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Enhancing Waste Management Practice – The Appropriate Strategy for Improving Solid Waste Management System in Vietnam Towards Sustainability

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This study aims to build the appropriate model of waste management practice (WMP) towards sustainable municipal solid waste (MSW) system in a city of developing country like Vietnam. A waste audit was performed and material flow analysis method was simulated to describe and analyse the current status of MSW system and its assumpted models. Four WMP models were built based on the feature of the region, the intention and optimisation of WMP, and the consensus of the government. This study shows that the improvement of the SWM system can reduce a significant amount of waste to landfill. Notably, the waste reduction performance is 5.0, 7.8, 11.11 and 29.3 % in S1, S2, S3 and S4, respectively. Also, the recovery performance of recyclables changes in proportional to the level of SWM practice and reach at 3.78, 5.843, 4.593, and 7.120 t/d, respectively. This study reveals that the improvement of SWM practice at source from intentional to optimal rate is the sustainable strategy for developing an SWM system in Hoi An City.

1. Introduction

Solid waste is becoming an urgent problem and a significant challenge to society due to the urbanisation and rapid development of the tourism industry in developing countries (Song-Toan et al., 2017). While municipal solid waste (MSW) system in developed countries is approaching sustainability, it seems a burden that developing countries are struggling to solve (Shivika et al., 2017). Sustainability is a goal of a long-term process that MSW system has to be implemented and upgraded gradually. In which, planning an oriented-strategy for MSW system is important. Specifically, in developing countries, MSW system that is sketchy aims to collect thoroughly generated waste and transferred to the disposal. Waste management practices (WMP) at source have not paid attention. Vietnam is a developing country in South-East Asia. The MSW system in Vietnam is also facing many significant challenges. The rapid growth of MSW, inefficiency in waste management, and low performance of waste collection caused to the overload of waste in urban areas and at the disposals (Giang et al., 2017b).

In the centre of Vietnam, Hoi An City (HAC) is known as one of several cities has a typical MSW system. HAC generates daily about 75 t of solid waste, in which waste from the tourism industry accounts for 65 % (Giang et al., 2017a). Recently, municipal waste in HAC increases quickly due to the speedy development of tourism activities. This leads to the overload of waste in the downtown of the city, brings obstacles to WMP and challenges to MSW system. Although waste separation at source has been implemented since 2012, its efficiency is still low due to non-consensus of society. So in the context of facing many challenges and lack of financial and technical conditions, what strategies of MSW system in Vietnam can solve current problems towards sustainability? Pham Phu et al. (2019) indicated that the accommodation industry in HAC has high

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potential to reduce waste generation by enhancing waste separation at source and recycling practice. The improvement of recycling was suggested as a suitable solution for establishing a sustainable MSW system in HAC (Song-Toan et al., 2018a). Also, Giang et al., (2018) optimised a waste treatment model for MSW in HAC aims to minimise cost, waste to landfill and emission. However, these treatment solutions require excellent WMP performance and appropriate policies. Therefore, this study aims to build a suitable strategy for enhancing WMP at source to contribute to developing the MSW system in HAC toward sustainability.

2. Methodology

2.1 Waste audit

Solid waste generation in HAC was summarised by a waste audit from seven waste sources. A waste audit was calculated by multiplying solid waste generation rate (SWGR) of each waste source with the number of stakeholders in (Table 1). In which, SWGR of each source was identified in the previous studies.

Table 1: Number of stakeholders and solid waste generation rate in each waste sources

Sources of waste	Accommodation	Households	Restaurant	Market	Shop	Handicraft production	Others
Total number	567	93.216	608	8	1124	272	-
SWGR (kg)	29.20	0.223	26.17	795	0.86	17.27	
References	(Song-Toan et al., 2018b)	(Giang et al., 2017b)	(Song-Toan et al., 2019)				

The SWM practice is considered as an important factor for developing municipal SWM system. Thus, the SWM system is simulated by different SWM practice rate in scenarios. The performance of the SWM system is described by Material flow analysis (MFA), and the efficiency of waste reduction and recycling enhancement is analysed and compared between scenarios.

2.2 Material Flow Analysis

The flow of municipal waste in HAC was described by MFA method with STAN software. STAN is a freeware was standardised using the Austrian Standard ONORM S 2006. In this study, MFA was used to provide a systems-oriented view of MSW processes and support the priority-oriented decisions to design MSW strategy. The MSW flow will be assessed in the defined space of HAC and the time by day. Three steps to simulate by STAN comprise graphical model, entering data, and calculation with mass balance.

2.3 Building the scenarios of municipal solid waste management practice development

In this study, five scenarios of MSW system were built based on the current status of WMP, the intention of residents and stakeholders in implement WMP, a feature of the region, and consensus of the government. Table 2 presents in detail the parameter of models of WMP. Notably, S0 describes the MSW system in the current status of WMP. S1 and S2 were assumed that MSW system in HAC will be planned with the minimalism in WMP. In which, waste is not sorted at sources and collected by trucks for landfilling, which is the common disposals in developing countries. Recycling activities are encouraged to improve with intention (S1) and optimal (S2) practice rates.

Table 2: Scenarios of municipal solid waste practice development in Hoi An City

	Scenario	Separation at source	Recycling	Composting
S0	Business as Usual (BaU)	Current	Current rate	Current rate
S1	Minimalism in waste practice at source	No separation	Intention rate	No
S2	Minimalism in waste practice at source	No separation	Optimal rate	No
S3	Enhancement of waste practice at source	Separate into three types	Intention rate	Intention rate
S4	Enhancement of waste practice at source	Separate into three types	Optimal rate	Optimal rate

In addition, S3 and S4 were built based on the sustainable concept of MSW practice. Whereby, waste separation at source is improved by three types such as biowaste, recyclables, and non-biowaste instead of two types as currently. The recycling and composting practice at sources were assumed to be gradually enhanced in S3 by intention rate and in S4 by optimal rate. The intention rate was identified by interview survey. Also, the optimal rate was measured by a combination of intention rate, the region feature, and the interference of waste regulation.

3. Results and discussions

3.1 Analysis of the models of municipal solid waste management practice

The flow of MSW in HAC in scenarios is described to analyse the waste management system in the city under different assumptions. In the first orientation for developing the MSW system in HAC, recycling practice is gradually enhanced, and the waste collection performance is aiming for optimisation. Figure 1 shows that waste from sources is un-sorted and collected daily by trucks. Whereas, recyclables are separated by the optimal recycling rate and collected by the itinerant buyers at sources. Also, recyclable materials in mixed waste are picked out again of trucks before loading by collection crews. These similar solutions are found in many developing countries corresponding to the current status of MSW system. In Nigeria, waste collection service was suggested to be upgraded in quantity and quality to solve the problems of increasing waste amount and illegal dumping sites. Also, recycling practice was planned to improve by developing co-operation between communities, the informal sectors and the authorities, and encouraging markets for recyclables. Whereas, in Malaysia, many solutions were presented to increase recycling practice such as providing recycling bins in every residential area, promoting recycling attitudes in households, and enhancing the accessibility of recycling facilities (Avraam and Stamatia, 2012). As a result, the improvement of recycling practice and optimisation of collection performance might be the desirable and urgent goals of MSW system for developing countries as Vietnam.

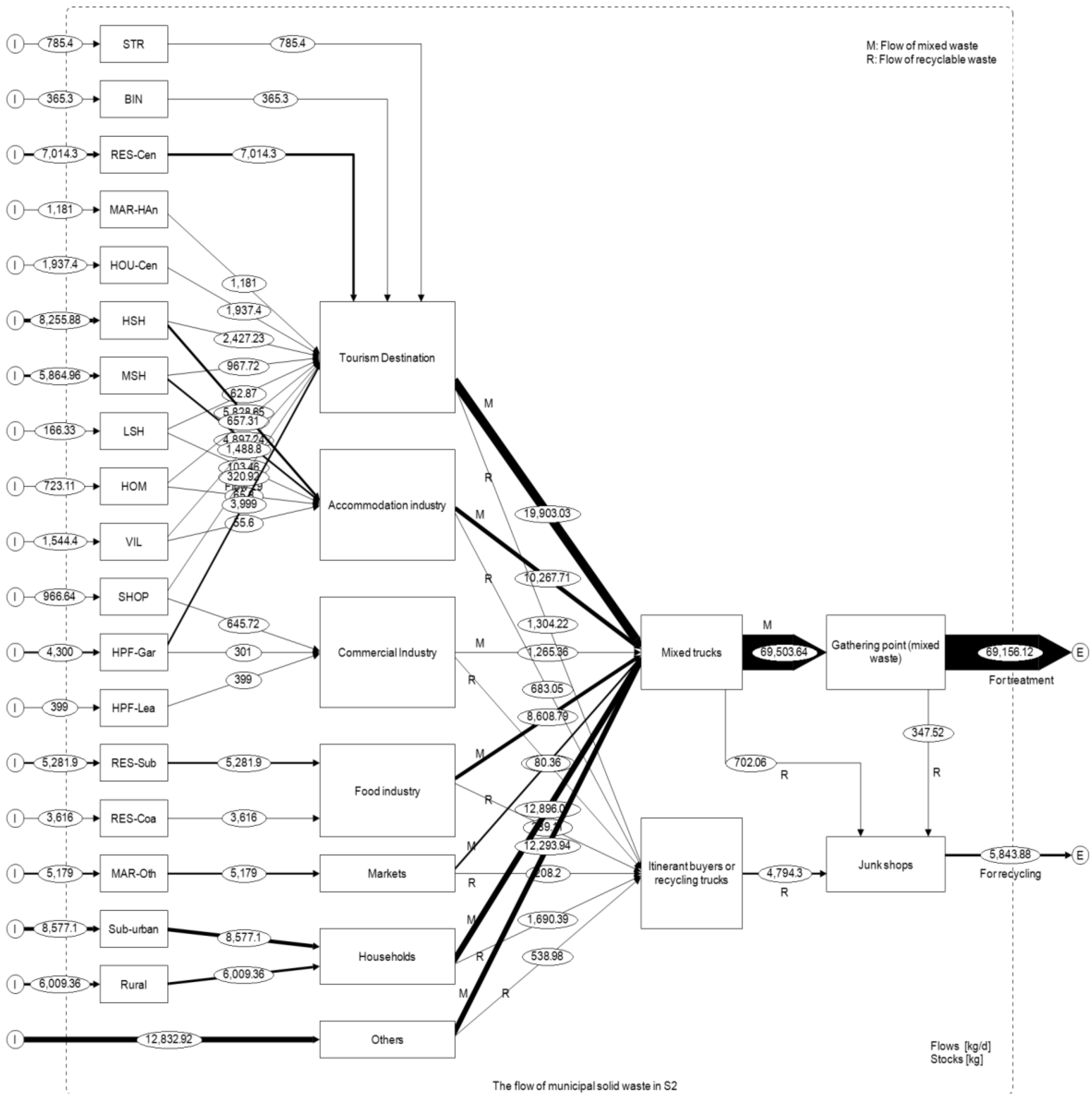


Figure 1: The flow of municipal solid waste in scenario 2

While the MSW system in developing countries is struggling to find suitable solutions, MSW system in developed countries is approaching sustainability. Inevitably, the optimisation of MSW system corresponding to the regional feature is essential, and the improvement of that system should be planned for sustainability (Mirza et al., 2019). In this study, the optimal model of MSW system in HAC was planned for sustainability is shown in Figure 2. Notably, waste is suggested to be sorted into three types instead of two types as the current regulation. This change in waste separation at sources brings favourable condition for improving recycling practice at sources, in which home-composting is an effective solution to reduce waste generation. Figure 2 indicates that a significant amount of biowaste is stocked in the waste flow by home-composting at the garden of hotels, restaurants and households. The rest of the biowaste is collected separately by trucks and treated by an existing composting facility. The informal sectors as itinerant buyers and service facilities for recycling should be upgraded by support from the government for collecting thoroughly recyclable materials at sources. Additionally, waste recycling practice rate may be enhanced by promulgating incentive policies and regulations, improving education and training skills. Hence, a significant amount of recyclables is recovered daily for recycling brings substantial economic benefits for residents and MSW system.

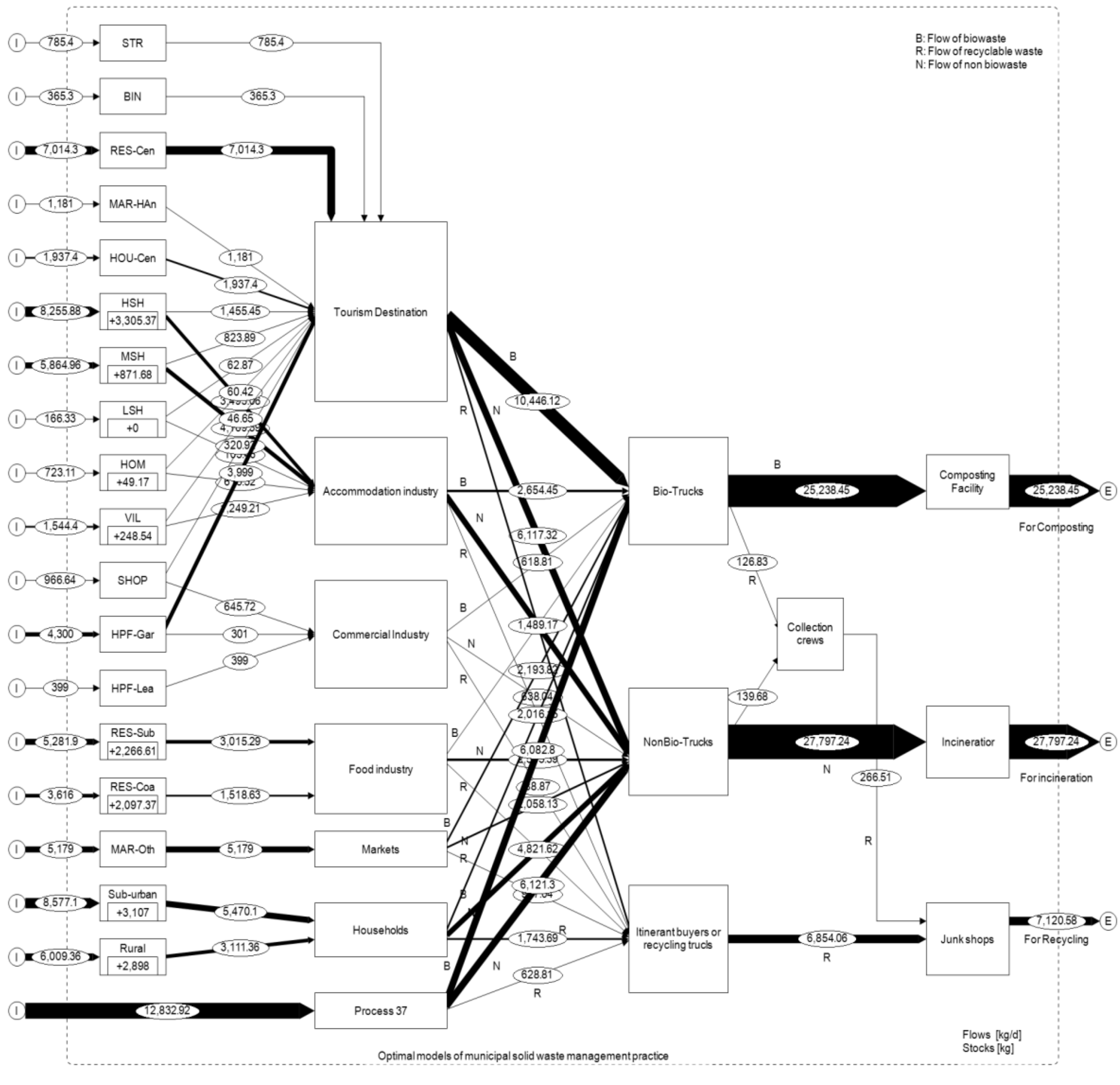
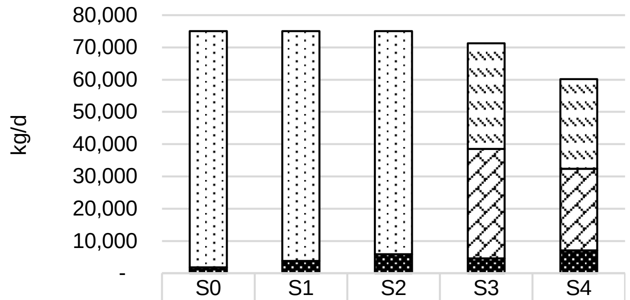


Figure 2: The flow of municipal solid waste in scenario 4

Figure 1 and 2 reveal that the more minimalist the waste management practice at source, the simpler the MSW system. However, the performance of MSW system in the different levels of WMP at source should be assessed by many criteria. In this study, the performance of waste reduction to landfill and recycling potential are two main parameters of waste planning strategy in HAC.

3.2 Assessment of the models of municipal solid waste management practice

Figure 3 indicates that the amount of waste in S1 and S2 is no change due to the minimalism of WMP at source. Whereas, waste generation volume in S3 and S4 gradually reduce proportionally to the efficiency of waste separation and the rate of WMP. In which, the organic waste is handled by home-composting with the significant amount by 3.7 and 14.9 t/d in S3 and S4, respectively. Home-composting activities are encouraged by the government, trained and supported to deploy in hotels, households, and restaurant with a garden. These implementers may receive immediate benefits such as tipping fee reduction and using compost as an organic fertiliser for the garden instead of buying (Pham Phu et al., 2019).
Additionally, Figure 4 also reveals that the amount of recyclables increase gradually from S0 to S2, and S4. Notably, the amount of recyclable materials rises from 1,835 kg/day to the double times and 3,2 times corresponding to the assumption of intention and optimal recycling practice rate in S1 and S2, respectively. Likewise, the amount of recyclables collected in S3 and S4 is higher 2.5 and 3.9 times than that of S0. The higher the recycling practice rate, the higher the recovery performance of recyclables. Comparing to the same level of recycling practice at source, Figure 3 indicates that the amount of recyclables in S3 and S4 is higher than that in S1 and S2 1.22 times, respectively. As a result, waste separation practice at source may bring higher performance in recovering recyclables.



	S0	S1	S2	S3	S4
Mixed waste	73,164	71,219	69,156		
Non Biowaste				32,794	27,797
Biowaste				33,904	25,238
Recyclable waste	1,835	3,780	5,843	4,593	7,120

Figure 3: Amount of waste collected in different scenarios

In term of macro-view, the MSW system significantly benefits from activities of WMP at sources. Notably, the amount of waste to the disposals significantly reduces by 5.0 %, 7.8 %, 11.1 %, and 29.3 % in S1, S2, S3, and S4, respectively due to the enhancement of recycling and composting practices. The minimisation of waste to the landfill may contribute to reduce the number of waste collection routes and mitigate the greenhouse gases emission from landfilling. Also, the development of recycling activities may bring many benefits to finance and material recovery. Another highlight of the MSW system in S3 and S4 is that waste is separated into biowaste and non-biowaste. The higher the separation rate, the higher the purity of each waste type. This is a favourable condition for bio-treatments or incineration (Dinh et al., 2018).
The increase in municipal solid waste is an inevitable consequence of the rapid development of urbanisation and industry taking place worldwide. In China, Shanghai City is struggling to find suitable solutions to reduce organic waste generation. A sustainable framework of organic waste management was studied focusing on developing some key drivers such as environmental policy and value of waste utilisation (Mirza et al., 2019). Likewise, the high rate of waste growth due to the development of income and urbanisation in India is presented by Shivika et al., (2017). A framework to integrate SWM strategy in Ahmedabad city was proposed. This study indicated that the local impact is a typical factor influencing to developing a sustainable strategy of the SWM system. Consequently, developing a strategy of SWM towards sustainability for a region is necessary and should be studied on many influencing factors. In which, the SWM practice the status, the feature of region, and the consensus of society are the important factors.
In general, this study indicates two directions of waste planning for a city in a developing country as Vietnam. There are specific advantages, difficulties and challenges in each direction. The minimalism in waste management practice at sources might receive a high consensus from residents and commercial sectors. This might bring many favorabilities in the deployment and management of MSW system. Also, the mixture of waste might simplify the collection system (including bin system and truck) and reduce investment cost. Furthermore, the waste classification may become meaningless if separated waste was transferred to the

same place and treated by landfilling which is the typical disposal in developing countries. Thus, in term of short-term strategic planning to address the urgent problems of MSW system in the limitation of facilities, the minimalism in waste management practice is a timely strategy. However, the minimalism in WMP at source may bring many challenges to MSW system such as the overload of waste disposal and the unfavourability for treatment which are can be reduced by improving waste management practice at source. Moreover, the resonance activities in waste management practice may bring many benefits not only to stakeholders but also to the MSW system, which are the favourability toward sustainability.

4. Conclusions

This study shows that the minimalism in WMP by combining with improving recycling activities is a feasible solution for urgently handling the current problems in MSW system with a positive response from residents and stakeholders. However, the enhancement of WMP at source should be considered as a key factor in the long-term development of MSW system. This study proves that the optimal model of WMP at source (S4) is an appropriate planning strategy for developing MSW system toward sustainability in HAC, Vietnam. Notably, this strategy is estimated that it might contribute to reduce 29.3 % of waste generation amount and substantially enhance the recovery performance of recyclables (3.9 times). This model might bring many benefits to the MSW system such as minimisation of cost, favourability of waste characteristic for treatment, and mitigation of emission.

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