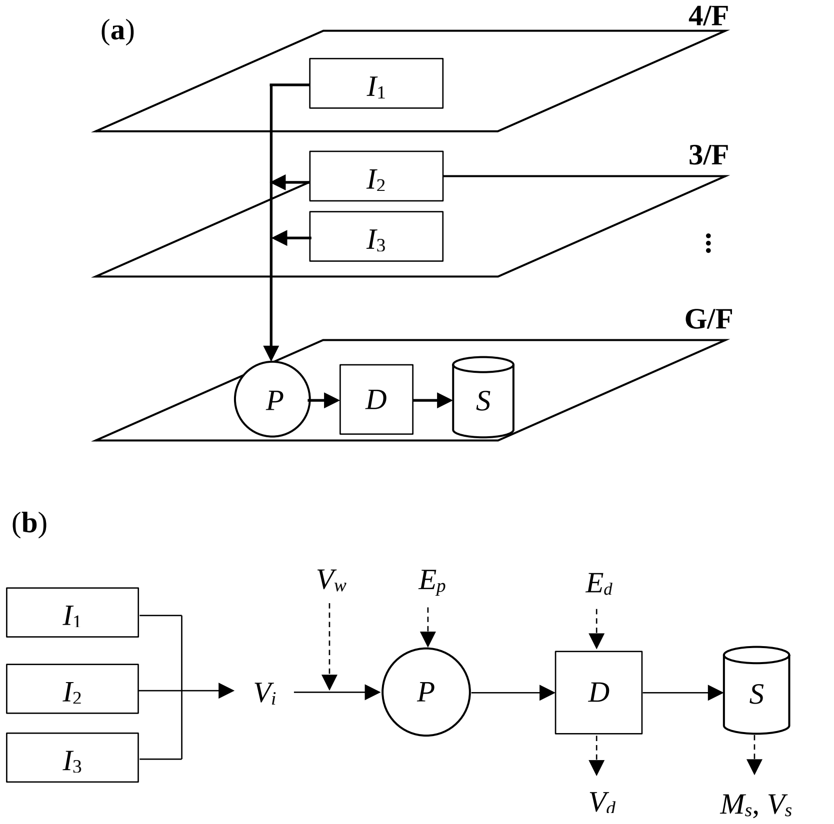

Figure 1. (**a**) Schematic diagram and (**b**) process diagram of food waste collection system.

Table 1: Unit costs of food waste management in countries

Country	Description	Unit cost
Hong Kong (Lam et al., 2018)	Six food waste handling and treatment methods, including anaerobic digestion and incineration, at the Hong Kong International Airport were studied Economic, environmental and social costs and benefits of the methods were analysed.	462–2,440 HK$ $tonne^{-1}$
Japan (Takata et al., 2012)	Various food waste treatment methods were assessed, including composting, feed production and bio-gasification. The labour, maintenance and utility costs were compared against the sales of final products.	-18,955–5,521 JP¥ $tonne^{-1}$ (-1,347–392 HK$ $tonne^{-1}$)
Taiwan (Chen, 2016)	The costs of compost production from six composting plants were analysed, including fixed, operation and maintenance, labour, electricity and water costs.	2,897–23,117 NT$ $tonne^{-1}$ (740–5,908 HK$ $tonne^{-1}$)
UK (Lee, Parfitt and Fryer, 2013)	The costs of food waste within the hospitality and food service sector were studied, costs related to administration, energy, food purchase, labour, transport, waste management and water were included in the analysis.	1,656–4,028 £ $tonne^{-1}$ (16,776–40,806 HK$ $tonne^{-1}$)