A study of solid waste generation from commercial and institutional sectors and its potential for recovery in Vietnam

「ベトナムにおける事業系廃棄物の発生及びその資源化ポテンシャルに関する研究」

PhD. Dissertation

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LIST OF ABBREVIATIONS AND ACRONYMS

HEPCO: Hue Urban Environment and Public Works State Limited Company

HSW: Household Solid Waste

MSW: Municipal Solid Waste

SWM: Solid Waste Management

GW: General Waste

SR: Separated Recyclable

SFR: Separated Food Residue

DWA: Direct Waste Analysis

HEPCO: Hue Urban Environment and Public Works State Limited Company

3R: Reduce, Reuse, Recycle

BC: British Columbia

Ave : Average

SD: Standard Deviation

WG: Waste Generation

ANOVA: Analysis of Variance

CI: Confidence Interval

VPM: Vietnam's Prime Minister

EPA: Environmental Protection Agency

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ABSTRACT

The amount of municipal solid waste (MSW) generated in Vietnam has been increasing in recent years. The rapid increase in MSW has posed significant challenges for Vietnamese solid waste management authorities. In addition, in 2015, the Vietnamese government issued a national strategy to manage waste and discarded material (Decree no. 38/2015/NĐ-CP), which indicated that daily-life solid waste must be classified and stored according to the following three categories: biodegradable organic, reusable and recycled, and "other". Determining the recyclable and organic amounts is indispensable for Vietnam's handling of waste in the years to come.

Currently, MSW management in Vietnam has been empirically planned without the use of reliable data, but it will include such data in the near future. Shortcomings in MSW data include inconsistencies in definitions and collecting data; lack of unification in reporting data among the municipalities; and differences in the amount of waste generated, which makes predicting trends difficult. It is important to understand the amount of waste generated, the waste composition, and the waste stream as the first step in developing an effective MSW strategy that includes 3R promotion (reduce, reuse, recycle). MSW is generated and discharged from various sources: households; commercial sources like hotels, restaurants, and markets; and institutional sources like educational facilities, medical facilities, and offices. In Vietnam, most studies have investigated the waste generation from resident area and very few studies considered on some categories of commercial and institutional sector.

To provide the scientific information that can contribute to the promotion of the 3Rs in a Vietnamese city, this dissertation aimed:

(1) To clarify the waste generation rate of various sectors by different business indicator (kg/unit/day);

(2) To provide the physical and detailed composition of waste in order to identify the recycling and composting potential;

(3) To explore the correlation between waste generation and relevant factors;

(4) To estimate the total waste generation in Hue, and contribution of commercial and institutional sector to total amount;

(5) To estimate the potential for recovery from general waste;

To estimate the interval estimation of the total waste in Hue, clarify the reliability of collected data and improve future tasks through uncertainty analysis.

The author conducted surveys for commercial and institutional sectors. Generally, the sample selection in this study was mainly based on the total list according to "The System of Economic Branches of Vietnam". The surveys conducted for 814 representative target samples in five markets, 95 beverage and restaurant sector, 35 educational facilities, 43 hotels, 245 home-based

businesses, 43 offices, 41 health-care facilities, 1 dormitory, 2 supermarkets in 5 months. This study was comprised of 3 surveys: waste generation survey, waste composition survey, and questionnaire survey.

Firstly, waste generation survey was conducted to acquire data on “General waste,” “Recyclables,” “Food residues,” for 7 consecutive days. During the waste generation survey, a waste composition survey was conducted for the selected samples. The waste was classified into 10 physical categories and 77 sub-categories. A questionnaire survey was also conducted by a face-to-face interview at the target samples to obtain data on relevant factors influencing waste generation such as business scale indicators, and the current status of recycling activities.

The waste generation ratesfor abovementioned commercial and institutional sectors (kg/unit/day) were calculated, and the interrelationships between the waste generation amount and the business scale indicators were analyzed. The influencing factors for waste generation were also explored, and the author developed the predictive models on waste generation.

Waste composition was analyzed and discussed in weight (g/day) and percentage (%). The potential for composting (food waste and garden waste), recycling (plastic and paper), and reducing waste (food residues) and financial potential in commercial and institutional sectors were identified.

The total waste generated in Hue was estimated to be 252.2 tons/day, of which 205 tons (80%) was general waste, 34.7 tons (13.5%) was recyclable, and 39.8 tons (16%) was food residues. General waste still contained 19.3% that could potentially be recycled and 102.4 % that could potentially be composted in the total waste amount. The total disposal amount sent to the landfill could be reduced from 205 tons (80%) to 27.1 tons (10.6%).

Regarding the commercial and institutional sectors, the total waste generated from commercial and institutional was 93.1 and 13.1 tons/day, respectively, of which 32.9 tons (31 %) wascollected by pig farmers for feeding livestock and 9.8 tons (10%) was sold to the recycling market and 63.3 (59%) tons was sent to the landfill site. The compostingpotential accounted for 23 % and the recycling potential accounted for 17% of total waste generationfrom commercial and institutional in Hue. By a Monte Carlo simulation, the interval estimation for total waste generation in Hue was simulated and estimated.

From the results of financial potential, the amount of recyclable recovering from general waste can earn 211 million VND/day, this also can create the job for 1,813 people with the basic salary is 3.5 million VND/month.

This is the first step for developing predictive models and total estimation of waste flow. Through these studies, it would be possible to develop predictive models on commercial and institutional waste generation, and they will support the waste authorities for prediction, planning, and establishing integrated solid waste management.

CHAPTER 1 INTRODUCTION

1.1 Research background

1.1.1 Overview of solid waste management

(1) Current situation of solid waste management

Waste is a continually growing problem at global, regional and local levels and one of the most intractable problems for local authorities in urban centers. With continuous economic development and improving living standards, the demands for goods and services are increasing rapidly, resulting in a commensurate increase in per capita waste generation (Narayana, 2008). In recent years, MSW management has attracted attention from bilateral and multilateral development agencies, due to the urgency of urban environmental problems and the increasing concern for capacity building at the level of municipal management. With its broad organizational implications and close links to other sectors, MSWM constitutes an important entry point for integrated urban management support (UNDP et al., 1996).

In every urban centre, huge quantity of solid waste is generated during various activities. These wastes are to be stored, collected, transported, processed, and disposed of in an environment friendly manner so as to keep the city neat and clean. In spite of incurred huge expenditure, the services provided to the solid waste management are not fulfilling the requirement, causing public health hazards and nuisance. Solid waste management is a large and vital public system spread over the entire city, area and the system is responsible for maintaining the public surroundings. Hence, the system has to be planned rationally for a long and short term (Gawaikar and Deshpande,2006).

As the first step to develop an effective SWM strategy for a given region, it is important to know the amount of waste generation, the waste composition, and the waste stream. The per capita waste generation rate is essential to predict future waste generation and to evaluate the waste generation trends (Bandara et al., 2007). Data on waste composition is required for the planning of collection, transportation, and treatment of MSW. Good data is the foundation of effective integrated waste management systems (Forbes et al., 2001).

However, it must be noted that, due to a lot of reasons, Vietnam in general and Hue city, have lacked a reliable database on SWM. Annually, Vietnam has a report on the state of the environment focusing on that year's prominent issue. Of all reports, only in 2004, SWM was paid much attention and became the main topic. The report, however, presented the information on physical composition of MSW around Vietnam and had not clarified the in-depth data of waste discharge flow and physical composition at various generation sources like households or business activities yet. As regards Hue city, Hue Urban Environment and Public Works State Limited Company (HEPCO) is the office in charge of the City's waste collection, transportation, and treatment. Up to now,HEPCO only surveyed on MSW composition in Hue city in 2004 (Yen, 2006).

Using unreliable data can lead to poor policy decision makings and the establishment of inappropriate waste management infrastructure (European Environment Agency, 2003). Therefore, urban authorities in developing nations, like Vietnam, should study on SWM, especially in waste generation and composition. These studies are not only the most suitable tool to support information on current situation and existing issues of waste management systems, but also the promotion of effective solutions for the current problems as well as the future planning.

(2) Current of methodologies on solid waste characterization

In Asia, MSW is commonly regarded as the waste that is generated from human settlements and small businesses, commercial and municipal activities. In other words, everything is collected and treated by municipalities (UNEP/ GRID-Arendal, 2006). It is categorized into two basic types: residential and non- residential wastes. For a particular area, the residential waste is almost uniform while the non- residential sector shows a variation, particularly the waste derived from institutions which have higher generation on weekdays and almost none during weekends and holidays. In contrast, the commercial sector has increased generation during weekends, holidays and festivals, and peak tourist seasons. However, in the case of industrial wastes, fewer changes in generation are noticed, unless the production capacity of the industry is increased and a particular category dominates the daily manufacture.

Table 1-3 shows the types of generators and corresponding waste categories. MSW in general does not include agricultural waste unless it is from small-scale units.

Regarding to the waste composition and quantification of MSW, Ireland (EPA, 1996) had formulated a methodology for household and commercial waste as follows:

- Waste analysis was carried out with three months interval. Sampling was avoided on Bank holidays, Christmas, Easter and Public holidays. To facilitate the sampling selection, it was suggested that social classes should be combined into three categories. For larger area, it was recommended to split the area into several small areas.
- The commercial sector was divided into four broad categories, namely, retail trade, wholesale trade, non-distribution and education. Total numbers of employees from the selected commercial areas were recorded so that the average weight of waste/ employee could be determined for each activity. In this case also, coning and quartering technique was adopted to reduce sample weight to 100 kg - 200 kg. After weighing and sorting the sample, picking out the large items such as glass, paper and plastic was done. The remaining material was passed through 20 mm mesh sieve and unclassified material was categorized as combustible and incombustible.

Table 1- 1.Sources and types of solid wastes in Asia (World Bank, 1999).

Source	Type of generator	Type of Waste
Residential	Single and multifamily units	*Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, white goods, batteries, oil, tyres), and household hazardous wastes*
Industrial	Manufacturing units, power and chemical plants	*Housekeeping, packaging and food wastes, ashes, construction and demolition debris, hazardous wastes, special wastes*
Commercial	Stores, hotels, restaurants, markets and malls	*Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes*
Institutional	Schools, hospitals, prisons, government offices	*Same as commercial*
Construction and demolition sites	New construction sites, road repair, renovation demolition sites	*Wood, steel, concrete, dirt, stones etc.*
Municipal services	Street cleaning, parks, beaches, and other recreational areas, treatment plants	*Street sweepings, landscape and tree trimmings, general wastes from parks, beaches, other recreational areas, sludge*
Processing	Heavy / light extraction andprocess units, refineries	*Process wastes, scrap materials, off-specificationproducts, slag, mineral tailings, unused raw materials*
Agriculture	Crops, farms, orchards, vineyards, dairies, feedlots	*Spoiled food wastes, crop and animal wastes, hazardous wastes (e.g., pesticides)*

Yu and Maclaven (1995) compared two waste streams quantification and characterization methodologies which contained direct waste analysis for determining the waste quantity and waste composition using a social science approach (questionnaire survey) for dealing with the same problem. The advantages and disadvantages of the method were described as follows:

- Direct Waste Analysis (DWA) involved the direct examination of waste set out for collection at point-of-generation or waste delivered to a waste processing facility or to a waste disposal site.
- In contrast to DWA, the questionnaire survey, methodology was normally restricted to collection of data at the point-of-generation, rather than at waste processing or waste disposal facilities. The methodology involved questionnaire survey for waste generators by means of face-to-face interview, mail or telephone surveys. Respondents were asked information based on the waste stream records and the visual inspection of waste containers about the quantity of waste discharged for disposal, the composition of waste, and the seasonal variation of waste generation.

Although various methods of waste quantification were discussed, the most common was the method of direct waste analysis. Many past researches on solid waste generation and composition applied this method. Although the direct waste analysis has some limitations such as high labor cost and errors in sample selection, it is still an appropriate method to determine MSW composition and determine the effect of spatial, temporal and socio-economical variations on waste composition. Besides, it provides a significant amount of information if combined a survey on factors affecting waste generation. Actually, there have been a lot of researches correlating socio-economic factors and solid waste generation (Bandara et al., 2007). In this literature review, some studies presented to see how the direct waste analysis was used. The direct waste analysis involves the actual quantification of waste through, sampling and weighing trucks as they enter a landfill or collecting samples from generators, and conducting waste audits and studies where samples are sorted by waste type and weighed. This method was selected because it can potentially provide data that is detailed and accurate.

British Columbia (1991) addressed the characterization of residential and commercial/institutional waste. The British Columbia (BC) manual recommended the use of a disposal site based approach and listed a number of advantages of this approach including:

1) It provides a better appreciation of the waste entering the landfill and ensures that a part of the waste stream is not overlooked;
2) It provides a better estimate of large and bulky items; and,
3) It is more cost effective.

The details of BC methodology were as follows:

- Sample Selection: the BC manual stated that vehicles from which samples were obtained should be chosen randomly with no bias towards morning or afternoon or, large and small loads. It recommended that the loads should come from the entire week, including weekends if possible. A systematic sampling methodology was recommended to select vehicles.

Each sub-waste stream (e.g. residential vs. IC&I, single family dwellings vs. multifamily dwellings, etc) studied was required to be considered separately. The BC manual described the use of the grid method for sampling waste from selected truck loads in order to ensure that the samples are obtained from random locations in the waste pile.

- Number of Samples: The BC manual provided a look-up chart for estimating the number of samples required based on the desired precision levels with 90% confidence and the coefficient of variation of the waste stream. The BC manual recommended a sample size of 136 kg after the removal and weighing of large and oversize items.
- Material Categories: The BC manual listed 15 main categories and 60 sub-categories. The manual recognized that depending on the goal of the study, fewer categories may be required.

Ontario Ministry of Environment (1991) recommended that the characterization of commercial waste should be based on sampling at the point of generation and included the following elements:

- Major groups of business sector were identified for study. In some cases general groups were desegregated to investigate the sub-groups within a group. The selection of the businesses included discussions with the operators and possibly site visits prior to sampling.
- Samples were collected a day prior to a scheduled pick-up. Some businesses were visited 3 or more times to collect a week's worth of waste. Two to three sites were sampled per day. Larger bins (6 – 8 cu. yd.) were only half sorted. The number of employees at the site was also recorded.
- Number and Size of Samples: the sampling involved the collection of one week of accumulated wastes from the selected businesses. The sample sizes varied from 2.4 to 5782 kg. The report recommended that number of samples and size of these samples should be determined taking into account the study's resource constraints (time and money).
- Material Categories: fourteen main categories and nearly 50 sub-categories of materials were defined in the study. The study recommended that, where an item composed of several materials is found; it should be classified on the basis of the predominant material by weight.

1.1.2 Overview of solid waste management in Hue city

(1) Location and social-economic condition

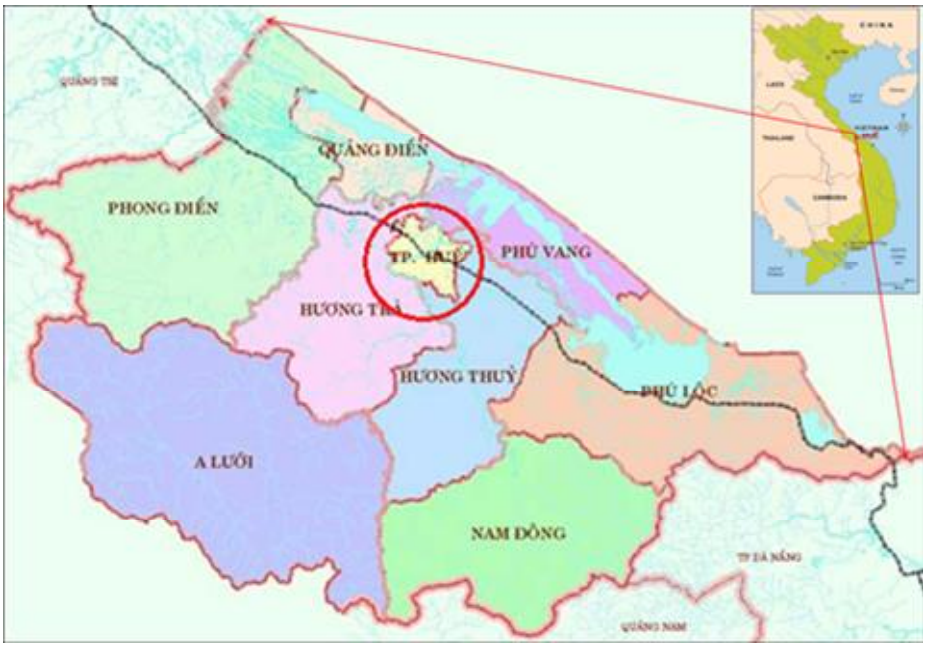

Figure 1-1. Location of Hue city, Vietnam

Hue city - the latest imperial capital of Vietnam under Nguyen dynasty is located in the central region of Vietnam, by the side of Perfume River, just a few miles inland from the East Sea. It is about 700 kilometers south of the national capital of Hanoi and about 1100 kilometers north of Ho Chi Minh City. The city has gone through 7 centuries of establishment and development. In 1802, Hue became Vietnam's capital when Emperor Gia Long, the first King of the Nguyen emperors, chose the location for the imperial city. The city remained to be the nation's capital until 1945. In the Vietnam War, Hue's central position placed it very near the border between North Vietnam and South Vietnam. Thanks to the long precious history, Hue has integrated material and spiritual values, which become its own unique special Culture. Hue is one of the main cultural, religious and educational centers of Vietnam. Architecture in Hue is the combination of royal architect, folk, religious ones, traditional and modern sides. Hue is also an important center of Buddhism. In Hue and the surroundings, there still exist tens of pagodas which were constructed more than 300 years ago, and a hundred of temples and pagodas built in the early century. Thanks to the historical values, Hue now is becoming an ideal destination not only for those who hope to enjoy lovely landscapes but also for those who seek cultural exchange opportunities of rich and lifelong history of education.

Hue is comprised of 27 wards with a total area of 71.7 km2 and a population of 342,556 as of 2011 [21]. Hue is well known for its historical monuments, which were deemed World Cultural Heritage sites on December 11, 1993, by the United Nations Educational, Scientific, and Cultural Organization (UNESCO). As a tourism center of the central Vietnam, Hue city considers tourism as a key economic sector. In 2008, Hue city got GDP growth rate of 13.7% with a GDP of $940 per capita. As a tourism center of the central Vietnam, Hue city considers tourism as a key economic sector. The tourism revenue in 2008 was 801.5 million VND, increased 35.5% in comparison with that in 2007 (Hue city Portal, 2010). The location of Hue city in Vietnam and Thua Thien Hue province was illustrated in.

(2) Climate

There are two distinct seasons in Hue city. The dry season, which comes with the hot south-west wind, lasts for four months, from April through to August.

The rainy season with high and unevenly distributed rainfall is from September to March. The annual rainfall ranges from 2,000–7,500 mm, with an average of 3,000–3,300 mm. About 80% of the total rainfall falls during this rainy season, the wettest months being November and December. Storms, floods, soil erosion and landslides are threats to the natural environment during this season (Thua Thien Hue Statistical Yearbook, 1999).

On the average, there are about 180 sunny days a year with an average temperature of about 280C during the hottest periods and 190C during the coldest months. Compared with other regions of Vietnam, Hue city in particular and the Central Coast in general, have inclement climatic conditions (Hue City Portal, 2010).

Table 1- 2. Waste composition atSWM facilities in Hue city

Unit:%

No	Typeof waste	Thuy Phuonglandfill site	Tam Sinh Nghia composting plant
1	Kitchen waste	77.11	78.03
2	Paper	1.92	2.12
3	Textile	2.89	2.74
4	Wood	0.59	1.09
5	Plastic	12.47	12.45
6	Leather and Rubber	0.28	0.56
7	Metal	0.4	0.31
8	Glasses	0.39	0.33
9	Ceramic	0.79	0.51
10	Stone and sand	1.7	0.71
11	Briquette coal	-	-
12	Dangerous	-	0.01
13	Diaper	1.46	1.13
14	Others	-	0.01
Total		**100**	**100**

(3) Current condition of MSWM in Hue city

Collection and transportation

MSW in Hue is managed by Thua Thien-Hue province. Hue Environment and Public Works

Company (HEPCO) is the only one state-owned company which engages in MSW collection and transportation in Hue city.

There are two collection methods applied in Hue.

- *Door-to-door collection by Handcart*: residents discharge waste on pavements, or in front of their houses. Then, collection workers use handcarts to collect on foot door-to-door in designed areas. When the handcarts are full, they are transported to designated transfer stations not far off where waste trucks transfer the waste and transport to the treatment or the disposal sites.
- *Dustbin collection by truck*: Dustbins are located in fixed points. Residents bring waste to discharge into those containers. Compactor trucks come to load waste from the containers directly and transport to treatment or disposal sites. Dustbin system has been applied since 1999 as a trial in three model areas. Since then, it has shown the advantages in sanitation improvement and been expanded to the whole area of Northern part of Huong river.

Waste generated from other sources such as small business units, commerce, institutions is collected by contracts with HEPCO. As regards waste from rivers, HEPCO has a special team with boats and tools to pick up waste. Hazardous medical waste is under the control of hospital (HEPCO, 2011).

c) Treatment and disposal

There are two facilities in Hue, one composting plant and one landfill site, located 15km far from the center of Hue city.

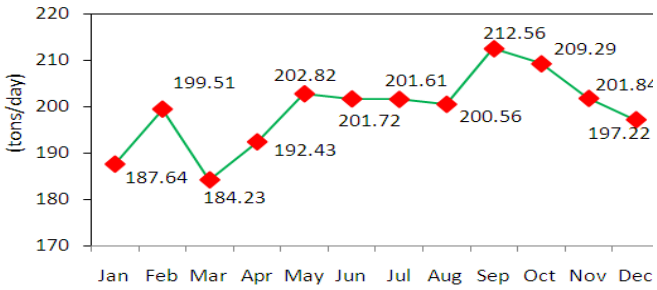

Figure 1- 2. Average waste collection amount (tons/day) collected by HEPCO (2011)

Table 1- 3. Outline of SWM facilities in Hue

No	Facility	Management Agency	Area	Remark
1	Thuy Phuong composting plant	Tam Sinh Nghia, JSC.,	4.2 ha	- Composting and recycling - Receiving: Around 200 tons/day - Compost product: 14 tons/day - Operation: 5 days/week (Closed on Saturday and Sunday)
2	Thuy Phuong landfill	HEPCO	10 ha	- Sanitary landfill - Receiving: around 200 tons/day - Operation: Receiving the residues from composting plant on weekdays, receiving all waste on weekends

(4) Remaining issues

As other urban areas in Vietnam and other developing nations, the present SWM system in Hue city is facing some difficulties. Firstly, as regards the waste collection and transportation service, there are many remaining issues. The waste collection rate in rural areas is still low. Secondly, the city has a waste treatment plant producing compost and other recyclable products from waste, but the city does not still have any separation-at-source activities. The experience from other countries show that, if the waste is properly separated at source, it will become useful items contributing to resource reservation as well as reducing pressure on waste treatment or disposal. Lastly, the citizen's perception toward SWM systems is also worth to mention. Although Hue city has daily waste collection services and a system of public dustbins along the street, there are still people who discharge waste by improper ways.

To plan an effective SWM system, it is necessary to collect data on waste generation and character. Waste characterization determines the type and proportion of materials discarded in a waste stream.Because the quantity and quality of waste is always changing, it is essential to conduct studies on waste generation and character continuously in order to make a systematic database serving for management and research task. Secondly, past researches have also shown that obtaining waste generation and composition data is essential for planning an integrated waste management system, since the source of waste will determine the collection method and strategy. Besides, once any particular waste item is identified what it is made of, it is easier to determine its suitability for material recycling (Forbes et al., 2001).

Lastly, concerning Hue city, 3R activities is highly suitable. Because Hue city has a small area and population, quite homogeneous waste stream, and an integrated waste treatment plant including a compost plant with plastic recycling factory and a landfill; the city has an advantage in planning and carrying out 3R activities

1.2 Objective of study

Design and operation of appropriate solid waste management systems are necessary for ensuring good sanitation and clean environment. The source specific solid waste quantification and characterization will be helpful in predicting the waste quantity from various waste generating sources in a city and this can be used as a basis for the planning of the system. This will also enable in saving of time, manpower, and financial inputs required to be spent for estimating the waste quantity for the entire city. Such a developed methodology can be very easily adopted by the municipal agency and would help them in managing the system in a befitting manner. Therefore, this study focused to achieve some objectives as follows:

1) To clarify the waste generation rate of various sectors by different business indicator (kg/unit/day);
2) To provide the physical and detailed composition of waste in order to identify the recycling

and composting potential;

3) To explore the correlation between waste generation and relevant factors;
4) To estimate the total waste generation in Hue, and contribution of commercial and institutional sector to total amount;
5) To estimate the potential for recovery from general waste;
6) To draw of waste flow in Hue city

1.3 Scope of study

The author surveyed the target samples for each component of commercial and institutional sectors composed of three surveys; a waste generation survey by actual measurement, a waste composition survey, and a questionnaire survey. All surveys were carried out simultaneously in dry season, from April 16th to September 25th. The components of research was presented in table 1-4

Table 1-4 Survey period of each category

Component	Category
Institutional waste	➢ *Educational facilities* ➢ *Healthcare facilities* ➢ *Office/Government office*
Commercial waste	➢ *Hotel* ➢ *Beverage and Food services* ➢ *Market & Supermarket* ➢ *Home-based business*

Based on the boundary of the study, the figure 1-3 presented the total schematic framework of entire research in this study.

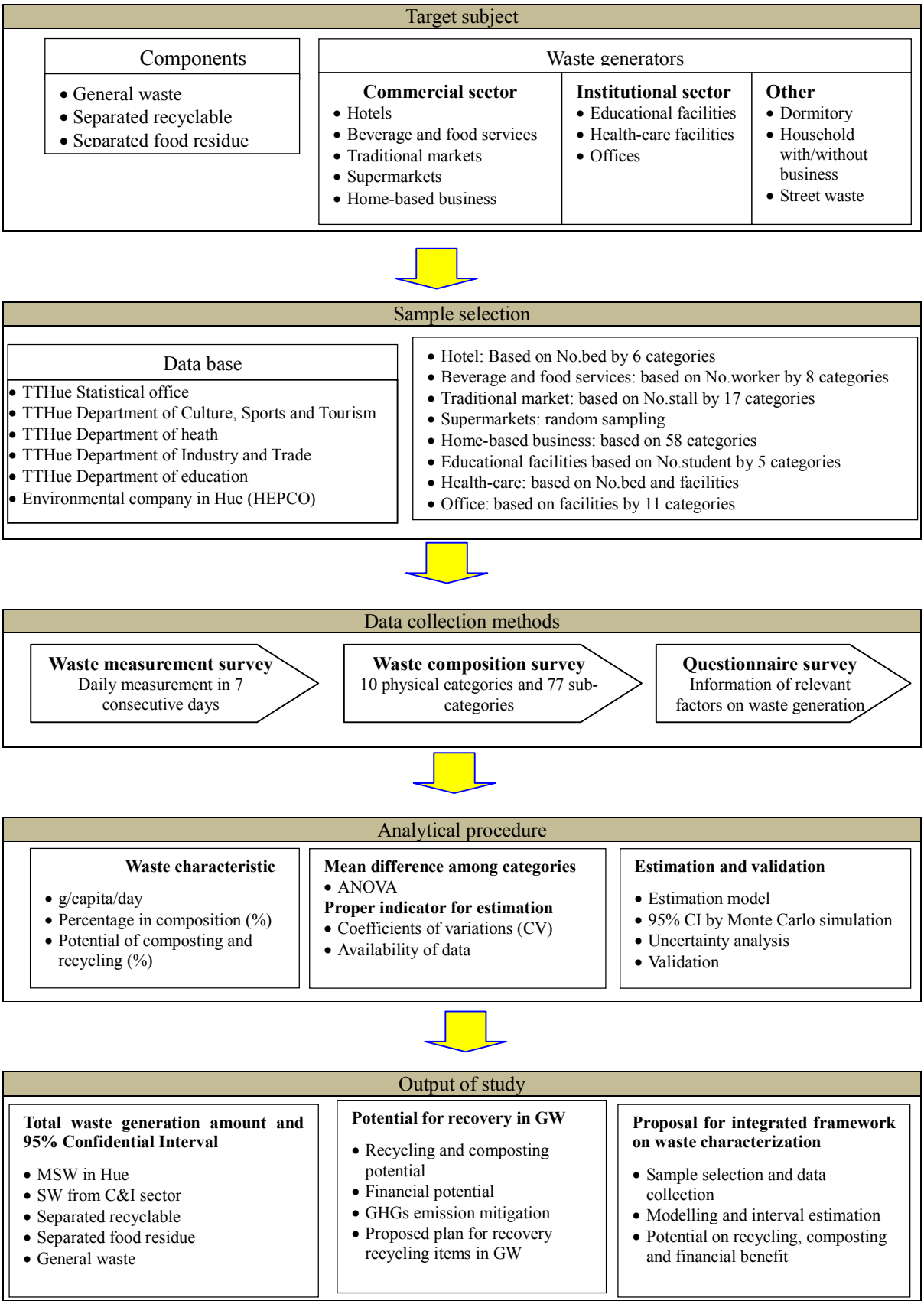

Figure 1_3 Schematic framework of entire research

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CHAPTER 2 SOLID WASTE GENERATION FROM COMMERCIAL SECTOR

2.1 Solid waste generation from hotel sector

2.1.1 Introduction

One of the challenges faced by waste management authorities is determining the amount of waste generation and characteristics in order to establish waste management systems. Everyday, a large quantity of solid waste is generated by various sources such as households, restaurants, markets, hotel and other business. Viet Nam consists of long coastlines, forests, and mountainous regions with numerous magnificent landscapes. As well, Viet Nam has a long history and diversified culture with variety of ancient architecture constructions, and wonderful legends. These factors have created a great potential for the tourism industry in Vietnam. In 2015, Viet Nam would welcome 7-7.5 million international tourist arrivals and 36-37 million domestic tourists with total revenue from tourism would reach US$10-11 billion, contributing 5.5-6% of GDP. In upcoming 2020, Viet Nam expected to receive 10-10.5 million international arrivals and 47-48 million domestic tourists; total revenue from tourism would reach US$18-19 billion, contributing 6.5-7% of the country's GDP. To meet the growth of international and domestic tourists, a lot of accommodation establishments have built in recent years. In the "*Strategy on Viet Nam's tourism development until 2020, vision to 2030*", the prime minister of Vietnam mentioned total accommodation suites would be 580,000 and 35-40% of which are of three to five-star standards (Decision 2473, 2011). The increasing number of accommodation establishment leads to the expansion in so many service sectors as well as their management operations, especially solid waste management.

Tourism is one of the activities that depend heavily on the environment (*Ishmael.,2005*). The hotel industry is one of the major contributors of organic/wet waste in landfills, which is the main cause of Green House Gas emission (*Nripendra et al., 2014*). Commercial sector, which hotels represents a large part, accounts for 35% to 45% of the municipal waste stream (*Franklin Associates,1999)*. Recently, *Otoma et al., 2012* found that the hotel sector contributed 9% of total municipal solid waste in Danang city, Vietnam. The literature revealed that the proper management of waste can lead to higher profitability for hotel and save environmental pollution (*Nripendra et al., 2014*). To develop an effective strategy for waste management, it is important to know the amount of waste generation, the waste composition, and the waste stream (*Bandara et al., 2007*).

There were several studies on hotel sector in the past literature. Two approaches are generally

adopted for estimating waste quantity and composition. Either questionnaires are sent to the producers of the waste, or a direct waste analysis of the waste stream is carried out at the point of waste production or at the waste treatment facility (*Yu and Maclaren 1995*). By the questionnaire method, in 2000, *Trung et al* conducted a survey in 37 hotels in nine major tourist provinces. The results showed the waste generation rate by guest at different hotel classes in different areas of Vietnam. However, the information on waste amount by questionnaire may not be reliable because the data much depends on the people who answered the question. By direct waste analysis, *Byer et al, 2004* conducted a survey in Halong, Vietnam on three hotels including 2-star, 3-star and 4-star hotel during one week. The study showed the generation rate by room, guest and composition on 9 physical categories with percentage of organic waste, inorganic waste and recyclable. This study, however, is limited by small sample size. Regarding estimation of total waste from hotel, Otoma et al, 2012 showed the estimated waste amount from hotel in Danang by number of room. Nevertheless, this study only showed the waste generation rate by hotel without consideration of hotel class that was proved significantly different in study of *Byer et al, 2004*. In hotels, the staff normally attempt to collect recyclables for sale and to give left over food waste to farmers for animal feeding (*Byer et al., 2006*). The recyclable amount and leftover food, thus, should be controlled to reflect the actual amount of waste generation from hotel. To date, there are no studies on solid waste generation on hotel sector in Vietnam considered the factors affecting waste generation, the amount of recyclable and amount of food. Furthermore, according to Vietnam's national strategy on management of waste and discarded material in 2015 (*Decree no.38/2015/NĐ-CP*), the daily-life solid waste must be classified and stored as the following groups: *biodegradable organic group,reusable and recycled group, the other group*.Therefore, determining the recyclable and organic amount is extremely important for Vietnam in years to come.

Predictive model on solid waste management is an essential tool for the waste planning and management. Model contributing to the improved estimation of present and future waste quantities and characteristics are aimed at enabling the best possible waste management planning decisions within the given constraints (*Beigl et al., 2008*). While many studies focused on modelling of household waste generation (*Benitez et al., 2008; Thanh et al., 2010; Lindh, 2003; Lebersorger et al., 2003*) or modelling on municipal solid waste in general (*Chang and Dyson., 2005; Daskalopoulos et al., 1998*), there were few studies on commercial sector. In 2000, *Salhofer et al* developed a model of businesses on 14 sectors for recyclabes, sector-specific wastes and residual waste using the number of employees. The results showed the total waste amount by 3 above-types on 14 sectors and revealed the differences between

large business and small/medium businesses. This study, however, did not focus detail on each sector, for example, they put the tourism and gastronomy together in one category without consideration of the differences in sector or detail business size. In 2012, *Kato et al* developed models on food residues recycling by swine breeders in Danang, Vietnam. From the model, the study had estimated the total food residue collection by swine breeder in Danang, but had not paid much attention of collection source.

Hue city is a tourism city, the authors decided to choose Hue city as a study area on determining the waste generation from hotel sector. In 2014, the government approved the plan of Hue to 2030 and oriented to 2050. In which, Hue city aimed to become a city that is friendly with environment and in harmony with nature (*Decree No.649, 2014*). Integrating the informal sector to formal sector in waste management is an important option to consider when attempting to create a sustainable city in developing countries (*Baud et al,. 2001*). Accurate data, concerning estimates of present and future production and composition of different types of waste, is essential for long-term efficient and economical waste management planning (*Pault, 2005*). As the first step to develop an effective SWM strategy in hotel, it is important to know the waste stream of hotel sector to predict future waste generation and to evaluate the waste generation trends. This study aims to clarify the parameters which help to understand the current situation of WG and to assess the future waste amount at hotel sector. The objectives of this study was to estimate the potential of recycling, composting of waste from hotel sector, to develop the predictive model on waste generation to estimate the total waste flows on hotel sector in Hue. Furthermore, the interval estimation of total waste amount and potential amount also estimated.

2.1.2 Methodology

2.1.2.1 Sample selection

Hue city, the city of Thua Thien Hue province situated in the center of Vietnam was selected as the study area. Hue city comprises 27 wards with 342,556 people and a population density of 4,779 persons per km^2. Hue is well known for its historic monuments, which have earned it a place in UNESCO's World Heritage Sites. As a tourism center of the central Vietnam, Hue city considers tourism as a key economic sector. The number of tourist arrivals in Hue has continued to rise in recent years. In

Table 2- 1Thetotal hotels in Hue

Category	Hotel	Room	Bed	Sample size
Guest house	242	2049	3214	8
1-star hotel	46	874	1643	10
2-star hotel	26	943	1832	7
3-star hotel	10	708	1319	8
4-star hotel	9	1231	2235	7
5-star hotel	4	648	990	3
Uncategorized hotel	65	1309	2427	-
Total number	402	7762	13660	43

2014, Hue city received 1.84 million international and domestic tourists that were a 5.6% increase from 2013 (Hue city, 2015). Regarding solid waste management, the amount of collected waste in Hue city is reported as approximately 210 tons/day. The general collection rate in the whole city was about 89%, and 90–95% in urban areas (HEPCO, 2012). Hue city has 402 hotels with different scales that are classified into 6 classes in considering 'the Decree TCVN 7799:2009 on the standards of tourist guest house' [3] and 'the Decree TCVN 4391:2009 on Hotel classification' [4]. Table 2-1 showed the total hotel in Hue by class and the sample size of targets in this study. Among them, 4 hotels belong to the 5-star hotel, 9 hotels belong to 4-star hotel, 10 hotels belong to 3-star hotel, 26 hotels belong to 2-star hotel, 46 hotels belong to 1-star hotel and the total guest house was 242. Moreover, there were 65 uncategorized hotels that might lack of some criteria to be certificated by authority. For simplicity, in this study, "Hotels" refers to both "Hotels" and "Guest house".

To acquire an accurate representation of hotels by size, the random sample of hotels was stratified according to 6 abovementioned hotel classes, ranging from guest house to 5-star hotel. Based on the total number of bed on each hotel class, the total list of hotel by class was prepared and sorted by number of bed. Then, the 43 target samples were selected systematically from the list. The number of samples by hotel class and separation status of hotel was shown in the Table 2-2.

Three types of waste generated were measured based on the original customs of target. *'Recyclables'*, *'Food residues'* and *'General waste'* defined as follows:

- *Recyclables*: items kept for recycling or sale to informal sectors or given to somewhere/someone by owners.
- *Food residues*: waste items kept for livestock (e.g. pigs) feeding; generally collected by livestock breeders.
- *General waste*: all remaining waste items excluding separated waste items described above. This type of waste is collected daily by an environmental company in Hue (HEPCO).

From Table 2-2, the survey also indicated that a majority of hotels engaged in recycling activity. There were 41 of 43 target hotels participated in some form of recycling, which is contrasted with the 2 of 43 hotels did not participate in any recycling activity. Of total hotels, most of hotels in 3-star, 4-star and 5-star class had separation of both recyclable and food residue (hereinafter referred to as "R&F Separation"). However, in the "*lower class*", the separation status was different. There was 86% of 2-star hotel having separation for both (recyclable and food residues). The rest 14% separated for recyclable only. Regarding the 1-star hotel, 40% hotel having separation for both, 30% separated

recyclable only, 20% separated for food residues only and the rest part (10%) did not separate waste in 3 parts. Regarding the guest house, due to no food service at this category, all of guest house did not separate food waste. 88% guest house separated recyclable only and 12% having no separation The recycling inactivity of this group was explained by the fact that recyclable or food residues amount were too small or it due to the time consuming, storage place and behavior of manager and staff at hotel.

2.1.2.2 Outline of survey

Table 2- 2 Waste separation status at the target samples

Hotel class		N	R&B Separation	Recyclable Separation	FR Separation	No Separation
Lower class	Guest house	10	1	7	1	1
	1-star hotel	10	4	3	2	1
	2-star hotel	7	6	1	-	-
Higher class	3-star hotel	8	8	-	-	-
	4-star hotel	7	7	-	-	-
	5-star hotel	3	3	-	-	-

R&B separation refers to hotels have separated both recyclable and food residue
Recyclable separation refers to hotels separated the recyclable only
FR separation refers to hotels separated the food residue only
No separation refers to hotels didn't engaging separation activity

The procedure of waste generation survey followed the methodology by *Matsui et al.* (2014). The authors conducted three surveys for all target samples: a waste generation survey by actual measurement, a waste composition survey, and a questionnaire survey. Surveys were conducted during 2-11 June, 2012. The waste generation survey was administered to acquire data on the amount of waste generation for 10 consecutive days. Of them, the first three days were spent for practice; the authors used the data for the latter seven consecutive days.

A waste composition survey was also conducted during the survey period. To provide information related to the recycling and composting potentials, the authors analyzed details of the waste composition of 'General Waste' for some representative targets. The waste was classified into 10 physical categories and 77 sub-categories. Descriptions of waste classification categories as well as potential for recycling and composting are presented in Table 2-3. The authors also conducted a questionnaire survey to assess attributes and the current status of hotel sectors in Hue.

By observation in study on hotel scale and service, the authors categorized 6 hotel classes into 2

categories: "*Lower class*" guest house, 1-star hotel and 2-star hotel and the remained classes belong to "*Higher class*".

In the "*Higher class*", most of hotels have large number of room (50 rooms or more) with a lot of services such as restaurant, bar, spa and meeting room to organize the events. In the "*Lower class*", normally the number of room is smaller than that of "higher class", some hotels have restaurants while some did not had. Most of hotels in this category did not organize the event due to the limited space excepting some special cases.

In our study, some target samples separated waste into 3 types: general waste, recyclable and food residue. On the other hand, some separated recyclable only, some separated food residue only while some did not separate recyclable and food residues. Most of hotels in "higher class" separated waste in 3 above-mentioned types while the hotels in the "lower class" had different styles in separating waste.

2.1.2.3 Analytical procedure

The authors calculated basic statistics related to waste generation rates by some indicators such as hotel class, number of room, number of check-in guest and number of staff. The authors also assessed the mean difference among hotel classes using analysis of variance (ANOVA) to check the differences

Table 2- 3. Classification category of waste from hotel

Category	*Code*	*Details*	*Recycling potential*
1. Plastic			
Container & Packaging	*101*	PET bottle	Re
	102	Other plastic bottle	Re
	103	Tray	Re
	*103**	Tray	NRe
	104	Tube	Re
	*104**	Tube	NRe
	105	Other shape	Re
	*105**	Other shape	NRe
	106	Shopping plastic bags	Re
	107	Other plastic packaging	Re
	108	Other *C&P* (e.g.: buffer)	Re
	*108**	Other *C&P*	NRe
Product	*109*	Plastic product	Re
	*109**	Plastic product	NRe
Other plastics	*110*	Other plastics	Re
	*110**	Other plastics	NRe
2. Paper			
Container & Packaging	*201*	Carton	Re
	202	Containers	Re
	203	Cardboard	Re
	204	Packaging	Re
	205	Other *C&P*	Re
Product	*206*	Newspaper/poster	Re
	207	Books	Re
	208	Notebooks	Re
	209	Photocopy	Re
	210	Disposal paper products	NRe
	*210**	Nappies/Diapers	NRe
	211	Other paper product	Re
	*211**	Other paperproduct	NRe
Other Paper	*212*	Other Paper	Re
	*212**	Other Paper	NRe
3. Kitchen waste			
Compostable	*301*	Kitchen waste	Co
Non-compostable	301*	Coconut/Durian shells	NRe
	302	Hard bones of animal	NRe
4. Rubber and leather			
	401	Rubber and leather	NRe
5. Grass and wood			
Garden waste	*501*	Garden waste	Co
	*501**	Garden waste	NRe
	502	Flower	Co

Category	*Code*	*Details*	*Recycling potential*
5. Grass and wood			
Container& Packaging	*503*	Containers & packaging	Co
	*503**	Containers & packaging	NRe
Product&Other	*504*	Grass and wood products	Co
	*504**	Grass and wood products	NRe
6. Textile			
	601	Clothes	Re
	602	Daily commodities	NRe
	603	Disposed commodities	NRe
	604	Other product	Re
7. Metal			
Aluminum	*701*	Containers	Re
	702	Other containers and packaging	Re
	*702**	Other containers and packaging	NRe
	703	Products and others	Re
	*703**	Products and others	NRe
Steel	*704*	Containers	Re
	*704**	Containers	NRe
	705	Other containers and packaging	Re
	706	Products and others	Re
Stainless	*707*	Products and others	Re
Lead	*707**	Products and others	NRe
Other metals	*708*	Other metals	Re
	*708**	Other metals	NRe
8. Glass			
Container	*801*	Returnable bottle	Re
	802	Disposal bottle	Re
	803	Other containers	Re
Products and others	804	Thermometers,Fluorescent	NRe
	805	Products and others	NRe
9. Ceramic			
	901	Containers	NRe
	902	Products and others	NRe
10. Miscellaneous			
	1001	Combustibles	NRe
	1002	Liquids_ edible	Re
	1002	Liquids _ inedible	NRe
	1003	Incombustibles (excluding ash)	NRe
	1004	Ash	NRe
	1005	Medical care (syringe, needle,	NRe
	1006	Batteries	NRe
	1007	E-waste	NRe
	1008	Others	NRe

[a] *Re, Recyclable; Co, Compostable; NRe, Non-recyclable & non-compostable item.The recycling potential of each item was defined based on reports from two junk-shop owners. The compostable item and non-compostable item weredefined based on the acceptable items in some composting plants.*

among hotel class. Moreover, the important variables that affect the quantity of waste generated from the hotels have been identified.

In this study, the authors developed predictive models for waste generation amount (WGA) on general waste, separated recyclable, separated food residues and total waste amount using the multiple regression analysis. The potential of recycling and composting that still remains in general waste was estimated based on the general waste amount and percentage of recycling part and composting part from composition survey.

By a Monte Carlo simulation, the interval estimation for total waste generation in Hue in 2012 and 2020 was simulated and estimated. The Uncertainty analysiswas conducted to evaluate the effects of each parameter on the total waste amount.

2.1.3 Results and discussion

2.1.3.1 Total waste amount by hotel class

The authors calculated and analyzed the measured data over 7 consecutive days. The averages of total waste amount for each hotel class were calculated by the average of each hotel in the same class. The standard deviation was also considered to show how the individual data of each hotel vary around the mean of hotel in the same class. The table 2-4 summarized the total waste amount by 6 hotel classed with mean, standard deviation and ANOVA results.

Table 2- 4Total waste generation amount of hotel by day (kg/day)

Class		n	Mean	Standard deviation	ANOVA F
Lower Class Hotel	Guest House	10	5.25	3.25	76.96***
	1 star Hotel	10	7.81	4.89	
	2 star hotel	7	29.43	18.84	
Higher Class Hotel	3 star hotel	8	68.75	36.72	
	4 star hotel	7	190.49	57.3	
	5 star hotel	3	271.75	13.49	

**p<0.05, ** p<0.01, *** p<0.001*

The ANOVA results showed that there was a significant difference among 6 hotel classes ($p<0.001$). The reason for that difference is the fact that the services, scale and area were so different among hotel classes. Hence, it is important to discuss waste generation rate of hotel class. This finding also suitable with some previous studies that also discuss on waste generation rate by hotel class. For instance, the study on hotel sector in Halong, Vietnam by Byer *el at* (2006) chose the target samples of hotel by hotel rating such as 2-star, 3-star, 4-star hotel. And another study by Trung *el at* (2003) discussed the waste generation rate by 4 hotel categories (4-star, 3-star, 2-star and resort).

Interestingly, there was a link between the rating and the waste generation amount. Since the higher rating hotels have tendency to produce higher waste generation amount. In which, the total waste

generation amount of 5-star hotel was considerably high with 271.75 kg/day, followed by 4-star hotel (190.49 kg), 3-star hotel (68.75 kg), 2-star hotel (29.43 kg), 1-star hotel (7.81 kg), and the lowest amount of 5.19 kg was from guest house.

These differences can be due to most of the hotels of "3-star hotel", "4-star hotel" and "5-star hotel" have food services such as restaurants and coffee shops/bars that serve foods and drinks for

Waste type	Number of room	Number of bed	Number of Check-in Guest	Number of event guest	Number of staff
Total waste	.863***	.811***	.584***	.713***	.863***
General waste	.811***	.762***	.517***	.698***	.840***
Recyclable	.707***	.650***	.527***	.511**	.692***
Food residues	.812***	.780***	.643***	.764***	.789***

breakfast, lunch, and dinner. These services were randomly appeared at "2-star hotel" and rarely at "1-star hotel". The author could not find any restaurant services at guest house in survey. The result of 4-star hotel in this study was similar with the result of study in Halong for 4-star hotel with 203.3 kg/day, and significantly lower than the amount for 3-star hotel (114.3 kg/day) and 2-star hotel (89 kg/day) of survey in Ha long [2]. However, the sample size in their study was too small with 1 sample at each hotel class, so it is difficult to compare the result of 2 studies.

The SD was very small at 5-star hotel class while that of 4-star, 3 star, 2 star, 1 star hotel and guest house were relatively large, respectively. It revealed that the slightly difference of average of total waste among 5 star hotels and the fluctuation among hotels in the other hotel classes.

2.1.3.2 Relevant factor influencing waste generation amount

To interpret the relationship between the waste amount of general waste, separated recyclable, separated food residues and total waste (4 waste categories) with relevant factors such as hotel class, number of room, net-sale, number of bed, staff, check-in guest and event guest, various statistical analysis procedures were employed. Table 4 showed the correlation of 4 waste categories with the above-mentioned factors.

The Pearson correlation was used to check the correlation between waste generation rate with some relevant factors such as number of room, number of bed, number of check-in guest, number of event guest and number of staff. The analyses were implemented by 4 waste types: general waste,

recyclable waste, food residues and total waste.The results indicated that significant differences were found in most of waste types and relevant with strong significant ($p<0.001$) except the correlation between recyclable waste with number of event guest with $p<0.01$. The results also revealed that the number of room, bed, staff, event guest and check-in guest were affected to the amount of general waste, recyclable, food residues and total waste.

2.1.3.3 Daily waste generation rate by category

Table 2-6 showed the detail waste generation rate by room, check-in guest and staff on total waste, general waste, separated recyclable and separated food residues.

The average amount of waste generation rate was still highest at 5-star hotel with 1.61 kg/room/day, followed by 4-star (1.46 kg/room/day), 3-star (1.16 kg/room/day), 2 star (0.76 kg/room/day). The waste generation rate by hotel at 1-star hotel was higher in guest house but the waste generation rate by room at 1-star hotel (0.39 kg/room/day) was less than guest house (0.48 kg/room/day). The difference in result may be due to the number of room in 1-star is larger than in guest house and the number worker, one of some factors affecting to waste generation rate, in 1 star hotel is also higher in guest house.

Table 2- 6 Daily waste generation rate by category

Category	N	Total waste		General waste		Recyclable		Food residues	
		Min-Max	Mean	Min-Max	Mean	Min-Max	Mean	Min-Max	Mean
Waste generation rate by room (g/room/day)									
Guest house	10	196-1127	534	117-1032	398	0-95	42	0-560	95
1-star hotel	10	175-717	389	140-478	294	0-95	35	0-155	61
2-star hotel	7	291-1165	757	250-575	415	26-96	45	0-653	297
3-star hotel	8	563-1998	1155	258-904	606	2-86	42	241-1012	507
4-star hotel	7	972-2200	1455	531-1240	769	39-147	86	356-822	600
5-star hotel	3	1197-2151	1607	685-1560	995	48-122	85	407-666	526
Waste generation rate by check-in guest (g/guest/day)									
Guest house	5	361-775	557	89-633	389	0-63	32	0-392	137
1-star hotel	4	465-717	594	321-717	484	0-73	35	0-155	75
2-star hotel	4	312-639	485	236-385	283	16-44	26	0-321	176
3-star hotel	7	782-2009	1335	425-1036	713	27-58	48	298-992	575
4-star hotel	6	1520-2558	1897	627-1560	1023	82-181	120	594-900	754
5-star hotel	3	2012-7969	5538	935-4939	3562	166-317	249	910-2713	1727
Waste generation rate by staff (g/staff/day)									
Guest house	10	992-6377	2133	245-5593	1744	0-784	216	0-932	172
1-star hotel	10	395-1238	793	331-973	604	0-165	67	0-466	122
2-star hotel	7	582-2562	1392	414-1417	756	30-164	82	0-1437	555
3-star hotel	7	882-1860	1403	516-1012	738	29-111	53	303-843	611
4-star hotel	7	665-1707	1151	405-962	606	25-114	68	234-702	476
5-star hotel	3	1063-1401	1263	652-961	757	42-116	70	311-634	436

2.1.3.4 Waste composition, potential of composting and recycling

Table 2-7 presented the hotel waste composition (in percentage) of general waste by 10 physical categories. It was revealed that food waste accounted for the largest proportion in all hotel categories. That proportion of food waste was the highest in 5 star hotel (56.6%), followed by 3 star hotel (54.6%), guest house (49 %), 1 star hotel (47.0%), 4-star hotel (43.6%) and 2 star hotel (41.7%). Another study on hotel in Danang conducted by Otoma et al. (2011) found that 65.5% of waste was food waste. However, it is unfeasible to compare two studies because the target hotels in 2 surveys were different. The composition result also showed that paper was the second largest ranging from 10.1% (5-star hotel) to 25.4% (1-star hotel), followed by plastic ranging from 10.1 % (3-star hotel) to 15.5% (guest house).

Table 2- 7Physical composition of hotel (%)

Physical	Guest	1-star	2-star	3-star	4-star	5-star
Plastic	15.5%	12.5%	11.1%	10.1%	11.6%	12.5%
Paper	17.5%	25.4%	15.6%	14.1%	20.2%	10.1%
Food waste	49.0%	47.0%	41.7%	54.6%	43.6%	56.6%
Rubber &	0.1%	0.2%	3.4%	0.4%	0.2%	-
Grass & Wood	2.8%	7.2%	9.7%	11.4%	6.7%	7.0%
Textile	2.9%	2.9%	7.1%	2.0%	4.1%	0.9%
Metal	0.9%	0.2%	1.8%	0.9%	0.4%	0.3%
Glass	3.9%	1.4%	3.5%	0.5%	1.4%	1.1%
Ceramic	1.3%	-	-	0.5%	0.6%	7.4%
Miscellaneous	6.1%	3.2%	6.1%	5.5%	11.1%	4.2%
Compostable	52.3%	47.7%	41.1%	62.2%	50.7%	65.4%
Recyclable	28.9%	28.3%	29.8%	17.0%	20.5%	12.4%
Other residue	18.8%	24.0%	29.1%	20.8%	28.8%	22.2%
Contribution of components in recyclable part						
Plastic_C&P	36.0%	30.5%	24.9%	45.3%	34.3%	36.6%
Plastic_product	8.2%	4.7%	5.3%	5.8%	6.9%	9.2%
Plastic_other	-	2.7%	2.6%	-	2.7%	0.1%
Paper_C&P	23.4%	35.3%	13.5%	25.8%	19.8%	26.7%
Paper_product	6.1%	11.8%	11.8%	4.8%	6.5%	5.3%
Paper_other	4.4%	3.6%	5.3%	1.8%	4.1%	8.0%
Other material	21.8%	11.4%	36.7%	16.5%	25.7%	14.2%
Contribution of components in compostable part						
Kitchen waste	92.0%	79.5%	63.3%	80.6%	83.9%	86.5%
Garden waste	3.9%	15.0%	22.9%	17.4%	12.8%	10.5%
Other item	4.1%	5.5%	13.7%	2.0%	3.3%	2.9%

C&P: container and packaging

Although the hotel sector in Hue city was doing recycling intensively by informal sector such as recycling market and livestock breeders, the large amount of compostable and recyclable parts were still remained in general waste. Because recycling activities were only performed on the material that easy to be separated, the items that were small and other organic waste were often put into general waste to discharge. Table 2-7 also presented waste composting and recycling potentials from general waste by hotel class according to the definition shown in the Table 5. It is apparent that the composting potential was very high in most of categories, especially at 5-star hotel (65.4%) and 3-star hotel (62.2%). The recycling potential was highest in the 2-star hotel with 29.8% followed by guest house (28.9%) and 1-star hotel (28.3 %), This results were similar with the study of Byer et al., 2006 and Otoma et al., 2013 in having high percentage of compostable.

The composition suvey also showed which components have largest contribution to the

recyclable part and compostable part in general waste.

2.1.3.5 Predictive model of waste generation from hotel sector in Hue

The authors assumed that total waste amount of hotel waste divided in 3 parts: waste generated from check-in guest who stayed in hotels, waste generated from event activity (i.g. wedding party or conference) and waste from other services at hotels (i.e. Spa, restaurant, bar, staff, etc)

Among those factors showed in the table 2-5, the authors chose the number of room, number of check-in guest and number of event guest as indicators for predictive model, because total number of these indicators was available in Hue city.

Regarding the "*Higher class*", most of hotels in this class normally hold some events, so the model for this category was developed by number of check-in guest, room and event guest. Regarding the "*Lower class*", there were rarely cases having events. So the author assumed that there were no event guest in this category, and the model for waste generation amount in this category was developed by

Table 2- 8Predictive model of waste generation

Class	Items	Separation	Room	Check-in Guest	Event Guest	R^2
Lower class	General waste	(1) R&B separation	173.3**	144.3**	-	0.86***
		(2) Recyclable separation	278.7***	-	-	0.692***
		(3) FR separation	159.1***	-	-	0.902***
		(4) No separation	425.7***	-	-	0.924***
	Separated Recyclable	(5) R&B separation	52.6***	-	-	0.875***
		(6) Recyclable separation	-	63.4***	-	0.958***
	Separated Food residue	(7) R&B separation	-	209.9***	-	0.872***
		(8) FR separation	75.3*	90.7*	-	0.834***
Highercla ss		(9) General waste	530.3***	194.7***	313.5***	0.904***
		(10) Recyclable	62.5***	23.8*	27.7*	0.737***
		(11) Food residue	356.5***	231.3***	223.0***	0.850***

*$p<0.05$; **$p<0.01$; ***$p<0.001$

number of room and check-in guest. The results of multiple regression analysis for general waste, separated recyclable and separated food residues are shown in the table 8.

Regarding "*Lower class*", the author developed the models of general waste for 4 cases: R&B separation, recyclable separation, FR separation and no separation. Results indicated that significance was found at all models. In the equation 1, the amount of total waste is possibly correlated with the number of room ($p<0.001$) and number of check-in guest ($p<0.001$). The R-square value of model 1 is

0.86, meaning that the abovementioned two variable explain about 86% of the variation of total waste amount. The result of this model showed that, on average, each room generate 182.2 g total waste per day and each check-in guest generate 208.0 g total waste per day

In the equation 2, there were significant correlation between general waste and number of room ($p<0.01$). The coefficients of determination R-square is quite high, around 89%. The results of this model showed that everyday each room generated 278.7 g general waste.

The equation 3 showed that the GW only correlated with number of room ($p<0.001$). The R-square value in this model is relative high with 0.92. Similarly, the model on food residues and recyclable also showed the correlation and the R-square in that table.

Regarding "*Higher class*", the results showed that 4 models had the correlation between 4 types (GW, SR, SFR) and almost predictor variables (number of room, number of check-in guest and number of event guest). The equation (9), (10) and (11) showed the model to predict the waste amount of GW, SR, SFR, Respectively.

2.1.3.6 Estimation of total waste generation from hotel sector

To draw the waste flow of solid waste generation from hotel sector in Hue in 2012, the estimation of waste generation was applied. At first, the authors estimated the total amount of general waste, separated recyclable and separated food residue. Then, using the results of composition survey with the estimated general waste amount, the authors estimated the potential of composting, recycling and other residue in general waste. With the estimated results of 5 components: recyclable, food residues, potential of composting, potential of recycling and other, the author draw the waste flow of waste generation amount from hotel sector in Hue.

The detail procedure such as definition of 5 components, calculation base for estimation and method of estimation was shown as follows:

Table 2- 9 Total number of room, check-in guest and event guest in Hue city in 2012 and 2020

Items	Year	Lower class	Higher class	Calculation base
Total room	2012	4650	3112	The total number of room for "*Lower class*"was 3,866, that for "*Higher class*" were 2587, and that for uncategorized hotels was 1309. For uncategorized hotels, the author allocated the number of room according to the ratio by Hue statistics in 2012 (lower class : higher class = 4:6)
	2020	17177	11494	Total room in Hue province in 2020 was estimated is 34,748. The contribution of total room in Hue city to Hue province in 2012 was 82.5%. The author used this ratio to calculate the total room of hotel in Hue city
Total check-in guest/day	2012	5543	3426	Total number of check-in guest/year in Hue province in 2012 was 3,343,711, and the contribution of Hue city was 97.9% in Hue Province. The check-in guest/night in Hue city was estimated as 3,343,711*97.9%/365=8,970. The total number of guest by hotel class was allocated according to the abovementioned total number of room.
	2020	13137	8791	The total guest in Hue province per night in 2020 was estimated is 8,174,200. The number of guest class was allocated by using the similar ratio with 2012 case
Total Number of event guest/day	2012	0	572	Event guests were only found at higher class. The total number of event guest was calculated based on the percentage of number of event guest to check-in guest (16.7%) from the survey result.
	2020	0	1468	

Component	Items	Lower Class				Higher Class
		R&B Separation	Recyclable Separation	FR Separation	No-Separation	
Waste Separation		40%	44%	8%	8%	100%
Waste Composition	Recyclable	37.4%	40.2%	30.4%	31.1%	16.0%
	Compostable	40.1%	41.3%	50.0%	60.4%	61.0%
	Other residue Portion	22.5%	18.5%	19.7%	8.5%	23.0%
Total predictors	Number of room	1860	2046	372	372	3112
	Number of check-in guest	2217	2439	443	443	3426
	Number of event guest	-	-	-	-	572

Estimation method of waste generation amount and potential of hotel sector in Hue

By assigning the total numbers of room, check-in guest and event guest into the predictive models for waste generation, the authors estimated the total amounts of "General waste", "Separated recyclable" and "Separated food residue" by the following equation:

$$\text{Recyclable Potential in GW} = \sum \text{AGWi} \times \%\text{Ri} \quad (1)$$

$$\text{Compostable Potential in GW} = \sum \text{AGWi} \times \%\text{Ci} \quad (2)$$

$$\text{Other residue in GW} = \sum \text{AGWi} \times \%\text{Oi} \quad (3)$$

Where,

AGWi: Total amount of General waste at the separation category i

%Ri: Percentage of recyclable portion in General waste at the separation category i

%Ci: Percentage of compostable portion in General waste at the separation category i

%Oi: Percentage of other residual portion in General waste at the separation category i

where the separation category i was defined as follows:

1: Both separation at Lower class hotel; 2: Recyclable separation at Lower class hotel; 3: Food residue separation at Lower class hotel; 4: No separation at Lower class hotel, and 5: Higher class hotel.

Table 2- 11Total estimation of waste generation from hotel sector in Hue city

(Unit:ton/day)

Category	Separation type	General Waste			Separated Recyclable	Separated Food residue	Total amount
		Recycling Potential	*Composting Potential*	*Other Residue*			
Lower Class	Both Separation	*0.24*	*0.25*	*0.14*	0.10	0.45	1.18
	Recyclable only	*0.23*	*0.24*	*0.11*	0.15	-	0.72
	Food residues only	*0.02*	*0.03*	*0.01*	-	0.07	0.13
	No Separation	*0.05*	*0.10*	*0.01*	-	-	0.16
Total in Lower Class		*0.53*	*0.61*	*0.27*	0.25	0.52	2.19
Total in Higher Class		*0.40*	*1.55*	*0.59*	0.30	2.07	4.91
Total hotel in Hue (tons)		*0.93*	*2.17*	*0.87*	0.54	2.59	7.10
%		***13.1%***	***30.5%***	***12.2%***	***7.7%***	***36.5%***	***100%***

Regarding the *"Lower class"* hotel, there are 4-0% hotels were separated waste into 3 categories. However, 44% hotels have separated only recyclables, the food residues were put into general waste in these hotels. Besides, there was only 8% hotels have

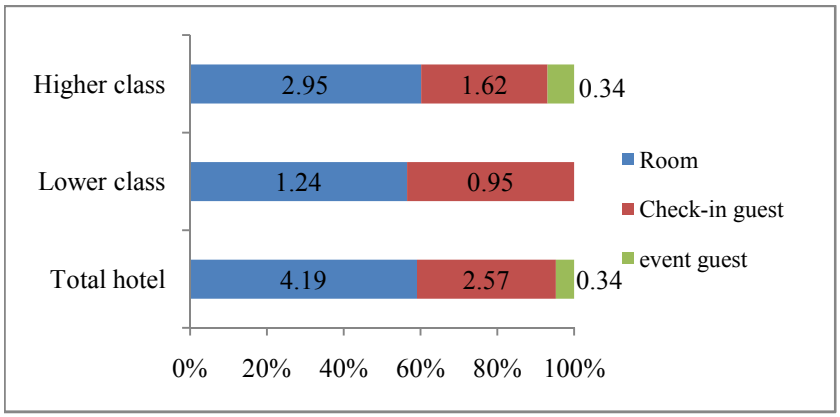

Figure 2- 1 Contribution to total WGA

separated food residue, the recyclables in these hotels waste put into general waste for discharge. And there were 2 target hotels accounted for 8% hotels have not separated waste, all of waste generated in these hotels was collected by environmental company.

Hue city has 413 hotels. By the above predictive models, the authors calculated the total amount of general waste, recyclable, food residue, and total waste of hotel sector in Hue. Table 2-11 presents details of waste generation from a hotel sector in Hue: non-recyclable, recycling potential, composting potential contained in general waste, recyclable, food residues, and total waste by weight (tons/day). The total waste generation amount was 7.1 tons, of which 7.7 % of waste was separated at the source as recyclable, 55.8 % was general waste, and 36.5 % was food residues. In general waste, the recycling potential accounted for 13.1%, composting potential accounted for 30.5%, and the remaining waste accounted for only 12.2 %.

Since the composting potential in general waste accounted for the large portion (30.5%) in total generation waste, targeting the compostable part would markedly reduce waste produce across hotel sector. Should all presently recyclable and compostable in general waste be diverted, the waste stream in hotel sector would decline from 55.8% to 12.2%.

2.1.3.7 Interval estimation and Uncertainty analysisfor hotel

As a validation of the unit waste generation rates, the author estimated the 95% confidence interval of *waste generation amount* by a *Monte Carlo Simulation* based on the means and standard errors of waste generation rates. The results showed that the 95% CI of total waste in Hue range from 6.51 tons/day to 8.23 tons/day.

Table 2- 12Calculation condition for interval estimation

Class	Room	Check-in Guest	Event Guest	R^2
Lower class	112.9** *(40.2)*	409.5*** *(24.6)*		.933***
Higher class	971.0*** *(70.3)*	433.7*** *(79.2)*	349.9*** *(92.4)*	.924***

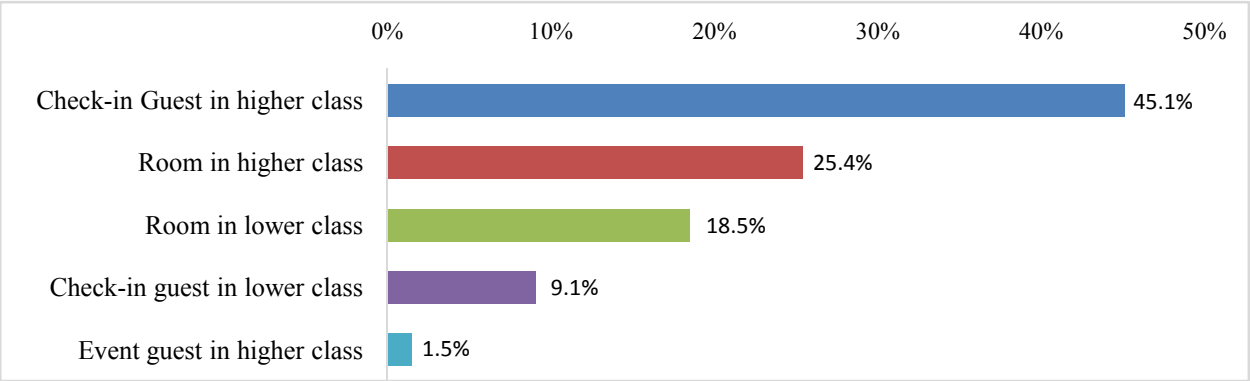

Figure 2- 2 Uncertainty analysis of total waste generationfrom hotel sector

Uncertainty analysiswas conducted to evaluate the effects of components on the overall results. Fig.2-2 showed the Uncertainty analysisresult of total waste generation from hotel sector in 2012. The results indicated that the total waste amount from hotel was mostly affected by the higher class hotel. In which, the waste generation by check-in guest had high influence (44.5%) on the total waste, followed by waste generation from room part in higher class (24.5%). The lower class had less impact to the total WGA of hotel.

Conclusions

The general waste was classified into 10 physical categories and 77 sub-categories. Food waste accounted for the largest proportion in all hotel classes, followed by plastic and paper. The results from sub-categories demonstrated the potential for composting and recycling.The authors also estimated the total generated waste, the recycling and composting potential for 269 hotels in Hue. The total waste generation amount was 6,750 kg/day. In general waste, the recycling potential accounted for 12.6 %, composting potential accounted for 32.3%, and the remaining waste accounted for only 14.2%. The total disposal amount sent to the landfill site can be reduced from 59.1 % to 14.2%.

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2.2 Solid waste generation from restaurant and beverage sector

2.2.1 Introduction

Viet Nam, after two decades of rapid economic growth, the living standard of citizens has been improved dramatically. As the eating behavior changed, the opportunity for consuming food in the restaurant has been increasing. Besides, Vietnam has also been a growing tourist destination for not only travelers within Asian, but also for increasing ones from the West. To fulfill the high demands from local people as well as foreigners, the food and beverage service sectors have been expanded rapidly in recent years. In FY 2014, the consumer price index of hospitality service in Vietnam has increased 39% compare with FY2010 [9]. In consequence, the waste generation from these sectors has become a growing problem. In recent years, 15 million tons of municipal solid waste is generated annually from various sources such as industry sector, household, food service, market, and other business. Among them, more than 80% (12.8 million tons/year) comes from municipal source [1]. Understanding the characteristic of waste (waste generation, waste composition, and waste flow) deriving from municipal sources, included food and beverage service sectors, is very necessary for designing the solid waste master plan. However, there are few studies have specifically examined on waste generation and characteristics (e.g. recyclable, compostable) from food and beverage service sectors.

In 2003, one study on municipal solid waste was conducted in Phnom Penh, Cambodia by Japan International Cooperation Agency (JICA). In this research, 70 samples from 5 restaurants were selected for waste amount and waste composition survey, which were conducted for seven consecutive days in the dry season and the rainy season. By multiplying the waste generation rate by table with the number of generation sources (table), the authors estimated the total waste generation amount from restaurants in Phnom Penh was 38.6 ton/day in the rainy season to 54 ton/day in dry season. Regarding the waste composition results, the authors also estimated the amount of combustible and noncombustible waste from restaurant sector in Phnom Penh [6].

In 2010, one survey on solid waste generation was conducted in Danang City, Vietnam by Otoma et al. For this study, six restaurants were chosen to measure the waste generation amount for one week. Daily wastes from the restaurant were required to put into baskets for segregating and measuring, without considering about waste sorting habit of owners. By multiplying with number of restaurant in Danang city, the authors estimated total waste generation amount was 6,314.4 kg/day [5].

In earlier studies mentioned above, the authors did not address the factors which might affect the waste generation amount, such as business scales, business type, etc. Besides, the waste sorting behavior

was not mentioned; therefore, the boundary of waste generation did not include separated recyclable waste and food residue, which were often kept and used for a particular purpose. Finally, the recycling potential and composting potential in the disposal waste, which are valuable information for 3R promotion, were not reported.

This study was undertaken to present a detailed description of waste flow in food and beverage service sectors in Hue city – a representative tourism city in Central of Vietnam. The authors surveyed 108 restaurants and cafe shops with different scales for ten consecutive days to identify the waste generation rate as well as their characteristics. The authors also estimated the total waste amount, the recycling and composting potentials from food and beverage sectors in Hue as the basis of rational municipal solid waste planning including waste reducing and recycling.

2.2.2 Methodology

2.2.2.1 Sample selection

Hue city, which is located in the center of Vietnam, comprises 27 wards with an area of 71.69 km2 and a population of 432,556 people [2]. Hue city is well known as the most famous tourism destination in the middle of Vietnam. In 2014, there were 1.84 million foreign and domestic tourists visiting Hue [2]. Regarding solid waste management, the amount of collected waste in Hue city is reported as approximately 210 ton/day. The general collection rate in the whole town was about 89%, and 90–95% in urban areas [3]. In 27 wards of Hue city, sampling points were selected based on urbanization level and geographical distribution. The total list of each sub-category was prepared and sorted by the number of workers. The target samples have been chosen systematically from the sorted list. The information of target samples was shown in Table 1.

2.2.2.2 Definitions and terminology

In Hue city, the food & beverage service sectors are divided into four main groups:

- Café (CF): a cafe shop serves coffee and/or other beverages. Based on the business scale, the target samples in beverage service category were classified into three subcategories: CF1, CF2, and CF3, which has one worker, two workers and three or more workers, respectively;
- Small scale restaurant (SR): a restaurant serves various kinds of food in a small scale, e.g. noodles, steamed rice, a various disk with drinks. The number of employees is less than ten in general. Based on the business scale, the target samples in small scale restaurant category were classified into four subcategories: SR1, SR2, SR3 and SR4, which has one worker, two workers, three workers, and four or more workers, respectively;

- Large scale restaurant (LR): a restaurant serves various kinds of food in a large scale. Sometimes it serves events, such as party, buffet. Number of workers is more than ten;
- Vendor (VR): Someone who sells goods without a contract for a particular period of time, generally located on the pavement. There is no statistical data about this sector.

During the survey, the target restaurant/cafe shops/vendors were requested to keep their waste in three categories by their original customs: *Recyclables*, *Food residues,* and *General waste* defined as bellows:

- **Recyclables waste (RW)**: separated recyclable waste is the items kept for recycling or sale to informal sectors or given to somewhere/someone by owners;
- **Food residues (FR)**: separated food residue is the waste items kept for livestock (e.g. pigs) feeding (generally collected by livestock breeders).
- **General waste (GW)**: all remaining waste items excluding separated waste items described above. This type of waste is collected daily by an environmental company in Hue (HEPCO).

For general waste, some amounts of recyclable and compostable were still remained. The authors defined 3 sub categories as bellows:

- **Recycling potential (RP)**: the recyclable portion discharged in general waste;
- **Composting potential (CP)**: the compostable portion discharged in general waste;
- **Remains:** The residual portion excluding recyclable and compostable portions discharged in general waste.

Table 2- 13 Information of target samples

	Cafe			**Small scale restaurant**				**Large scale restaurant**	**Vendor**
Code	CF1	CF2	CF3	SR1	SR2	SR3	SR4	LR	VR
Number of worker	1	2	≥ 3	1	2	3	≥ 4	>10	-
Number of target samples	9	7	7	14	24	15	12	15	5
Total number in Hue city [2]	921	793	211	1068	836	212	190	131	N/A

2.2.2.3 Outline of survey

The procedure of waste generation survey followed the methodology by Matsui et al. (2014) [4]. The authors conducted three surveys of all target samples: a waste generation survey by actual

measurement, a waste composition survey, and a questionnaire survey. Surveys were conducted during July 11th to July 21st 2012. The waste generation survey was administered to acquire data on the amount of waste generation for 10 consecutive days. Of them, the first three days were spent on practicing; the authors used the data for the latter seven consecutive days.

A waste composition survey was also conducted during the study period. To provide information related to the recycling and composting potentials, the authors analyzed details of the waste composition of 'General waste' for some representative targets. The waste was classified into 10 physical categories and 77 subcategories, as shown in Table 2. This classification category was based on Materials, Plastic, Paper, Kitchen waste, Rubber & Leather, Grass, Textile, Metal, Glass, Ceramic, and Miscellaneous, Types (Container/Packaging, Product and Other), Recycling potential (recyclable and non-recyclable) and Composting potential (compostable and non-compostable). The authors also conducted a questionnaire survey of the attributes and the current status of food & beverage service sectors in Hue.

2.2.2.4 Analytical procedure

The authors calculated key statistics related to waste generation rates by some business scale indicator such as the number of workers, the number of tables, and the business area. The authors also assessed the mean difference by business scale by analysis of variance (ANOVA) as well as rank correlation analysis. The waste composition by percentage (%) was calculated according to the physical category and by recycling and composting potentials.

By multiplying the waste generation rate by worker and total number worker of each restaurant and cafe shop in Hue, the authors estimated the total waste generation amount from food and beverage service sectors in Hue city. The 95% confidence interval of total waste generation amount was calculated by the Monte Carlo simulation (100,000 times). The authors also analyzed the sensitivity as a percentage of the contribution from each parameter to the variance of the final result.

2.2.3 Results and discussion

The valid response rate was 88% (95/108) in the survey, excluding the responses with errors and data lacks.

2.2.3.1 Total waste generation amount

The waste generation amount of food and beverage service sectors were calculated by each category. Table 14 presents the number of target samples, mean and standard deviation of waste generation amount (g/day) of café shop, small scale restaurant, large scale restaurant, and vendor in Hue

city. There was a significant difference among the category. In food service sectors, large scale restaurant (LR) discharged a large amount 45 kg/day, three times higher than small scale restaurant (SR) with only 15 kg/day. Regarding Otoma et al., the waste generation amount of restaurant in Danang city was 35 kg/shop/day, but the scale of the restaurant was not mentioned [5].

Table 2- 14 Total waste generation amount by each category by day

WGA	CF		SR		LR		VENDOR		F (ANOVA)
	n	Ave±SD	n	Ave±SD	n	Ave±SD	n	Ave±SD	
g/day	19	6,326±6,659	58	15,162±13,201	13	44,962±24,479	5	1,779±1,364	23.141***

*: p<0.05, **: p<0.01, ***: p<0.001

2.2.3.2 Total waste generation rate

Table 2- 15 Total waste generation rate of each category

Total WGR	CF		SR		LR		VENDOR		F (ANOVA)
	n	Ave ± SD	n	Ave ± SD	n	Ave ± SD	n	Ave ± SD	
g/worker/day	19	2,764±1,407	58	5,686±3,758	13	3,877±1,386	5	1,779±1,364	6.226**
g/table/day	19	591±414	58	1,358±1,220	13	1,681±888	-	-	7.197***
g/m2/day	15	146±136	38	318±289	6	345±109	-	-	3.964*

*: p<0.05, **: p<0.01, ***: p<0.001

In Table 15, the authors showed waste generation rate by the following three business scale indicators: the number of workers, the number of tables and the business area. The number of samples, averages and standard deviations (Ave ± SD) of waste generation rates of 95 cafe shops and restaurants were shown. The average waste generation rate by worker from cafe shops was 2,764 g/worker/day. In food service sector, the waste generation rate by worker from small scale business (SR) and large scale business (LR) was 5,686 g/worker/day and 3,877 g/worker/day, respectively. There were significant differences among these categories. The average waste generation rate by table was from 1,358 to 1,681 g/table/day, which was similar to the rate 1,560 g/table/day reported in the study of Otoma et al. (2013) in Danang City, Vietnam [5]. Another study in Cambodia reported that the waste generation rate by table in restaurant sector were 1,387 - 1,940 g/table/day [6].

2.2.3.3 Waste separation status

Table 2- 16 Waste separation participation of target samples

Business Category	Both separation		Recyclable separation only		Food residue separation only		Without separation	
	n	%	n	%	n	%	n	%
CF	2	11%	11	58%	4	21	2	11%
SR	30	52%	4	7%	22	38%	2	3%
LR	11	85%	0	0%	1	8%	1	8%
VR	0	0%	2	40%	1	20%	2	40%

The waste separation activity of target samples was categorized in 4 cases: Both separation, recyclable separation only, food residue separation only, and without separation. The waste separation activities of 95 target samples were shown in Table 16 with the number of cases and the percentage. The large scale restaurants (LR) were the most positive in waste separation with 85% cases separating both recyclable and food residue, followed by small scale restaurants (SR) (52%) and Café shop (CF) (11%). In Café shop, the food residue (considered as the kitchen waste) was mainly green waste, mostly coffee ground, which was sometimes used as compost. Typically, the shop owners discharged it with general waste.

2.2.3.4 Detail waste generation rate by business category

The basic stats (number of cases, Min, Max and Average) of general waste, recyclable waste and food residue by each category were shown in Table 17. The waste sorting affected the recyclable waste and food residue data with “0 value”, therefore, the authors did not show the SD for these categories. However, the total waste generation was not affected by waste separation activity.

Table 2- 17 The basic stats waste generation rate of food and beverage service sector.

Business Category	n	General waste		Recyclable waste		Food residue		Total waste	
		Min – Max	Ave	Min – Max	Ave	Min – Max	Ave	Min – Max	Ave
Waste generation rate by worker (g/worker/day)									
CF	19	631 – 4,637	2,100	0 – 700	110	0 – 3117	553	768 – 4,871	2,764
SR	58	199 – 5,814	1,808	0 – 416	70	0 – 11,234	3,808	508 – 17,186	5,686
LR	13	627 – 2,391	1,550	0 – 504	195	0 – 4,193	2,132	1,996 – 5,915	3,877
VR	5	0 – 1,759	782	0 – 2,452	754	0 – 1,216	243	555 – 3,406	1,779
Waste generation rate by table (g/table/day)									
CF	19	158 – 1,546	449	0 – 78	21	0 – 889	121	192 – 1,624	591
SR	56	81 – 2,515	553	0 – 347	23	0 – 5,632	1,137	0 – 8,494	1,358
LR	11	322 – 2,389	849	0 – 315	90	0 – 1,782	1,047	0 – 2,664	1,681
VR	–	–	–	–	–	–	–	–	–
Waste generation rate by m2 (g/m2/day)									
CF	15	23 – 464	110	0 – 23	7	0 – 211	29	39 – 487	146
SR	38	17 – 580	137	0 – 64	5	0 – 1,043	382	34 – 1,573	318
LR	6	77 – 287	162	0 – 37	13	0 – 335	345	212 – 472	345
VR	–	–	–	–	–	–	–	–	–

2.2.3.5 Factors influencing waste generation rate

Rank correlation analyses were conducted on the business scale (number of employees) with the waste generation rate by worker with different waste types (general waste, recyclable waste, food residues, and total waste). In beverage service sector, there was a negative correlation between the waste generation rate by worker of general waste, total waste and number of worker ($F = - 0.542$, $p<0.05$).

The authors also conducted analysis on variable on the waste generation rate by worker and several factors, such as independent business/household with business, fuel with ash/without ash, food type, with/without waste sorting. However, there was no significance different among them. In food type, there was a significant difference on recyclable waste generation by worker between a restaurant serving various dishes and alcohol drinks (181 g/worker/day) and others (53 g/worker/day) ($p<0.001$). It was responsible due to the drinking restaurant regularly discharged more cans and glass bottles than others.

2.2.3.6 Waste composition

Table 19 presents the food and beverage sectors' waste composition of general waste by ten physical categories. The food waste was the largest proportion in all categories, 37.1% - 49.8%. In the cafe, the food waste was quite high due to the amount of coffee grounds, which is compostable. In small scale restaurant category, the percentage of grass and wood was quite high (22.7%) is explainable that they frequently offered one-time-used chopsticks than others.

Table 2- 18. Physical composition, composting and recycling potential

Physical category	CF	SR	LR
Plastic	8.3%	11.4%	8.5%
Paper	31.2%	11.4%	34.0%
Food waste	49.8%	49.1%	37.1%
Rubber & leather	0.0%	0.0%	0.8%
Grass & Wood	3.6%	22.7%	8.2%
Textile	0.0%	2.5%	4.7%
Metal	1.6%	1.0%	1.8%
Glass	0.0%	0.8%	1.4%
Ceramic	0.1%	0.3%	2.6%
Miscellaneous	5.2%	0.7%	0.9%
Total	100%	100%	100%
Remains	27.1%	15.3%	51.4%
Recycling potential	20.2%	18.6%	17.0%
Composting potential	52.6%	66.2%	31.6%

Table 18 also shows the potential for recycling and composting in general waste of food and beverage service sectors. Although the easily separated items or valuable ones had been already separated, some parts of them remained in general waste for discharge. The composting potential is the highest in SR category with 66.2%, followed by CF (52.6%) and LR (31.6%).

2.2.3.7 Estimation of total generated waste

To estimate the waste generation amount by five components, the authors recalculated the waste generation rate by each category by four types of waste separation cases: (1) both separation, (2) recyclable waste separation only, (3) food residues separation only, and (4) no separation.

By assuming that Separated Recyclable Waste (SRW), Separated Food Residue (SFR) and Total Waste (TW) were in proportion, the ratio (for example: based on data of Small Scale Restaurant category) was identified as followed:

SRW : SFR : TW = 2 : 75 : 100

From this ratio, the authors calculated the Unseparated Recyclable Waste and Unseparated Food Residue for cases: (2), (3) and (4).

For General Waste, the authors assumed that Recycling Potential Portion (RP) (except the Unseparated Recyclable Waste), Composting Potential Portion (CP) (except the Unseparated Food

Residues) and Remains Portion (RP) were in proportion. Therefore, the ratio (for example: based on data from the Small Scale Restaurant category) was identified as followed:

RP : CP : RP : TW = 4 : 15 : 4 : 100

Finally, the authors calculated the Recycling Potential Portion, Composting Potential Portion and Remain Portion for every case. By using these assumptions, the authors recalculated the waste generation rate by each category. The average and standard error for each class were shown in Table 8.

Table 2- 19The recalculated waste generation rate by worker by each category

Unit: g/worker/day

Business Category		Recycling Potential	Composting Potential	Remains	Separated Recyclable	Separated Food Residue	Total Waste
Cafe	Ave	154	591	241	176	1,601	2,764
	SE	22	110	27	35	214	323
Small restaurant	Ave	301	1,071	247	111	3,956	5,686
	SE	30	106	24	12	373	493
Large restaurant	Ave	240	445	724	225	2,242	3,877
	SE	25	46	75	44	320	384

Hue City has 4,362 restaurants and beverage shops, with different business scale. By multiplying the waste generation rate by worker and the total number of worker by each category in Hue, the authors estimated the total amount of general waste, recyclable, food residues and total waste in food and beverage service sector in Hue city. The authors also determined the potentials of recycling and composting in the general waste of food & beverage service sectors in Hue city. The total waste generation amount was calculated by the following equation:

$$Total = \sum (RW_i + FR_i + RP_i + CP_i + RM_i)$$

Where:

Total: Total waste generation amount (ton/day);

i: Business category (Café, Small Scale Restaurant, Large Scale Restaurant);

RW_i: Separated recyclable waste by each category (ton/day);

FR_i: Separated food residues by each category (ton/day);

RP_i: Recycling potential portion in general waste by each category (ton/day);

CP_i: Composting potential portion in general waste by each category (ton/day);

RM_i: Remains waste in general waste by each category (ton/day);

The separated recyclable waste amount was calculated by the following equation:

$$RW_i = n_i \times RWS_i \times RWGR_i \times 10^{-6}$$

Where:

n_i: number of worker by each business category;

RWS_i: Recyclable separation participation, (%);

$RWGR_i$: Recyclable waste generation rate by worker, (g/worker/day);

The unseparated recyclable waste was calculated by the following equation:

$$URW_i = n_i \times (1 - RWS_i) \times RWGR_i \times 10^{-6}$$

Where:

URWi: Unseparated recyclable waste amount by each category, (ton/day);

n_i: number of worker by each business category;

RWS_i: Recyclable separation participation, (%);

$RWGR_i$: Recyclable waste generation rate by worker, (g/worker/day);

The separated food residue amount was calculated by the following equation:

$$FR_i = n_i \times FRS_i \times FRGR_i \times 10^{-6}$$

Where:

n_i: number of worker by each business category;

FRS_i: Food residue separation participation, (%);

$FRGR_i$: Food residue generation rate by worker, (g/worker/day);

The unseparated food residue amount was calculated by the following equation:

$$UFR_i = n_i \times (1 - FRS_i) \times FRGR_i \times 10^{-6}$$

Where:

UFRi: Unseparated food residue amount by each category, (ton/day);

n_i: number of worker by each business category;

FRS_i: Food residue separation participation, (%);

$FRGR_i$: Food residue generation rate by worker, (g/worker/day);

For this study, the authors assumed that the unseparated recyclable waste was disposed of together with general waste; therefore, the recycling potential portion in general waste was calculated by the following equation:

$$RP_i = n_i \times \%RP_i \times GWGR_i \times 10^{-6} + URW_i$$

Where:

n_i: number of worker by each business category;

$\%RP_i$: Percentage of recycling potential portion in general waste, (%);

$GWGR_i$: General waste generation rate by worker, (g/worker/day);

URWi: Unseparated recyclable waste amount by each category, (ton/day);

By the same concept mentioned above, the authors also assumed that unseparated food residues were disposed of together with general waste; therefore, the composting potential portion was calculated by the following equation:

$$CP_i = n_i \times \%CP_i \times GWGR_i \times 10^{-6} + UFR_i$$

Where:

n_i: number of worker by each business category;

$\%CP_i$: percentage of composting potential portion in general waste, (%);

$GWGR_i$: General waste generation rate by worker, (g/worker/day);

UFRi: Unseparated food residue amount by each category, (ton/day);

The remains in general waste were calculated by the following equation:

$$RM_i = n_i \times \%RM_i \times GWGR_i \times 10^{-6}$$

Where:

n_i: number of worker by each business category;

$\%RM_i$: percentage of remains portion in general waste, (%);

$GWGR_i$: General waste generation rate by worker, (g/worker/day);

Figure 1 showed details of waste generation amount and its' contribution by each business category of food and beverage service sectors in Hue city. The total waste generation amount was 39.85 ton/day, in which, the highest amount was separated food residues with 20.27 ton/day (50.9%), following by general waste with 18.60 ton/day (46.7%), and separated recyclable waste with 0.98 ton/day (2.5%). For general waste, the composting potential was the highest amount with 7.86 ton/day (19.7%), following

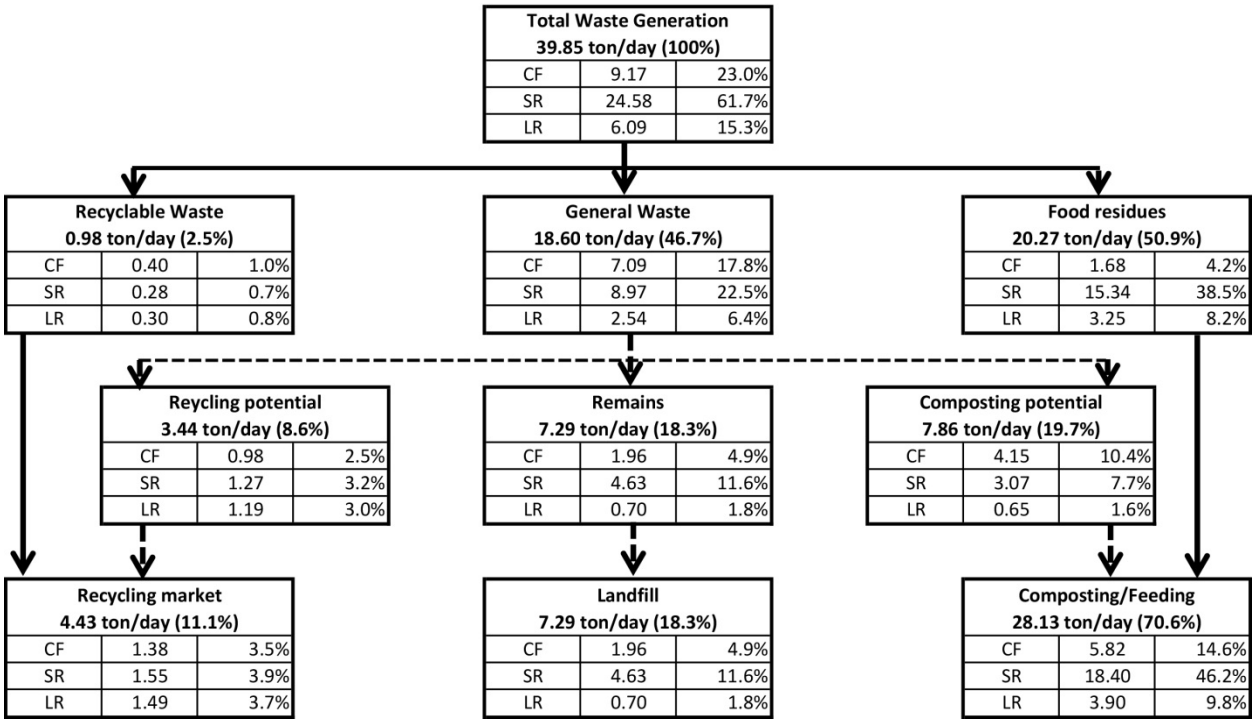

Figure 2- 3 .Waste stream from food and beverage service sectors in Hue city

by remains and recycling potential portion with 7.29 ton/day (18.3%) and 3.44 ton/day (8.6%), respectively.In food and beverage service sectors, the small scale restaurants contributed the highest amount of waste with 24.58 ton/day (61.7%), following by café with 9.17 ton/day (23.0%) and large scale restaurants 6.09 ton/day (15.3%). The small scale restaurants had the highest recycling potential portions among three categories with 1.27 ton/day (3.2%) while the café had the largest composting potential part with 4.15 ton/day (10.4%).

Even though the waste separation participation was high among three categories (Table 5), the recycling rates, however, still low according to the total separated amount. For recyclable waste separation rate, the Café had the highest recycling rate of 29% (0.4/1.38 ton/day), followed by the large restaurant and small restaurant with 20% (0.3/1.49 ton/day) and 18% (0.28/1.55 ton/day), respectively. For food residue separation rate, the large scale restaurant and the small scale restaurant had the same rate with 83% (3.25/3.9 and 15.34/18.4 ton/day), followed by Café with 23% (1.68/5.82 ton/day). The results also showed that the total disposal waste amount delivered to landfill site can be reduced from 18.60 to 7.29 ton/day by separation activity (about 60% amount).

2.2.3.8 Interval estimation

For this study, the authors conducted the 95% confidence interval (CI) of total waste generation from food and beverage service sectors in Hue by a Monte Carlo simulation based on the means and the standard errors of waste generation rates, the waste composition, and the percentage of separation activities among the categories.

For simulation assumption, all the variables were defined as Normal distribution, except variables of the percentage of recyclable waste separation and food residue separations were defined as Beta distribution. The Beta distribution has been applied to model the behavior of random variables limited to intervals of finite length in a wide variety of disciplines. In the past studies, Beta distribution has been widely used for the lot fraction defective in industrial management field [7]. M. Yusof Sulaiman applied beta distribution to model the sunshine data in Malaysia [8].etc. For this study, the authors used Beta distribution to represent a probability distribution of probabilities - that is, it represents all the possible values of probability when the probability of waste separation was unknown. The 95% CI of total waste generation was wide 36.01 – 43.64 ton/day as shown in Table 9. The results also showed that the recycling potential and composting potential were 3.08 – 3.81and 6.82 – 8.91 ton/day, respectively. Further study should be conducted on the detailed market value of recyclable waste from general waste for waste separation promotion in food and beverage service sectors.

Table 2- 20. The 95% confidential intervals of waste generation

Waste category	Unit	Median	95% CI	
			Lower bound	Upper bound
Recyclable waste	Ton/day	0.98	0.78	1.18
Food residues	Ton/day	20.26	17.26	23.28
Recycling potential portion	Ton/day	3.44	3.08	3.81
Composting potential portion	Ton/day	7.86	6.82	8.91
Remains	Ton/day	7.30	6.13	8.45
Total	Ton/day	39.84	36.01	43.64

Uncertainty analysis

To estimate the impact of each waste generation rate affecting the CI of the total waste amount, a sensitive analysis for all categories of food & beverage service sectors were conducted. Figure 2 presents the result of sensitive analysis of total waste generation amount. The food residue generation rate of small scale restaurant category contributed the highest effect on sensitivity (69.5%), followed by food residues generation rate of Café category (12.8%) and food residue generation rate of large scale

restaurant (6.8%). It can be explained that the food waste from small scale restaurant was the highest amount of 38.5% of total waste generation amount; therefore, it had the largest contribution to the Uncertainty analysisresult. However, to improve the reliability of total estimation, further investigation must be conducted to clarify the factors affecting waste generation rate in these categories.

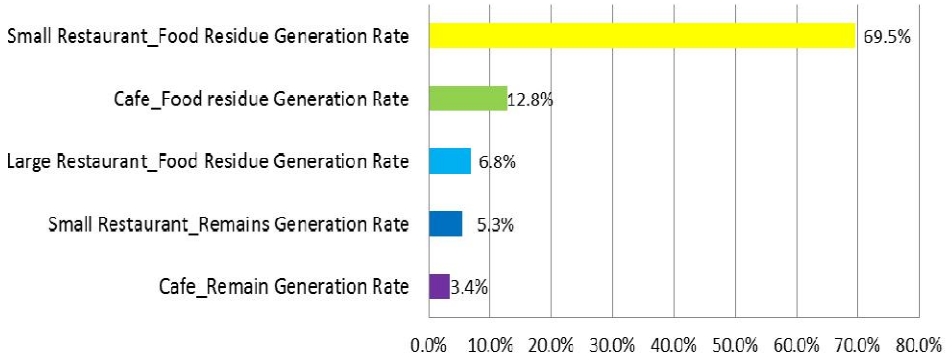

Figure 2- 4. Uncertainty analysis of total waste generation amount from food and beverage service sector

Conclusion

1) In order to clarify the waste generation rate from food & beverage sectors and relevant factors, the authors conducted a survey for 10consecutive days in Hue City, Vietnam with 108 target samples with different business scale.

2) There was a significant different among business category on the waste generation rate (by worker, by table and by area) and the business type. However, there was no significant difference among categories of the waste generation rate and several factors, such as; independent business/household business, fuel with/without ash, food type, with/without waste sorting. There was a significant difference in recyclable waste generation by worker between restaurant serving various dishes and alcohol drinks (181 g/worker/day) and others (53 g/worker/day) ($p<0.001$).

3) The small scale restaurant (SR) had the highest waste separation participation with 97% target samples, followed by large scale restaurant (LR) with 92% target samples. Waste separation efficiency in café and vendor were 68% and 60%, respectively. Based on the separated waste mount, however, the waste separation rate was not high among categories. Recyclable waste separation at Café category was the highest with 29%, followed by large restaurant and small restaurant with 20% and 18%, respectively. For food residue separation rate, the small restaurant and large restaurant had the same rate with 83%, followed by Café with 23%.

4) For general waste, food waste accounted for the largest proportion in all categories, 37.1% - 49.8%. The composting potential and recycling potential percentage were 31.6% - 66.2% and 17% - 20.2%, respectively.

5) Based on the waste generation rate by worker and the total number of worker of each category in Hue city, the author estimated the total waste generation amount from food & beverage service sectors in Hue city, which was 39.85 ton/day. For general waste, the recycling potential, and compostable potential accounted for 3.44 ton/day (8.6%) and 7.86 ton/day (19.7%), respectively. The total amount of disposal waste delivered to landfill site can be reduced from 18.60 ton/day (46.7%) to 7.29 ton/day (18.3 %).

6) The 95% confidential interval estimation of total waste generated from food and beverage service sectors in Hue City was 36.01 - 43.64 ton/day. The 95% CI of recycling potential and composting potential amount were 3.08 - 3.81 ton/day and 6.82 to 8.91 ton/day, respectively.

7) The food residue generation rate of small scale restaurant (SR) had the highest contribution in Uncertainty analysis, due to its highest percentage of discharged amount in total waste generated amount.

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2.3 Solid waste generation from home-based business

2.3.1 Introduction

Determining the volumes and types of waste generated within a region is of fundamental significance for waste management planning. Data gathered with regard to waste type, quantity and origin are important factors when designing collection systems, planning treatment capacities for recyclables and determining the dimensions of waste disposal facilities such as incinerators or landfills. In the past decade, strong economic growth and rapid rates urbanization have greatly magnified the problems with solid waste management system in Vietnam, pushing waste management to the forefront of environmental challenges with which it must contend. It is important to quantify the volumes of waste generated according to type and origin. Furthermore, baseline data is important to ensure proper monitoring of results.

In 2007, The Prime Minister of The Government issued Decision No. 10/2007/QD-TTG dated January 23, 2007. It is called the System of Economic Branches of Vietnam. According to this Decision when people register the business, they must fill the code of the System of Economic Branches in the Application for Investment License for easy management. That system has total 642 economic branches in detail. In order to provide the scientific information that can contribute to promotion of 3Rs at home-based business, this study aimed to clarify the detail description of solid waste generation and composition of Home-based business in Hue City, Vietnam. The authors surveyed 245 households that belong to 7 business categories at level 1. The authors conducted a survey on the waste collected by formal sectors, and also measured the amount of separated recyclable and food residue collected by informal sectors. The waste collected by formal sectors was classified into ten physical categories and 77 sub-categories to identify potentials on recycling and composting contained in waste. This study also conducted an interval estimation of total waste amount from home-based business in Hue, and intended to clarify the reliability of collected data and future tasks to improve it by uncertainty analysis.

2.3.2 Methodology

2.3.2.1 Sample selection

There are totally 11,639 home-based businesses with 18,777 employees in Hue city. The authors covered 7 Home-based business categories at level 1 according to "*The system of economic branches of Vietnam, 2007*". The detail sampling method was described as follows:

The System of Economic Branches of Vietnam

According to this Decision, The System of Economic Branches of Vietnam comprises five Levels as follows:

- Level 1 comprises 21 branches coded by the letters of the alphabet in alphabetical order from A to U;
- Level 2 comprises 88 branches; with each branch coded by **two numbers** after those of the corresponding **Level 1**;
- Level 3 comprises 242 branches; with each branch coded by **three numbers** after those of the corresponding **Level 2**;

- Level 4 comprises 437 branches; with each branch coded by **four numbers** after those of the corresponding **Level 3**;
- Level 5 comprises 642 branches; with each branch coded by **five numbers** after those of the corresponding **Level 4**.

Table 2- 21. The System of Economic Branches of Vietnam

Level					BRANCH	Target category
1st	2nd	3rd	4th	5th		
A	1-3	242 branches, each branch coded by three numbers after those of the corresponding Level 2	437 branches, each branch coded by four numbers after those of the corresponding Level 3	642 branches, each branch coded by five numbers after those of the corresponding Level 4	Agriculture, Forestry and Aquaculture	
B	5-9				Mining Minerals	
C	10-33				Manufacturing and Processing Industries	HH with business
D	35				Production and Distribution of Electricity, Natural Gas, Hot Water, Steam and Air-Conditioning	
E	36-39				Water Supply, Waste and Sewage Management	
F	41-43				Construction	
G	45-47				Sale and repair of automobiles, motors, motorbikes, etc. Wholesale and retail	HH with business & Market & supermarket
H	49-53				Transport and Warehouse	Office
I	55-56				Accommodation and Restaurant Services	Restaurant & Hotel
J	58-63				Information and Communication	HH with business & Office
K	64-66				Finance, Banking and Insurance	Office
L	68				Real-Estate Business	Office
M	69-75				Professional Practice, Science and Technology	Office
N	77-82				Administrative Services and Assistant Services	HH with business & Office
O	84				The Communist Party, Civil society, State administration, National defense security, etc.	Office
P	85				Education and Training	Hbb & education services
Q	86-88				Health and social support activities	Hospital & healthcare services
R	90-93				Artistic, recreational activities	HH with business & Office
S	94-96				Other Services	HH with business & Office
T	97-98				Hired Labor services for Households, Producing Home Consumption Material Products	HH with business
U	99				Operation of International Organizations and Agencies	Office
21	88	242	437	642		

Based on the total list household with business in Hue, the total list of each sub-category was prepared and selected systematically from the list. The sub-categories with more than 10 facilities were chosen to survey (only 55 in total 85 sub-categories were considered and surveyed).

Table 2- 22. Sample selection of home-based business

Level 1	Level 2	Category	Total worker	Total facility	N
C	10	Manufacturing and processing foodstuffs	1182	469	20
	11	Producing beverages	55	29	2
	13	Weaving	107	49	2
	14	Producing garments	1655	991	5
	15	Producing leather and related products	170	79	4
	16	Processing wood and producing products from wood, bamboo and neohouzeaua (except for beds, wardrobes, tables, chairs); producing products from straw, thatch and plaited materials	650	255	4
	17	Producing paper and paper products	477	223	5
	18	Printing, copying text of various types	105	48	3
	20	Producing chemical and chemical products	132	70	4
	22	Producing products from rubber and plastic	119	45	2
	23	Producing products from other non-metal minerals	282	136	5
	24	Producing metal	126	44	3
	25	Producing products from prefabricated metal (except for machines and equipment)	772	362	10
			2	1	
	30	Producing other means of transport	27	6	2
	31	Producing beds, wardrobes, tables, chairs	705	400	5
	32	Other processing and manufacturing industries	24	13	2
D	35	Producing and distributing electricity, natural gas, hot water, steam and	59	23	2
G	45	Sale, repair of automobiles, motors, motorbikes and other motor	1303	767	16
	46	Wholesale (excluding categories in 45)	332	184	10
	47	Retail (excluding categories in 45)	7458	5358	90
J	61	Telecommunications	515	315	6
K	77	Leasing machines, equipment (without operator); lease of household or	207	148	1
	82	Administrative practice, office assistance and other business assistant services	154	102	4
R	92	Lottery, betting and gambling	30	26	2
	93	Sporting and recreational activities	453	220	3
S	95	Repair of computers, personal and household tools	399	320	5
	96	Other personal support services	1533	1022	10

2.3.2.2 Outline of survey

The authors surveyed the waste collected by formal sectors, and also measured the amount of separated recyclable and food residue collected by informal sectors. The procedure of waste generation survey followed the methodology by Matsui et al. (2014). The authors conducted three surveys for all target facilities: a waste generation survey by actual measurement, a waste

composition survey, and a questionnaire survey. And the study also focused on waste generation from business and from home separately. A waste measurement survey was conducted to acquire data on generation amount for seven consecutive days. Before the survey period, the authors spent 3 days for preparation and practice for surveyors and target facilities. The target facilities separated and kept generated in three categories by their original customs; waste collected by formal sectors (hereinafter referred to as "General waste (GW)"), recyclable sold to informal sectors (hereinafter referred to as "Separated recyclable (SR)"), and food residue sold/given to pig farmers (hereinafter referred to as "Separated food residue (SFR)").

Descriptions of waste classification categories were illustrated in Table 2.1-6. The authors asked the persons in charge of facility management or waste handling on the attributes and current status of target facilities by the structured questionnaire and interview. The questionnaire was designed to obtain the detailed information on relevant factors (business scale indicators) influencing waste generation, recycling activities and attitudes toward solid waste management at each facility

2.3.2.3 Analytical procedure

The authors calculated basic statistics relating to waste generation rate (WGRs) by waste generation amount from business activity and household separately. The WGRs from business is mainly discussed by number of employee by detail business category. The mean differences of WGRs of total waste among detail categories were assessed by Krustall-Wallis. Regarding the WGRs from household, the authors try to find the relationship between WGR and some factors such as household member, number of meal, number of worker, business categories.

The waste composition of GW by percentage (%) was calculated according to the 10 physical categories by Hbb category. And, based on 77 sub-categories, the authors also assessed the potentials on recycling and composting in GW. The total waste generation amount from business activity at Hbb in Hue was determined by extrapolating by total number of employee in Hue and the waste generation rate by employee.

2.3.3 Results and discussion

2.3.3.1 Waste generation rate

Home-based business activities were classified into 7 business categories at level 1: Manufacturing and Processing Industries; Production Natural Gas, Hot Water; Wholesale and retail; Information and Communication; Administrative and Assistant Services; Recreational activities; Other Services. The waste generation rate of business facilities was calculated by *g/worker/day*, and the waste

generation rate of household was also separately estimated by *g/capita/day in the chapter 4*.

Table 2.3-3 presented theaverages and standard deviations (Ave ± SD) of waste generation rates by *g/worker/day* from business activities. The significant difference among 7 categories was found by ANOVA at total waste amount ($p<0.05$). The waste generation rate was high at category 1 (Manufacturing and Processing Industries) and category 3 (Wholesale and retail). Standard deviations in all categories were relatively wide because of containing various sub-categories.

Table 2- 23. Waste generation rate at level 1

Level 1	Categories	N	General Waste	Recyclable	Food residue	Total
1	Manufacturing and Processing Industries	82	828±2127	439±1817	200±1279	1467±2875
2	Production Natural Gas, Hot Water, etc.	2	39±55	0±0	0±0	39±55
3	Wholesale and retail	126	696±1644	136±430	323±2369	1154±2998
4	Information and Communication	6	143±129	31±67	0±0	174±190
5	Administrative and Assistant Services	5	65±98	172±317	0±0	237±316
6	Recreational activities	6	437±685	126±112	0±0	563±735
7	Other Services	18	139±190	135±295	0±0	274±363
ANOVA (F)			10.9	7.4	1.7	13.0*

To understand more about the waste generation rate in each categories at level 1, the table 2.3-4 showed the detail of waste generation rate and standard deviations on general waste, recyclable, food residue and total waste amount at 27 categories at level 2. The code 1 contained 16 sub-categories, while other categories included only 1 to 3 sub-categories.

Table 2- 24. Waste generation rate at level 2

Level 1	Level 2	Categories	N	General Waste	Recyclable	Food residue	Total
1	10	Manufacturing and processing foodstuffs	19	847±2587	1451±36	481±2096	2779±4384
	11	Producing beverages	3	156±270	82±142	2408±417	2646±3980
	13	Weaving	4	352±307	0±0	0±0	352±307
	14	Producing garments	6	78±99	0±0	0±0	78±99
	15	Producing leather and related products	4	591±410	0±0	0±0	591±410
	16	Processing wood and wood products	5	1666±1146	403±761	0±0	2069±776
	17	Producing paper and paper products	5	169±158	76±154	0±0	246±134
	18	Printing, copying text of various types	3	131±94	48±60	0±0	180±80
	20	Producing chemical and chemical	4	256±254	301±360	0±0	557±398
	22	Producing rubber and plastic products	3	444±731	631±107	0±0	1075±925
	23	Producing other non-metal minerals	5	91±96	238±173	0±0	329±221
	24	Producing metal	3	2376±3678	0±0	0±0	2376±3678
	25	Producing prefabricated metal product	10	308±346	66±98	0±0	374±406
	30	Producing other means of transport	2	438±619	320±326	0±0	757±945
	31	Producing wooden furniture	4	5891±5105	0±0	0±0	5891±5105
	32	Other processing and manufacturing	2	21±29	45±64	0±0	66±93
2	35	Producing and distributing steam and air-	2	39±55	0±0	0±0	39±55
3	45	Sale, repair of motors and other motor	18	205±255	266±901	0±0	470±1027
	46	Wholesale (excluding 45)	11	2272±4449	1±4	0±0	2273±4449
	47	Retail (excluding 45)	97	609±1053	127±304	419±2695	1155±3036
4	61	Telecommunications	6	143±129	31±67	0±0	174±190
5	77	Lease of household, personal tools, non-	1	44±0	2±0	0±0	46±0
	82	Administrative practice and other assistant	4	70±112	214±350	0±0	284±343
6	92	Lottery, betting and gambling	2	0±0	148±209	0±0	148±209
	93	Recreational activities	4	656±768	116±78	0±0	771±845
7	95	Repair of computers and household tools	8	165±147	295±398	0±0	460±431
	96	Other services	10	118±224	6±20	0±0	125±223
ANOVA (F)				47.32*	46.99*	16.08	48.41**

Table 2- 25. Waste generation rate at level 4

Level 4	Category	N	General Waste	Recyclable	Food residue	Total
1020	Aquaculture products	3	3839±6594	53±59	0±0	3892±6548
1061	Grinding and producing coarse flour	3	0±0	8938±4183	0±0	8938±4183
1062	Producing refined flour and starch	2	0±0	0±0	0±0	0±0
1071	Producing bread from flour	5	318±214	77±123	0±0	395±228
1073	Coco, chocolate and jam production	3	537±247	49±14	0±0	586±237
1079	Producing other foodstuffs	2	691±544	32±45	0±0	722±499
1079a	Producing tofu	1	0±0	0±0	9138±0	9138±0

Lv 2	Level 4	Category	N	General Waste	Recyclable	Food residue	Total
45	4520	Maintenance, repair of automobiles	2	439±259	83±66	0±0	522±193
	4530	Sale parts of automobiles	3	8±13	0±0	0±0	8±13
	4541	Sale of motors and motorcycles	3	37±63	85±146	0±0	121±127
	4542	Maintenance and repair of motors	7	246±287	72±108	0±0	318±258
	4543	Sale parts of motors and motorcycles	3	317±295	1286±2227	0±0	1603±2494
46	4610	Agency, intermediary, auction	2	89±62	0±0	0±0	89±62
	4620	Wholesale of agricultural and forestry raw	2	93±131	0±0	0±0	93±131
	4669	Other wholesale	7	3518±5291	2±5	0±0	3520±5291
47	4711	Foodstuff, beverages, cigarettes and other	2	847±91	46±65	0±0	893±26
	4719	Goods in department stores	6	120±104	393±437	0±0	513±377
	4721	Foods	3	85±102	6±11	14±24	105±81
	4722	Foodstuff	22	1085±1068	101±229	1847±5518	3033±5658
	4723	Beverages	3	54±50	151±261	0±0	205±260
	4724	Cigarettes, rustic tobacco.	2	546±737	0±0	0±0	546±737
	4741	Computers, software and	3	44±32	9±15	0±0	53±25
	4742	Audiovisual equipment	1	28±0	0±0	0±0	28±0
	4751	Cloth, wool, fibre and other textile goods	3	213±87	28±48	0±0	241±119
	4752	Gold, silver, copper, iron and tin, and	13	872±1912	319±630	0±0	1191±2523
	4759	Household interior furniture and	6	268±441	65±107	0±0	332±428
	4761	Books, newspapers & magazines	4	281±368	251±241	0±0	533±512
	4762	Audio, video tapes and discs	2	57±14	3±5	0±0	60±18
	4763	Sports equipments	1	221±0	37±0	0±0	257±0
	4764	Games and toys	2	105±12	0±0	0±0	105±12
	4771	Apparel, footwear, leather goods	6	360±319	51±125	0±0	411±382
	4772	Medical equipment, cosmetic products	3	115±79	209±78	0±0	323±25
	4773	Other commodities	12	785±1091	31±99	0±0	816±1117
	4774	Second-hand commodities	3	1305±1839	47±82	0±0	1352±1806

Table 2- 26. Waste generation rate at level 5

		N	General Waste	Recyclable	Food residue	Total
47221	Meat and products from meat	7	1628±845	0±0	5804±8931	7431±8715
47222	Retail of aquatic products	3	236±311	0±0	0±0	236±311
47223	Vegetables and fruits	5	2087±1058	251±434	0±0	2338±962
47224	Dairy products, and products from grain, flour	4	123±123	145±180	0±0	269±230
47229	Other foodstuffs	3	282±224	131±122	0±0	414±102
47521	Gold, silver, copper, iron and tin	2	292±299	169±23	0±0	461±321
47522	Paint, colour and varnish	3	38±15	125±217	0±0	163±209
47523	Construction glass	2	383±345	0±0	0±0	383±345
47524	Construction materials	3	2495±3944	828±1211	0±0	3323±5155
47529	Installing construction equipment	3	796±840	315±546	0±0	1111±1370
47731	Flowers, ornamental plants	5	1241±1112	69±154	0±0	1310±1149
47735	Gas, fuel coal	2	1496±1825	12±17	0±0	1508±1808
47739	Other new commodities	5	44±48	1±1	0±0	45±48

2.3.3.2 Waste composition and potential

Table 2.3-7 presents the composition of GW by 10 physical categories per business facility. It was revealed that plastic, paper, and food waste were dominant in most business categories. However, the composition was relatively different among categories in level 1. The results showed that food waste accounted for the largest part at category 3, 6, 7 in comparing to other physical categories. Paper was dominant at category 2, 4, 5. Rubber & leather was found at the category 1 with 15% because in category 1, there was a sub-category produce this material.

Table 2- 27. Waste composition and potential

Level 1	N	Plastic	Paper	Food waste	Rubber & leather	Grass & Wood	Textile	Metal	Glass	Ceramic	Other	Recycling potential	Composting potential	Other residue
1	24	12%	6%	29%	15%	5%	7%	8%	7%	0%	11%	25%	31%	44%
2	1	7%	48%	22%	0%	2%	21%	0%	0%	0%	0%	48%	18%	34%
3	49	12%	17%	36%	3%	5%	4%	2%	1%	4%	17%	27%	40%	33%
4	4	20%	43%	17%	0%	0%	0%	7%	0%	0%	13%	56%	17%	27%
5	3	21%	58%	22%	0%	0%	0%	0%	0%	0%	0%	27%	22%	52%
6	2	7%	10%	63%	0%	1%	5%	3%	6%	0%	5%	22%	64%	14%
7	4	13%	4%	58%	0%	0%	0%	20%	0%	0%	5%	30%	59%	11%

Although the some business facilities in Hue separated some recyclables and food residue collected

by informal sectors, some recyclable and compostable portions were discharged as GW. The authors categorized each component of GW according to the potential shown in Table 2.3-4, and aggregated the data by the following components: “Recycling potential in GW,” “Composting potential in GW,” and “Other residue in GW”.Table 2.3-7 also showed the recycling and composting potential of 7 categories at level 1.

2.3.3.3 Estimation of WGA from home-based business

To draw the total waste flow diagram of solid waste generated from business part in Hue, the authors estimated the total amount of three components (GW, SR, SFR) from the business facilities in Hue by each category. Additionally, the authors estimated the total recycling potential, composting potential, and residual food amount in GW.

Table 2.3-8 presents the estimation of total waste and the breakdown of the waste generated from business facilities of home-based business. The total waste generated from business part in Hue was 25,151 kg/day, of which 18,257 kg (73%) was GW, 4,767 kg (2.6%) was SR, and 2128 kg (8%) was SFR. The low percentage of SFR revealed that pig farmers were not played an important role in MSW systems in this sector.

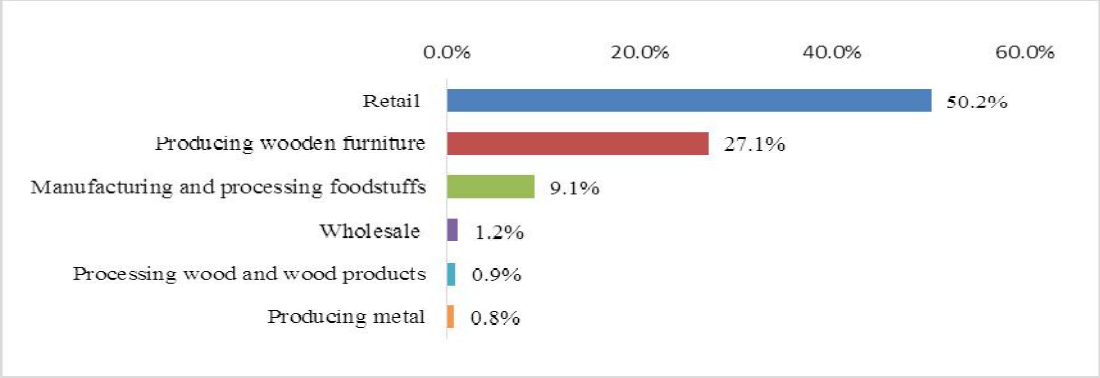
Table 2- 28. Total estimation of WGA from home-based business

Level 2		worker conver	RESIDUE	Re potentia	Food potentia	Separated re	Separated food	Total	
10	M & Pc foodstuffs	1859	655	407	280	1573	781	3696	14.7
11	Pd beverages	83	6	4	3	7	199	218	0.9%
13	Weaving	161	28	17	12	0	0	56	0.2%
14	Pd garments	2483	95	59	41	0	0	195	0.8%
15	Pd leather and	255	74	46	31	0	0	151	0.6%
16	Pc & Pd wood,	975	563	350	241	393	0	1547	6.2%
17	Pd paper and paper	716	59	37	25	54	0	176	0.7%
18	Printing, copying	158	10	6	4	8	0	28	0.1%
20	Pd chemical	198	25	15	11	60	0	110	0.4%
22	Pd rubber and	179	39	24	17	113	0	192	0.8%
23	Pd products from	423	19	12	8	101	0	139	0.6%
24	Pd metal	189	219	136	94	0	0	449	1.8%
25	Pd prefabricated	1158	174	108	75	76	0	433	1.7%
27	Pd electric	3	0	0	0	0	0	0	0.0%
29	Pd motor vehicles	3	0	0	0	0	0	0	0.0%
30	Pd other means of	41	9	5	4	13	0	31	0.1%
31	Pd beds, wardrobes, tables,	1058	3041	1887	1301	0	0	6229	24.8 %
32	Other M & Pc	36	0	0	0	2	0	2	0.0%
35	Pc and distributing	89	1	3	0	0	0	3	0.0%
45	Sale, repair of	1955	134	108	158	519	0	919	3.7%
46	Wholesale	498	382	308	451	1	0	1141	4.5%
47	Retail (excluding	11848	1834	1479	2167	1498	1148	8126	32.3
61	Telecommunication	773	27	57	26	24	0	134	0.5%
77	Leasing	311	7	4	3	1	0	14	0.1%
82	Administrative	231	8	4	4	49	0	66	0.3%
92	Lottery, betting and	45	0	0	0	7	0	7	0.0%
93	Sporting and	680	61	100	285	79	0	524	2.1%
95	Repair of	599	11	29	58	176	0	275	1.1%
96	Other personal	2300	30	81	161	15	0	287	1.1%
Total (kg)		29299	7512	5286	5459	4767	2128	25151	
%		116%	30%	21%	22%	19%	8%	100%	

2.3.3.4 Interval estimation and Uncertainty analysis

The 95% CI of the total waste amount from home-based business sector Hue was also estimated by Monte Carlo simulation (100,000 times) assuming normal distributions based on the means and standard errors of the WGRs shown in Table. The results showed that the range for a 95% CI was 15.07-27.78 tons/day.

The authors also examined the sensitivity as a percentage of the contribution from the WGR of home-based business category to the variance of the total waste amount. Figure presents the results of



Uncertainty analysison the total waste generated at home-based business sector. "Retail" was identified as the category with the largest impact on the CI of the total waste amount (50.2%), followed by "Producing wooden furniture" (27.1%), "Manufacturing and processing foodstuffs" (9.1%), and "whole-sale" (0.9%). To improve the reliability of the total estimation, the authors should start by improving the data reliability at "Retail" by a further survey to increase the sample size and clarify the influencing factors on WGRs of SFR and GW.

Conclusion

1) This study aimed to provide a detailed description of the solid waste generation and composition from business part at home-based business in Hue, Vietnam. The authors surveyed 245 households for seven categories at 1st level over seven consecutive days.
2) The WGRs by worker were assessed by business category by three waste categories: general waste (GW), separated recyclables (SR), and separated food residue (SFR).
3) The mean differences of WGRs of the total waste among the school categories were assessed by ANOVA test. There were significant differences in WGRs among categories.
4) GW was classified and measured by 10 physical categories and 77 sub-categories. Plastic, paper, and food waste were the dominant forms of waste in all categories.
5) The total waste generated from business part in Hue was 25,151kg/day, of which 18,257 kg (73%) was GW, 4,767 kg (2.6%) was SR, and 2128 kg (8%) was SFR. GW still contained 21% that could potentially be recycled and 22% that could potentially be composted in the total waste amount. The total disposal amount sent to the landfill could be reduced from 18,257 kg7512 kg

6) The 95% CI of the total waste amount was estimated to be 15.07-27.78 tons/day. According to the Uncertainty analysis, the WGRs of the "Retail" category were identified as having the largest impact on the CI of the total waste amount.

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2.4 Solid waste generation from traditional markets and supermarket

2.4.1 Introduction

In economically developing countries, the amount of municipal solid waste is approaching the capacity of existing waste facilities. It is impossible to continue waste disposal that is heavily dependent on landfill. Central and local governments must develop solid waste management (SWM) plans that include waste reduction and recycling.

Municipal solid waste is a growing problem in Vietnam, which is showing rapid economic growth year by year. Vietnam produces over 15 million tons of municipal solid waste each year from various sources. More than 80% (12.8 million tons/yr) derives from municipal sources: households, restaurants, markets, and businesses [1] As the first step in designing integrated waste management systems, it is indispensable to ascertain detailed and reliable information related to waste generation, waste composition, and waste streams [2]. However, Vietnam lacks reliable and detailed data related to SWM. The latest report on SWM in Vietnam published in 2011 presented information related to overall waste generation and physical composition of MSW around Vietnam, but did not clarify details related to waste generation from different sources or details related to waste composition such as recycling or composting potential.

Regarding the municipal solid waste sources, traditional markets are known to be a considerable source of waste generation in economically developing countries. One earlier study [3] found that markets contributed about 20% of total waste generation in Indonesia. According to the Vietnam Retail Association, traditional markets still constitute the major channel of the retail sector. About 8,550 traditional markets existed in Vietnam in 2011. However, few studies have specifically examined wastes from traditional markets. In Lao PDR, Byer et al

[4] surveyed one early morning market (EMM), and clarified the waste generation rate by six business categories: fruits and vegetables, packaged goods, meat/ fish/ eggs, food stalls, noodles and blood, rice, and charcoal. They assessed the physical composition, but reported no potential for recycling and composting. In Cambodia and Vietnam, two surveys [5]

[6] have assessed the waste generation rate by the total waste amount divided by the total number of stalls in target market, but they did not address differences in waste generation rates among business categories.

This study was undertaken to present a detailed description of waste generation and characteristic of traditional market in Hue city, Vietnam. The authors chose five markets from three

market classes, and allocated the targets by 17 business categories considering '*The System of Economic Branches of Vietnam*'. The authors also estimated the total waste amount, the recycling and composting potentials from all markets in Hue as the basis of rational SWM planning including waste reduction and recycling.

2.4.2 Methodology

2.4.2.1 Sample selection

Hue city, the latest imperial capital of Vietnam under the Nguyen dynasty, is located in the central region of Vietnam [7]. Hue city comprises 27 wards with area of 71.69 km^2 and a population of 350,345 people. There are two distinct seasons in Hue city: the dry season comes with the hot southwest wind for four months during April– August; the rainy season comes with high and unevenly distributed rainfall during September–March [8].

Regarding solid waste management, the amount of collected waste in Hue city is reported as approximately 210 tons/day. The general collection rate in the whole city was about 89%, and 90–95% in urban areas [9]

Table 2- 29. Outline of five target markets

Name	Tay Loc	Vy Da	Xep	Phuoc Vinh	Thong
Market class	1st	2nd	2nd	3rd	3rd
Number of cleanings	4	2	1	2	1
Number of stalls	682	280	365	179	112
Number of vendors	168	21	75	34	3-5
Number of target samples	91	66	63	58	30

Hue city has 23 traditional markets with different scales. According to Government Decree No. 2/2003/NĐ-CP [10] on market development and management, 23 markets in Hue city are classified into three classes in terms of their scale, trade volume, and facility conditions. Among them, 3 markets belong to the first class, 6 markets belong to second class, and 14 markets belong to the third class. Markets sell widely diverse items such as food, vegetable, meat, clothes, and household equipment.

Table 2- 30.Definition of business category

ID	Business category
1	Rice & powder
2	Meat and meat products
3	Chicken & Duck
4	Eggs
5	Fish & fish products
6	Vegetable
7	Betel and areca
8	Fruits
9	Coconut
10	Spice, Grocery, Cakes & candy
11	Food stalls
12	Beverages
13	Textiles, apparel, footwear
14	Fresh flowers, ornamental plants
15	Daily commodity, incense, porcelain
16	Service (hair cutting, foot repairing, other)
17	Recyclable, Second-hand clothes

There are businesses of two types in Hue, defined as follows.

- *Stall: a shop selling goods at a designated place with a contract for a certain period of time, normally located inside a market building*

- *Vendor: someone who is selling goods without contract for a certain period of time, normally located outside of market building*

Stalls and vendors in markets generate waste of many kinds such as rubbish from commodities, containers and packaging. Some of them separate recyclable items for recycling markets and food residues for animal feed in Hue.

For this study, the authors chose Tay Loc market from first class, Vy Da and Xep markets from second class, and Phuoc Vinh and Thong markets from third class as the target considering location and scale. An outline of the five markets is shown in Table 2-29.

Markets have widely diverse business categories. Prime Minister of the Government of Vietnam (VPM, 2007) issued '*The System of Economic Branches of Vietnam*' [11] and defined the business category in 642 branches. By referring the official definition, the authors defined 17 business categories for market as shown in Table 2-30. For target selection, the authors allocated target kiosks and vendors to cover 17 business categories.

2.4.2.2 Outline of survey

The authors conducted three surveys for all target samples: a waste generation survey by actual measurement, a waste composition survey, and a questionnaire survey. Surveys on Tay Loc, Xep and Phuoc Vinh market were conducted during 3 - 12 September. Surveys on Vy Da and Thong market were

conducted during 9 - 17 September. The waste generation survey was administered to acquire data on the amount of waste generation for 10 consecutive days. Of them, the first three days were spent for practice; the authors used the data for the latter seven consecutive days. The target stalls and vendors were requested to keep their waste in three categories by their original customs: *'Recyclables'*, *'Food residues'* and *'General waste'*,defined as follows.

- ✓ *Recyclables*: items kept for recycling or sale to informal sectors or given to somewhere/someone by owners.
- ✓ *Food residues*: waste items kept for livestock (e.g. pigs) feeding; generally collected by livestock breeders.
- ✓ *General waste*: all remaining waste items excluding separated waste items described above. This type of waste is collected daily by an environmental company in Hue (HEPCO).

A waste composition survey was also conducted during the survey period. To provide information related to the recycling and composting potentials, the authors analysed details of the waste composition of 'General waste' for some representative targets. The waste was classified into 10 physical categories and 77 sub-categories. The classification categories were based on Materials (Plastic, Paper, Kitchen waste, Rubber & Leather, Grass, Textile, Metal, Glass, Ceramic, and Miscellaneous), Types (Container/Packaging, Product and Other), Recycling potential (recyclable and non-recyclable), and Composting potential (compostable and non-compostable). The recycling potential was defined based on the practical trading status of recycling market in Hue city. Recyclable items contained plastic, paper, glass, metal, and textiles that can be bought and sold at a recycling market. The composting potential was defined based onthe acceptable items of some composting plants. Organic wastes are divisible into compostable and non-compostable wastes. Compostable items consisted of vegetables, food residue, grass, leaves, flowers, egg shells, fish bones, fruit, and fruit skins. Non-compostable items consisted of coconut shells, hard bones of animal, seashells, bamboos, large tree branches, and wood products. In this study, non-recyclable items were all items that could not be recycled or composted. Descriptions of waste classification categories are presented in Table 2-3. The authors also administered a questionnaire survey to assess attributes and the current status of businesses of target stalls and vendors.

2.4.2.3 Analytical procedure

The authors calculated key statistics related to waste generation rates by business category. The authors also assessed the mean difference among market classes using analysis of variance (ANOVA). The waste composition by percentage (%) was calculated according to the physical category and by recycling and composting potentials.

By multiplying the waste generation rate by stall/vendors by total number of stall/vendors in Hue, the authors estimated the total waste generation amount from traditional market in Hue. The authors also calculated the 95% confidence interval of total waste generation amount from a Monte Carlo simulation (100,000 times) based on the mean and standard error of waste generation rate by business category. Monte Carlo simulations are used widely to assess error propagation for model parameters [12] The authors inferred the sensitivity as a percentage of the contribution from each parameter to the variance of the final result [14]

2.4.3 Results and discussion

2.4.3.1 Waste generation rate of traditional markets

(1) Waste generation rate by stall/vendor

Table 2- 31. Waste generation rate by stall (g/stall/day)

Category	*N*	General waste	Recyclable	Food residues	Total waste
		Mean ±Standard deviation			
Rice, powder	6	89±89	8±20	13±31	110±95
Meat/meat product	13	268±305	-	20±40	289±299
Chicken &duck	12	102±165	-	2664±3264	2766±3194
Egg	4	445±644	291±314	-	737±555
Fish& fish product	32	248±269	-	2513±2445	2761±2486
Vegetable	40	4893±5525	-	250±727	5143±5657
Betel & areca	2	1138±597	140±37	-	1278±634
Fruit	31	3865±2921	520±853	184±1023	4568±3343
Spice & Grocery	37	392±866	149±301	218±939	759±1342
Food stall	21	762±717	9±42	2754±3594	3525±3801
Beverages	10	2829±3023	170±271	324±1023	3323±2955
Textiles & Apparel	16	195±157	43±166	-	238±242
Fresh flowers	11	3209±4009	-	-	3209±4009
Daily commodity	18	271±283	182±514	-	453±566
Service	14	190±114	8±27	-	198±116
Second-hand shop	4	292±491	124±152	-	416±409

Table 2- 32. Waste generation rate by vendor (g/vendor/day)

Category	N	General waste	Recyclable	Food residues	Total waste
		Mean ±Standard deviation			
Rice, powder_vendor	1	268	-	-	268
Egg_vendor	2	412±197	-	-	412±197
Fish& fish product_vendor	2	-	-	1628±462	1628±462
Vegetable_vendor	11	3918±3117	-	88±212	4006±3039
Betel and areca_vendor	2	4226±4848	-	-	4226±4848
Fruit_vendor	7	1811±1911	71±123	-	1882±1867
Coconut_vendor	2	91801±1040	-	-	91801±1040
Spice & Grocery_vendor	3	291±375	-	-	291±375
Food stall_vendor	5	493±418	-	876±1206	1369±868
Textiles & Apparel_vendor	1	23	-	-	23
Fresh flowers_vendor	2	1451±84	-	-	1451±84

Table 2- 33. Waste generation rate by floor area

Category	Tay Loc					Xep				
	Area	GW	Re	FR	Total	Area	GW	Re	FR	Total
	m^2	$g/m^2/day$				m^2	$g/m^2/day$			
Rice&powder	3.2	42±24	8±11	-	49±34	1.69	1	1	-	2
Meat&meat product	2	250±247	-	-	250±247	1.69	272±266	-	-	272±266
Chicken &duck	3.6	-	-	178±7	178±7	2.25	40±63	-	2050±1670	2090±1622
Egg	-	-	-	-	-	2.25	338±408	167±189	-	505±218
Fish&fish product	3.6	126±115	-	1209±913	1335±940	1.69	163±164	-	739±925	903±861
Vegetable	3.6–10.8	2274±1531	-	49±63	2324±1518	1.69–3.38	964±575	-	78±100	1042±557
Betel & areca	-	-	-	-	-	2.25	693	74	-	767
Fruit	3.6	1248±857	-	-	1248±857	1.69–3.38	1362±886	402±625	211±596	1975±1288
Spice & Grocery	2–6.4	73±47	80±129	-	153±159	2.25–4.5	23±12	73±90	-	96±86
Food stall	3.6–7.2	199±207	-	1085±1030	1283±949	2.25–4.5	353±351	14±35	1252±2149	1619±2464
Beverages	3.6	2095±235	69±11	-	2163±246	2.25–4.5	397±400	147±69	-	544±469
Textiles & Apparel	3.6–12	66±38	-	-	66±38	4.5	13±9	-	-	13±9
Fresh flower	3.6–7.2	1224±1465	-	-	1224±1465	2.25–7.29	444±269	-	-	444±269
Daily commodity	2–4	125±126	29±64	-	154±182	1.69–14.58	83±70	4±7	-	88±73
Service	2–3.6	53±22	-	-	53±22	7.29	23	14	-	37
Second-hand shop	3.2	91±153	39±48	-	130±128	-	-	-	-	-

GW, General waste; *Re, Recyclable*; *FR, Food residue*

The waste generation rates of traditional market were calculated using business categories. Table 2-31 presented the mean and standard deviation of waste generation rate (g/stall/day) of stall in three market classes. Regarding the waste generation rate by business category, '*Vegetable'*, '*Fruits'*, '*Beverage*' and '*Fresh flowers*' were higher in all wastes, whereas *'Rice'*, *'Meat'*, *'Service*' and '*Second-hand shop*' were identified as having lower generation rates. The result resembled that reported from a previous study by Byer et al

[4]. They reported that 'Fruits and vegetables' generated the largest amount (6.49 kg/day) because of their high moisture contents.

Regarding fresh items that are easily be perishable after 1–2 days under normal conditions such as *'Meat & meat product'*, '*Chicken & duck'*, *'Fish & fish product'*, *'Vegetable'*, *'Fruit'*, *'Fresh flowers'*, the category of *'Meat & meat product'* generated the smallest amount with 289 (g/stall/day), whereas the other categories generated much higher waste amounts.In the category of *'Vegetable'* and *'Fruit',* even though the total waste amount was rather large, the amounts of food residues were quite small because the rotten or leftover vegetables and fruits were normally unsuitable for feeding animals. Conversely, the categories of '*Chicken & duck', 'Fish & fish product'* generated a large amount of food residues because these categories had processing services on site. Therefore, normally the internal organs and unnecessary parts were separated as food residues.

Some dry-food items such as '*Rice/powder'* and *'Spice and grocery'* produced smaller amounts with 110 and 759 (g/stall/day), respectively. Regarding food services, *'Food stalls' & 'Beverage'* respectively produced similar total waste amounts, with 3,525 and 3,323 (g/stall/day). However, *'Beverage'* generated small amounts of food residues, whereas a major amount of wastes in *'Food stalls'* were food residues. Table 4 also shows that some business categories such as '*Meat'*, '*Chicken & Duck'*, '*Fish'*, '*Vegetable'*, and '*Freshflowers*' did not separate recyclables.

Table 2-32 presents the mean and standard deviation of waste generation rate (g/vendor/day) of vendors in three market classes. The *'Coconut_vendor'* category was separated from '*Fruit_vendor*' because the waste generation rate of *'Coconut_vendor'* was extremely high, with 91,801 g/day, which was much higher than that of *'Fruit_vendor'* with 1,882 g/vendor/day. Comparing the waste generation rate of a stall with that of a vendor, some categories with higher waste generation rates such as *'Fish & fish product'*, *'Vegetable_vendor'*, *'Fruit'*, *'Food stall' and 'Fresh flowers',* the waste generation rate of a stall was higher than that of a vendor. That result is explainable that the space and business scale of vendors were normally smaller than those of stalls; the resultant waste generation rate was lower. The

vendors did not separate recyclables in most business categories excluding *'Fruit_vendor'*; the food residue amount was small excluding *'Fish_vendor'* and *'Food_vendor'* as stalls, probably because they had insufficient space to keep such wastes.

(2) Waste generation rate by floor area

In the traditional market, the stall areas differ among market classes and business categories. The authors calculated the waste generation rate by floor area for two markets for which the managers of markets provided the official data on floor area of each stall, Tay Loc as a first class market and Xep as a second class market. Table 2-33 presents the means and standard deviations of waste generation rate of 17 business categories by floor area (g/m^2/day) in two markets.

The floor areas in most business categories in the first class market were larger than those of the second class market. For '*Rice & powder'*, '*Fish & fish product'*, '*Vegetable'*, '*Spice & Grocery'*, '*Beverage'*, '*Textile & Apparel'*, '*Fresh Flowers'*, '*Daily commodity*' and '*Service'* categories, the waste generation rate of total waste by square meter was higher for the first class market than for the second class market. For '*Meat & meat product'*, '*Fruit'* and '*Food stall*' categories, the waste generation rate of total waste by square meter was higher for the second class market, but the waste generation rate of total waste by stall was higher for the first class market. In most of business categories, the stalls in first class market discharged more waste than those in the second class. In the first class market, no stalls existed for '*Egg*' and '*Betel & areca*' categories. These items were sold only at vendors in the first class market.

Regarding the '*Chicken &duck'* category, the waste generation rate of total waste by square meter in the first class market was 178 g/m^2/day, which was much lower than that in the second class market at 2,090 g/m^2/day. By the observation in both markets, the difference noted above can be explained by the habit of stall owner in keeping internal organs of '*Chicken & duck*' in each market. In the first class market, the owners generally separated internal organs and sold them to customers, whereas the owners in the second class market normally put internal organs into containers as food residues for livestock breeders and occasionally sold them to customers upon request.

(3) *Mean difference in waste generation rate by market class*

Regarding comparison among three market classes, the authors assessed the mean difference in waste generation rates among the three market classes by 17 business categories using ANOVA. The authors found significant mean differences for *'Fish'* and *'Vegetable'*.Table 2-34 shows means and SDs of waste generation rates for *'Fish'* and *'Vegetable'* by three market classes and ANOVA results. The waste generation rate was the highest in the first class, and lower in the second class and the third class.

Table 2- 34. Waste generation rate by market class (g/stall/day)

Category	Market	*N*	General waste	Food residues	Total waste
Fish& fish product	1	7	452±412	4352±3288	4804±3384
	2	14	207 ±224	1428 ±1095	1635 ±1018
	3	11	169±137	2725±2533	2894±2493
ANOVA (*F* value)			***3.001***	***4.077****	***4.74****
Vegetable	1	9	11785±7877	340 ±564	12125 ±8134
	2	14	2928 ±2757	199±358	3127±2996
	3	17	2863 ±1653	245 ±1009	3108 ±1504
ANOVA (*F* value)			***15.972*****	***0.098***	***15.351*****

**p<0.05; **p<0.01; ***p<0.001*

The differences among three markets are explainable by the fact obtained from questionnaire survey that, in the first class market, the area was largest and the operation time was very long, whereas the area and operation time were smaller in the second and third class markets, which can be expected to influence the amounts of sales and waste generation.

2.4.3.2 Waste composition of market

(1) Physical composition

The physical composition of general waste by business category is shown in Table. The physical composition differs among business categories. The results indicated that food waste accounts for the largest part with subsequent plastic or grass. The proportions of food waste were high, with 93.2%, 81.7% and 77.2%, respectively, in 'Vegetable', 'Fruit' and 'Beverage'. Previous reports have described that the major portion of solid waste in market is food waste and other organic matter. A survey conducted in Danang
[6] reported that the organic part accounted for 81.5%. A survey in Thailand also presented that the organic from market was 85% [14].

Table 2.4-7. Physical composition by business category (%)

ID	*N*	Plastic	Paper	Food	Rubber	Grass	Textile	Metal	Glass	Ceramic	Other
Rice, powder	6	6.8%	0.7%	52.6%	0.1%	21.5%	-	-	-	-	18.3%
Meat	15	48.2%	0.9%	44.8%	-	2.9%	-	-	-	-	3.3%
Chicken &duck	2	51.8%	9.9%	24.4%	11.3%	1.5%	-	1.0%	-	-	-
Egg	7	9.4%	2.1%	67.8%	-	20.5%	-	-	-	-	0.1%
Fish	30	32.6%	0.2%	45.1%	-	4.7%	-	-	-	-	17.4%
Vegetable	17	2.8%	0.3%	93.2%	-	1.3%	-	-	-	-	2.4%
Betel & areca	2	2.2%	0.1%	14.7%	-	83%	-	-	-	-	-
Fruit	14	1.6%	3.5%	81.7%	0.1%	12.7%	-	-	-	-	0.3%
Spice & Grocery	33	26.4%	14.7%	52.5%	1.6%	2.2%	0.1%	0.5%	-	-	2%
Food stalls	25	7.4%	8.3%	25%	0.2%	51.9%	2.9%	-	-	-	4.3%
Beverages	8	8.1%	0.1%	77.2%	-	8.6%	-	-	-	-	6.1%
Textiles &footwear	13	40%	15.1%	20.3%	21.2%	-	0.7%	2.1%	-	-	0.5%
Fresh flowers	6	2.1%	1.7%	21.7%	-	74.5%	-	-	-	-	-
Daily commodity	11	10.4%	12.7%	62.3%	0.2%	3.8%	2.3%	0.1%	-	8.0%	0.1%
Service	5	30.1%	2.4%	31.6%	0.1%	2.4%	11.6%	0.8%	-	-	21%
Second-hand shop	2	29.0%	69.5%	-	-	-	-	-	-	-	1.4%

The categories of '*Meat*', '*Fish*', '*Textile*' and '*Spice'* generated plastics with higher percentage, using mainly single-use plastic bags for packaging, whereas *'Betel & areca', 'Fresh flower'* and *'Food stalls'* categories generated grass with higher percentages. These results directly reflected the fact that some parts of *'Betel and areca'* and *'Fresh flower'* such as stems, leaves, and un-needed parts are often removed according to requests from customers. 'Food stalls' generated large amounts of grass because Vietnamese people have a habit of wrapping some foods in leaves such as banana or lotus leaves. They discard them after use. Glass was not found in all categories, and ceramic was only found in *'Daily commodity*' with 8%. Rubber was found in *'Chicken & duck'* because rubber bands are usually used to tie live chicken or duck legs. The '*Textiles & footwear'* category generated some rubber because rubber pieces were often used to repair shoes.

(2) Recycling and composting potential of waste from traditional markets

Table 2-35 presents waste composting and recycling potentials from general waste by business category according to the definition shown in Table

Table 2- 35. Recycling and composting potential of general waste (%)

Category	N	Non-recyclable	Recyclable	Compostable
Rice/powder	6	18.1%	6.4%	75.5%
Meat	15	8.7%	48.9%	42.4%
Chicken &duck	2	26.1%	46.4%	27.5%
Egg	7	3.0%	10.5%	86.6%
Fish	30	18.0%	32.3%	49.7%
Vegetable	17	2.8%	2.9%	94.3%
Betel & areca	2	1%	1.3%	97.7%
Fruit	14	3.8%	4.1%	92.1%
Spice & Grocery	33	8.7%	37.8%	53.5%
Food stalls	25	14.4%	9.5%	76.1%
Beverages	8	6.2%	8.2%	85.7%
Textiles &footwear	13	11.9%	63.6%	24.4%
Fresh flower	6	2.7%	2.7%	94.5%
Daily commodity	11	14.5%	21.4%	64.1%
Service	5	34.6%	24.7%	40.7%
Second-hand shop	3	1.4%	98.6%	0.0%

3. It is apparent that the composting potential was very high in some categories such as *'Betel & areca', 'Vegetable', 'Fruit' and 'Fresh flowers'.* The recycling potential was highest in the category of *'Second-hand shop'* with 98.6%followed by *'Textiles & apparel'* with 63.6%, *'Meat' with 48.9%* and *'Chicken & duck'* with 46.4%.

2.4.3.3 Estimation of total waste generation from traditional market in Hue

(1) Validation of general waste at three markets

To validate waste generation rates, the authors estimated the 95% confidence intervals (CIs) of total amount of general waste for three target markets, Tay Loc in the first class, Xep in the second class and Phuoc Vinh in the third class, and compared the CIs with the measured waste amounts by actual measurement on site. By multiplying the waste generation rate by the stall/vendor by total number of stall/vendor in target markets, the authors calculated the total amounts of general wastes for the target markets. The 95% confidence interval for each market was estimated using Monte Carlo simulation (100,000 times) based on the mean and standard error of the waste generation rates shown in Tables 2-31 and 2-32. Table 2-36 presents the 95% CIs of general waste (kg/day) and the measured waste amounts in three markets. The results show that the measured waste amounts were in the 95% CI range for the three markets.

Table 2- 36. Interval estimation of three markets and actual amount

Market	95% CI of general waste (kg)	Actual amount (kg)
Tay Loc market	1412–2163	1766
Xep market	286–502	473.8
Phuoc Vinh market	252–363	343.5

(2) Total waste generation from traditional markets

Table 2- 37. Waste amounts by business category from 23 markets (kg/day)

Category	N	General waste			Recyclable	Food Residues	Total
		Non - recyclable	*Recycling potential*	*Composting potential*			
Rice&powder	220	4	1	15	2	3	24
Meat	630	15	83	72	-	13	182
Chicken &duck	75	2	4	2	-	200	208
Egg	18	0	1	7	5	-	13
Fish	1,045	48	86	133	-	2,737	3,004
Vegetable	951	132	135	4,422	-	238	4,928
Betel &Areca	50	1	1	56	7	-	64
Fruit	427	63	68	1,520	222	79	1,951
Coconut	5	459	-	-	-	-	459
Spice &Grocery	1,315	45	195	276	196	286	998
Food stalls	265	29	19	154	2	730	934
Beverages	90	16	21	218	15	29	299
Textiles & Apparel	968	23	120	46	42	-	231
Fresh flowers	64	6	6	194	0	-	205
Equipment, watch	545	21	32	95	99	-	247
Service	181	12	9	14	2	-	36
Second-hand shop	61	0	18	0	8	-	25
Rice&powder_vendor	36	2	1	7	0	0	10
Egg_vendor	16	0	1	6	0	0	7
Fish& fish product_vendor	79	0	0	0	0	129	129
Vegetable_vendor	436	48	49	1,611	0	38	1,746
Betel and areca_vendor	20	1	1	83	0	0	85
Fruit_vendor	224	15	17	374	16	0	422
Coconut_vendor	6	551	0	0	0	0	551
Spice & Grocery_vendor	141	10	7	53	0	124	193
Food stall_vendor	31	0	0	0	0	0	1
Textiles & Apparel_vendor	16	1	1	22	0	0	23
Amount (kg)		***1,502***	***872***	***9,377***	***616***	***4,605***	***16,972***
Amount (tons)		***1.5***	***0.9***	***9.4***	***0.6***	***4.6***	***17.0***
Percentage		***8.8%***	***5.1%***	***55.2%***	***3.6%***	***27.1%***	***100%***

Hue city has 23 traditional markets. Because of a lack of information exists for the floor area by each business categories in 23 markets, in this study, the author used only the number of stalls by business category as an indicator for estimation the total amount of waste from traditional market in Hue. By multiplying the waste generation rate by stall/vendor by the total number of stall/vendors in 23 markets, the authors calculated the total amount of general waste, recyclable, food residue, and total waste by business category. The authors also estimated the potentials of recycling and composting in general waste separately.

Table 2-37 presents details of waste generation from a traditional market in Hue: non-recyclable,

recycling potential, composting potential contained in general waste: recyclable, food residues, and total waste by weight (kg/day) by business category. The total waste generation amount was 17.0 tons, of which 3.6% of waste was separated at the source as recyclable, 69.2% was general waste, and 27.1% was food residues. In general waste, the recycling potential accounted for 5.1%, composting potential accounted for 55.2%, and the remaining waste accounted for only 8.8%. This result indicates that waste generation in markets has high potential up to 82.3% of total for composting and livestock feeding. The total disposal amount sent to the landfill site can be reduced from 69.2% to 8.8%.

Regarding the *'Coconut'* category, the waste generation rate was the highest with 91.8 kg/stall/day and was mainly composed of coconut shell. Therefore, we did not bring it to the laboratory to examine the composition. The authors assumed that the total generated waste from the '*Coconut'* category was non-recyclable

Regarding composting potential, *'Vegetable'* accounted for the largest amount with 4,422 kg/day, followed by *'Vegetable_vendor*', (1,580 kg/day) and *'Fruit'* (1,520 kg/day). These results suggest that these sources would contribute immensely to promoting waste reduction. Regarding about the recycling potential, the largest contribution category was *'Spice & grocery'* with 195 kg/day, followed by *'Vegetable'* (135 kg/day), *'Textiles & apparel'* (120 kg/day*), 'Fish'* (86 kg/day), and *'Meat*' (83 kg/day). The results revealed that these categories should be considered heavily for promotion for recycling for market.

The total estimated composting potential was 9.4 tons, which contributes mostly to the total general waste in the market. The large quantity of composting potential present in the MSW stream has a great impact on the production of high-quality compost and offers great potential for resource recovery. Such recovery is expected to play an important role in reducing total waste generation amount and in mitigating the negative effects on environmental quality and natural resource conservation.

2.4.3.4 Interval estimation of total waste generation from traditional market in Hue

The 95% confidence interval (CI) of total waste amount from 23 markets was also estimated using Monte Carlo simulation (100,000 times) based on the mean and standard error of waste generation rate shown in Tables 4 and 5. The results showed that the range of 95% CI was 14.9–18.9 tons/day.

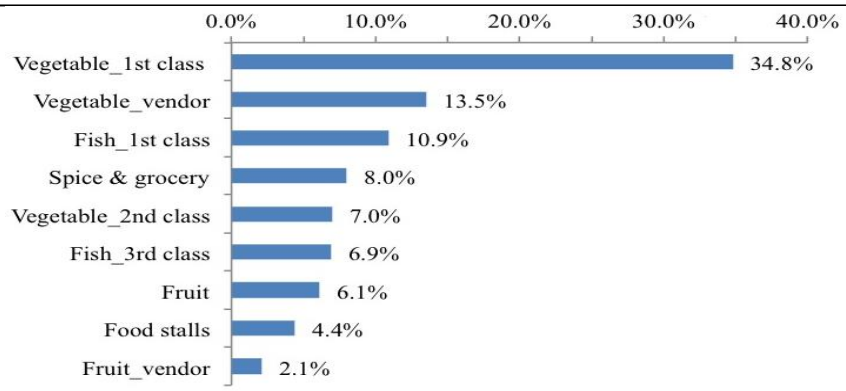

Figure 2- 6. Sensitivity analysis of total waste generation.

The authors also examined the sensitivity as a percentage of the contribution from the waste generation rate of each business category to the variance of the total waste amount. Figure 2-6 presents the result of Uncertainty analysis. '*Vegetables of first class market*' was identified as the category with the largest contribution (34.8%) to the variance of the total waste amount, followed by *'Vegetable_vendor'* (13.5%)and'*Fish of first class,'* (10.9%). To improve the reliability of total estimation, the sample size should be increased. Further investigation must be undertaken to clarify the factors affecting waste generation rate in these categories.

2.4.4 Waste generation from supermarket

The total waste amount from super market was estimated as 2.5 tons/day

Conclusions

1) This study produced a detailed description of waste generation and composition by 17 business categories in a traditional market in Hue city, Vietnam. In all, 309 stalls/vendors in five markets were surveyed for 10 consecutive days in the dry season.

2) The waste generation rate by stall/vendor was assessed by each business category by three waste categories: general waste, recyclable, food residues. The waste generation rates of '*Vegetable*', '*Fruits*', '*Beverage'* and '*FreshFlowers'* were higher in all wastes, whereas those of '*Rice*', '*Meat*', '*Service'* and '*Second-hand shop'* were identified as having lower generation rates.

3) Significant mean differences of total waste amount were found in '*Fish'* and '*Vegetable'* categories. The waste generation rate was highest in the firstmarket class and lower in the second market class and third market class.

4) The waste generation rate by floor area was also calculated in two markets in first and second classes. In most business categories, the stalls in the first class market discharged more waste than those in the second class.

5) The general waste was classified into 10 physical categories and 77 sub-categories. Food waste accounted for the largest part, followed by plastic and grass. The results from sub-categories demonstrated the potential for composting and recycling.

6) As the validation of waste generation rate, the authors estimated the 95% confidence intervals (CIs) of total amount of general waste for three target markets and compared the CIs with the measured waste amounts by actual measurements conducted on site. The measured waste amounts were in the 95% CI range for the three markets.

7) The authors also estimated the total generated waste, the recycling and composting potential for 23 traditional markets in Hue. The total waste generated from market was 17.0 tons/day, of which 4.6 tons (27.1%) was collected by pig farmers for feeding livestock and 0.6 tons (3.6%) was sold to the recycling market. The composting potential accounted for 55.2% and the recycling potential accounted for 5.1% of total waste generation from traditional market in Hue. The total disposal amount sent to the landfill site would be reduced from 69.2% to 8.8% of the total.

8) By the Monte Carlo simulation, the confidence interval of total waste generation from traditional market in Hue was estimated. The 95% CI of total waste was 14.9–18.9 tons/day. By Uncertainty analysis, '*Vegetable of first class market*' was identified as the category with the largest contribution to the variance of the total waste amount with subsequent *'Vegetable_vendor' and 'Fish of first class'*. To improve the reliability of total estimation, the sample size should be increased and further investigation is necessary to clarify the factors affecting waste generation rates in these categories.

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CHAPTER 3. SOLID WASTE GENERATION FROM INSTITUTIONAL SECTOR

3.1 Solid waste generation from educational facilities

3.1.1 Introduction

The amount of municipal solid waste (MSW) generated in Vietnam has been increasing in recent years. The amount of MSW was approximately 19 million tons in 2008 [1] and increased to 23 million tons in 2014 [2]. The amount of waste is expected to increase to 61.6 million tons by 2020 [3]. The rapid increase in MSW has posed significant challenges for Vietnamese solid waste management authorities. In addition, in 2015, the Vietnamese government issued a national strategy to manage waste and discarded material (Decree no. 38/2015/NĐ-CP), which indicated that daily-life solid waste must be classified and stored according to the following three categories: biodegradable organic, reusable and recycled, and "other" [4]. Determining the recyclable and organic amounts is indispensable for Vietnam's handling of waste in the years to come.

It should also be noted that some categories of waste are collected by informal sectors in developing countries; these include recyclables for sale and leftover food waste for farmers to feed animals [5]. A survey in Hanoi showed that recyclable waste accounted for approximately 20% of MSW [6]. As for food residue, the estimated amount of recycled food residue was 4.1% of the domestic waste collected in Danang, Vietnam [7]. However, most previous studies in Vietnam mainly focused on MSW collected by formal sectors [8-11]. To design a comprehensive MSW plan, Vietnamese authorities need to determine the total material flow of MSW, including the waste recovered by informal sectors.

Currently, MSW management in Vietnam has been empirically planned without the use of reliable data, but it will include such data in the near future. Shortcomings in MSW data include inconsistencies in definitions and collecting data; lack of unification in reporting data among the municipalities; and differences in the amount of waste generated, which makes predicting trends difficult [1]. As some previous studies have mentioned, it is important to understand the amount of waste generated, the waste composition, and the waste stream as the first step in developing an effective MSW strategy that includes 3R promotion (reduce, reuse, recycle) [12, 13].

MSW is generated and discharged from various sources: households; commercial sources like hotels, restaurants, and markets; and institutional sources like educational facilities, medical facilities, and offices. To promote the 3Rs, it is indispensable for all members of society to separate valuable items such as recyclables and food residue. In particular, the public sector is responsible for raising awareness

and promoting waste separation. Educational facilities could assume a role in educating individuals, and take the lead in 3R promotion.

Previous studies have investigated the generation of waste from educational facilities, but some studies have focused only on universities [14, 15, 16], and other studies have surveyed waste from primary and secondary schools [17, 18]. They did not cover all school categories from nursery school through university. One study in Vietnam surveyed waste from educational facilities, but the study did not provide details on waste composition, the potential for recycling and composting, or waste collected by informal sectors [19].

In order to provide the scientific information that can contribute to the promotion of the 3Rs at educational facilities, this study aimed to provide a detailed description of the solid waste generation and composition from educational facilities in Hue, Vietnam. The authors surveyed six school categories, ranging from "Day-care center" to "College & University," including "Private tutoring," according to "The system of economic branches of Vietnam, 2007" [20], and analyzed differences by category. The authors conducted a survey on the waste collected by formal sectors, and also measured the amount of separated recyclables and food residue collected by informal sectors. The waste collected by formal sectors was classified into 10 physical categories and 77 sub-categories to identify the potential for recycling and composting the waste. This study also conducted an interval estimation of the total waste in Hue, and aimed to clarify the reliability of collected data and improve future tasks through uncertainty analysis.

3.1.2 Methodology

3.1.2.1 Sample selection

Hue, the capital city of Thua Thien Hue province, located in the center of Vietnam, was selected as the study area. Hue is comprised of 27 wards with a total area of 71.7 km^2 and a population of 342,556 as of 2011 [21]. Hue is well known for its historical monuments, which were deemed World Cultural Heritage sites on December 11, 1993, by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) [22]. Regarding solid waste management, the amount of collected waste in Hue is reported to be approximately 210 tons/day. The collection rate in the entire city was about 89%, and 90–95% in urban areas, in 2011 [23].

There are a total of 402 educational facilities in Hue. The authors covered six school categories according to "The system of economic branches of Vietnam, 2007": "Day-care center," "Kindergarten," "Primary school," "Secondary school," "College & University,"and "Private tutoring." For the sample

selection, the authors used the lists of schools by school category. For “Kindergarten,” “Primary school,” “Secondary school,”and “College & University,”the lists provided the number of students at each school. Thus, the authors sorted the lists by the number of students and chose target schools by systematic sampling. Regarding “Day-care center” and “Private tutoring,” the lists did not include data on the number of students at each school. Therefore, the authors chose target schools from the original lists without sorting by systematic sampling. A total of 35 targets were selected. The total number of facilities in Hue, the number of targets, and the description by school category are shown in Table 1.

3.1.2.2 Outline of survey

This survey focused on MSW and did not include construction and demolition waste, medical waste, or hazardous waste. The procedure for the waste generation survey followed the methodology presented byMatsui et al. (2014) [24]. The authors conducted three surveys for all target facilities: a waste generation survey by actual measurement, a waste composition survey, and a questionnaire survey.

A waste measurement survey was conducted to acquire data on the generation amount for seven consecutive days. Before the survey period, the authors spent three days to prepare and practice with surveyors and target facilities. The target facilities separated the waste into three categories according to their usual customs; waste collected by formal sectors (hereinafter referred to as “general waste (GW)”), recyclables sold to informal sectors (hereinafter referred to as “separated recyclables (SR)”), and food residue sold/given to pig farmers (hereinafter referred to as “separated food residue (SFR)”). The surveyors measured and recorded the amount of waste per category (GW, SR, SFR) daily. The separation rates for recyclables and food residue were as follows:

- Day-care center: 0% for recyclables; 0% for food residue
- Kindergarten: 33% for recyclables; 100% for food residue
- Primary school: 57% for recyclables; 86% for food residue
- Secondary school: 78% for recyclables; 67% for food residue
- College & University: 100% for recyclables; 100% for food residue
- Private tutoring: 0% for recyclables; 0% for food residue

Table 3- 1. Total number of and samples from educational facilities in Hue by school category

Category	Total number in Hue	Number of targets	Description [25]
Day-care center	126	6	Provides nurturing and caring for children from 3 months old to 3 years old.
Kindergarten	49	9	Accepts children from 3 to 6 years of age. This service is offered by both public and private sectors.
Primary school	37	7	Consists of five grades (Grades 1 to 5), starting with 6-year-old children. Children will complete primary schools at the age of 11.
Secondary school	35	9	Includes two levels: lower and upper secondary education. Lower secondary education consists of four grades (Grades 6 to 9). Upper secondary education comprises three grades (Grades 10 to 12).
College & University	11	2	Includes colleges, universities, and academic research institutes.
Private tutoring	55	2	Provides learning services to help students preparing for important examinations or to simply enhance their knowledge in specific subjects (e.g., English, mathematics, etc.)

The authors conducted a waste composition survey for GW during the survey period. To acquire the information relating to recycling and composting potential contained in GW, the authors classified GW into 10 physical categories and 77 sub-categories. This classification system was based on material (plastic, paper, kitchen waste, rubber & leather, grass, textiles, metal, glass, ceramic, and miscellaneous), type (container/packaging, product, and other), and potential to recycle and compost. The recycling potential was based on the practical trading status of the recycling market in Hue. Recyclable items contained plastic, paper, glass, metal, and textiles that can be bought and sold at a recycling market. The composting potential was based on the acceptable items as determined by some composting plants in Vietnam. Descriptions of waste classification categories are included in Table 2-3. The authors asked the persons in charge of facility management or waste handling to record the attributes and current status of target facilities by using the structured questionnaire and through interviews. The questionnaire was designed to obtain detailed information on relevant factors (business-scale indicators) influencing waste generation, recycling activities, and attitudes toward solid waste management at each facility.

3.1.2.3 Analytical procedure

The authors calculated basic statistics relating to waste generation rates (WGRs) by waste generation amount divided by five indicators: facility, classroom, baby/kid/student (hereinafter referred to as "Student"), staff members (including lecturers, managers, researchers, and other people who provide service at educational facilities), and area. The mean differences of WGRs of total waste among the six school categories were assessed by analysis of variance (ANOVA). The authors also calculated the coefficients of variations (CVs: standard deviations divided by means) of WGRs, and compared the CVs among five indicators. The CV was used as the indicator of reliability in this study. The authors chose WGRs with smaller CVs among five indicators for further analyses.

The waste composition of GW by percentage was calculated according to the 10 physical categories by school category. In addition, based on 77 sub-categories, the authors assessed the recycling and composting potential in GW. The total waste generated from educational facilities in Hue was determined through extrapolating by the total number of facility/student in Hue and the waste generation rate by facility/student. ("Day-care center" and "Private tutoring" were estimated by facility. "Kindergarten," "Primary school," "Secondary school," and "College & University"wereestimated by student). The authors also calculated the 95% confidence interval (CI) of the total waste generated by a Monte Carlo simulation (100,000 times) based on the mean and standard error of the WGR by student/facility per educational category. Monte Carlo simulations are used widely to assess error propagation for model parameters [26]. The uncertainty of the result is affected by the uncertainty of the input data [27]. The authors intended to estimate the sensitivity as a percentage of the contribution from each parameter to the variance of the final result [28].

3.1.3 Results and discussion

3.1.3.1 Waste generation rates of educational facilities

Table 3-2 presents the means and standard deviations (Mean ± SD) of WGRs of GW, SR, SFR, and total waste per school category according to the following indicators: daily amount at the facility (kg/facility/day), daily amount by student (g/student/day), daily amount by classroom (g/classroom/day), daily amount by staff member (g/person/day), and daily amount by area (g/m^2/day). The authors also indicated the result of ANOVA on the mean difference among school categories, as seen in Table 3. The result indicated that there were significant differences in WGRs by all indicators ($p<0.001$) among school categories.

Regarding the total WGR by facility, "College and University" generated the largest amount (117.2 kg/facility/day), followed by "Primary school" (51.8 kg/facility/day), "Kindergarten" (39.4

kg/facility/day), “Secondary school” (32.7 kg/facility/day), and “Day-care center” (2.1 kg/facility/day). “Private tutoring” generated the smallest amount (0.8 kg/facility/day). Regarding the total WGR by student, “Kindergarten” was the category with the highest WGR (141 g/student/day), followed by “Day-care center” (81 g/student/day) and “Primary school” (76 g/student/day).

Table 3- 2. Waste generation rates of educational facilities

Category	N	General		Separated		Separated		Total waste			
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	CV	ANOVA (F value)
By facility (kg/facility/day)											
Day-care center	30	2.1	2.3	0	0	0	0	2.1	2.3	1.1	27.39***
Kindergarten	43	15.5	13.0	0.1	0.5	23.8	19.3	39.4	31.1	0.8	
Primary school	35	26.1	22.9	0.8	1.2	24.9	22.7	51.8	42.8	0.8	
Secondary school	41	22.9	12.7	2.8	3.3	7.0	6.6	32.7	17.0	0.5	
College &	9	93.9	55.5	4.9	2.7	18.5	5.5	117.2	48.6	0.4	
Private tutoring	9	0.8	0.4	0	0	0	0	0.8	0.4	0.5	
By student (g/person/day)											
Day-care center	30	81	40	0	0	0	0	81	40	0.5	67.67***
Kindergarten	43	54	17	0.5	2	87	30	141	33	0.2	
Primary school	35	40	18	1.0	2	35	27	76	37	0.5	
Secondary school	41	23	14	2.0	2	5	5	29	12	0.4	
College & University	9	19	6	1.0	1	5	3	25	2	0.1	
Private tutoring	9	34	33	0	0	0	0	34	33	1.0	
By classroom (g/classroom/day)											
Day-care center	30	1,205	646	0	0	0	0	1,205	646	0.5	53.41***
Kindergarten	43	1,947	852	14	62	2,974	1325	4,934	1885	0.4	
Primary school	35	1,533	619	58	93	1,346	992	2,937	1346	0.5	
Secondary school	41	1,064	447	129	136	309	284	1,502	625	0.4	
College & University	9	1,059	557	61	39	226	86	1,346	444	0.3	
Private tutoring	9	514	356	0	0	0	0	514	356	0.7	
By staff member (g/person/day)											
Day-care center	30	670	469	0	0	0	0	670	469	0.7	25.96***
Kindergarten	43	512	179	4	19	804	290	1,321	334	0.3	
Primary school	35	681	359	22	35	587	443	1,290	671	0.5	
Secondary school	28	324	152	35	37	48	44	407	167	0.4	
College &	9	229	104	15	10	53	24	296	72	0.2	
Private tutoring	9	610	426	0	0	0	0	610	426	0.7	
By area (g/m2/day)											
Day-care center	30	11.3	8.7	0	0	0	0	11.3	8.7	0.8	16.03***
Kindergarten	38	6.8	3.2	0.1	0.3	12	6.0	18.8	8.5	0.5	
Primary school	35	10.1	4.0	0.3	0.5	8.2	6.3	18.5	7.5	0.4	
Secondary school	41	4.0	3.4	0.3	0.4	1.7	3.1	6.0	6.2	1.0	
College &	9	4.8	4.1	0.1	0.1	0.6	0.4	5.6	4.4	0.8	
Private tutoring	9	22.3	19.5	0	0	0	0	22.3	19.5	0.9	

*** $p<0.001$

The higher WGRs from “Kindergarten” and “Primary school” facilities were mainly attributable to the large amount of SFR. The higher WGR at “Day-care center” facilities was considered to be due to the waste generated in infant care, such as disposal diapers.

The total WGRs were smaller at “Secondary school” (29 g/student/day), “College & University” (25 g/student/day), and “Private tutoring” (34 g/student/day). The total WGRs in these categories were close to the reported value (21 g/student/day) in a 2010 study in Cambodia [18]. Table 3 also shows the CVs of WGRs for total waste. The WGRs by student had the smallest CVs in most of the school categories. Therefore, the authors chose the WGR by student as the representative indicator for waste generation, which was used for further analyses

3.1.3.2 Mean difference in waste generation rates by food service provided

At “Primary schools,” some schools provided food service at their own canteens, and others did not. The authors analyzed the mean difference of the WGR by food service provided by ANOVA, as shown in Table 3-3. The WGR for total waste differed significantly between “Primary school with food service” (85 g/student/day) and “Primary school without food service” (25 g/student/day). The difference was considered to be due to the large contribution of SFR at “Primary school with food service” (41 g/student/day). “Primary school without food service”did not separate recyclables and food residue.

Table 3- 3. Waste generation rate of primary school by food service

Category	Primary school with food service	Primary school without	ANOVA (F value)
General waste	42±18	25±11	3.9
Separated	2±2	0	0
Separated Food	41±24	0	0
Total waste	85±33	25±11	15.7***

3.1.3.3 Waste composition at educational facilities

(1) Physical composition

Table 3-4 presents the composition of GW by 10 physical categories per school category. It was revealed that plastic, paper, and food waste were dominant in most school categories. The results in this study were in line with the following reported values on waste from schools in Ho Chi Minh City [19]:

food residue ranged from 23.5% to 75.8%, followed by plastic, which ranged from 8.5% to 34.4%, and paper, which ranged from 1.5% to 27.5%. Food waste accounted for the highest portion at "Kindergarten" facilities (54.8%), whereas it was lowest at "Secondary school" facilities (5.2%). This difference could be explained by the fact that the entire "Kindergarten" category provided food service, and some inedible cooking residue is discharged as GW. At the "Secondary school" facilities, the students rarely ate inside the buildings. Paper accounted for a larger portion at "Day-care center" facilities (47.5%), followed by "Private tutoring" (35.4%). Paper at "Day-care center" facilities was mainly baby diapers. This resulted in the lower recycling potential at "Day-care center" facilities. Grass and wood accounted for a large portion at "Primary school with food service" (15.2%), "Secondary school" (14.5%), and "Primary school without food service" (12.4%).

Table 3- 4. Physical composition of GW at educational facilities (%)

Physical category	Day-care center	Kinder-garten	Primary school with food service	Primary school without food service	Secondary school	College & University	Private tutoring
Plastic	16.3%	14.4%	25.5%	38.6%	35.1%	18.4%	21.7%
Paper	47.5%	18.9%	15.4%	12.3%	28.1%	22.6%	35.4%
Food waste	22.9%	54.8%	31.4%	20.7%	5.2%	45.6%	19.7%
Rubber & leather	0.1%	0.2%	0.2%	0.0%	0.1%	2.0%	0.0%
Grass & wood	3.0%	3.1%	15.2%	12.4%	14.5%	2.4%	5.1%
Textiles	1.7%	1.3%	1.4%	4.2%	1.4%	1.2%	0.0%
Metal	0.6%	0.3%	0.3%	0.6%	0.6%	0.6%	0.0%
Glass	0.0%	0.5%	0.0%	0.0%	0.0%	2.3%	0.0%
Ceramic	5.1%	0.7%	0.5%	0.2%	1.9%	0.0%	0.0%
Miscellaneous	2.8%	5.7%	10.1%	10.8%	13.1%	4.9%	18.2%

(2) Recycling and composting potential of general waste at educational facilities

Although the educational facilities in Hue separated some recyclables and food residue collected by informal sectors, some recyclable and compostable portions were discharged as GW. The authors categorized each component of GW according to the potential shown in Table 2-3, and aggregated the data by the following components: "Recycling potential in GW," "Composting potential in GW," and "Other residue in GW."

Table 3- 5. Recycling and composting potential from general waste by school category (%)

Physical category	Day-care center	Kinder-garten	Primary school with food service	Primary school without food service	Secondary school	College & University	Private tutoring
Composting potential	23.7%	57.2%	46.7%	35.5%	42.0%	39.2%	35.1%
Recycling potential	35.7%	28.2%	33.7%	43.0%	33.0%	27.8%	53.9%
Other residue	40.6%	14.6%	19.5%	22.0%	25.2%	33.0%	11.0%
Contribution of components in recycling potential							
Plastic C&P	32.8%	35.7%	43.6%	53.8%	42.3%	39.7%	24.5%
Plastic product	1.9%	4.3%	6.1%	3.9%	6.1%	2.1%	0.0%
Plastic other	0.0%	0.2%	0.1%	0.4%	0.0%	8.7%	0.0%
Paper C&P	47.9%	38.4%	15.4%	15.1%	24.8%	17.1%	35.2%
Paper product	6.5%	6.9%	21.1%	13.1%	25.1%	19.2%	15.0%
Paper other	0.4%	2.8%	2.4%	2.2%	3.1%	5.7%	2.4%
Other material	10.5%	11.7%	11.2%	11.4%	8.6%	7.6%	23.0%
Contribution of components in composting potential							
Kitchen waste	83.3%	92.6%	64.0%	54.0%	38.7%	98.8%	53.6%
Garden waste	8.7%	3.3%	30.6%	30.8%	51.0%	0.2%	0.7%
Other item	8.0%	4.1%	5.4%	15.2%	10.3%	0.9%	45.8%

C&P: containers and packaging

Table 3-5 presents the potential to compost and recycle and provides a detailed breakdown from GW by school category. "Composting potential in GW" accounted for a large portion, from 23.7% at "Day-care center" to 57.2% at "Kindergarten." Table 6 also shows that "Recycling potential in GW" accounted for a large portion among educational facilities, which ranged from 28.2% at "Kindergarten" to 53.9% at "Private tutoring." These results were similar to a 2009 study at the University of Northern British Columbia, which indicated that the recyclable materials made up more than 37% of waste in most of the activity areas on campus [29]. "Plastic C&P," "Paper C&P," and "Paper product" showed higher contributions in recycling potential. "Kitchen waste" accounted for the highest portion in all school categories, and "Garden waste" showed a higher contribution at "Primary school without food service," "Primary school with food service," and "Secondary school" in composting potential. To promote recycling and composting at educational facilities, these five items should be considered as major target items for initial separation.

3.1.3.4 Estimation of total waste generation from the educational sector

To draw the total waste flow diagram of solid waste generated from educational facilities in Hue,

the authors estimated the total amount of three components (GW, SR, SFR) from the educational facilities in Hue by each category. Additionally, the authors estimated the total recycling potential, composting potential, and residual food amount in GW by the contribution of each component presented in Table 6 multiplied by the total amount of estimated GW amount

Table 3-6 presents the estimation of total waste and the breakdown of the waste generated from educational facilities. The total waste generated from educational facilities in Hue was 5.76 tons/day, of which 3.29 tons (57.2%) was GW, 0.15 tons (2.6%) was SR, and 2.33 tons (40.5%) was SFR. The high percentage of SFR revealed that pig farmers played an important role in MSW systems, recovering 40.5% of the total waste from educational facilities. Although the educational facilities achieved a certain level of recycling and separating of food residue, the GW still contained 19.3% that could be recycled and 22.4% that could be composted. Based on the comparison of the SR amount and the recycling potential by school category, it was suggested that the separated portion of recyclables was quite low, especially at "Kindergarten" and "Primary school" facilities; the amount of SR was only 0.01 tons (4.5%) in 0.22 tons of total recyclables and 0.03 tons (12.0%) in 0.25 tons of total recyclables, respectively. The composting potential was more than one-third the GW amount. Some past studies have mentioned that organic waste is typically the heaviest component of a waste stream and has the highest potential to emit greenhouse gases once buried in a landfill [30]. The result of this study suggested that the total disposal amount sent to a landfill could be reduced from 3.29 tons (57.2%) to 0.89 tons (15.5%) by recovering the recyclables and compostable parts within GW.

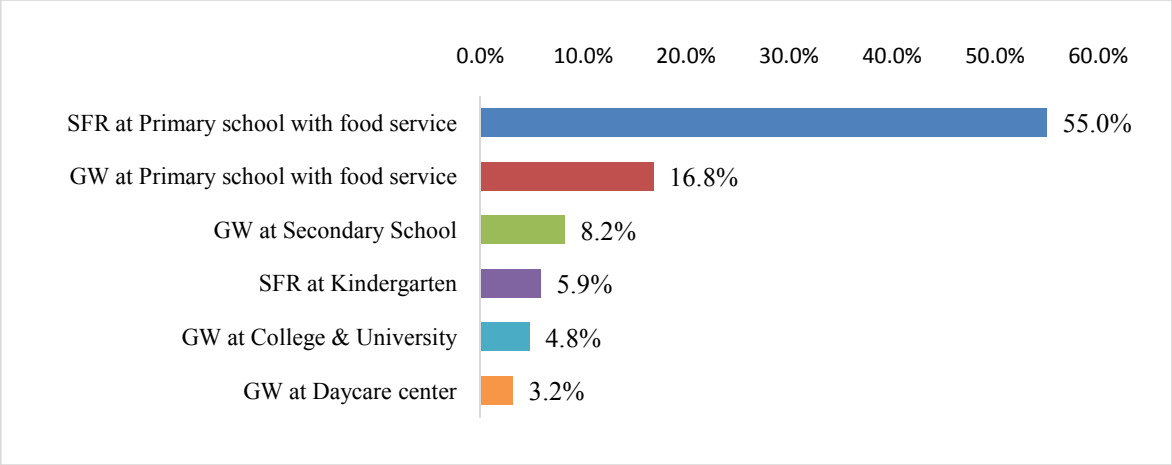
Regarding the contribution from each school category, "Kindergarten" was identified as the largest generation source with 1.99 tons/day, followed by "Primary school with food service" (1.5 tons/day), "Secondary school" (1.04 tons/day), "College & University" (0.83 tons/day), and "Day-care center" (0.26 tons/day). The "Private tutoring" category generated the smallest amount, with 0.04 tons/day. It is clear that the GW from "Secondary school," "Primary school with food service," "Kindergarten," and "College & University" categories contained larger recycling and composting potential. To promote recycling and composting at educational facilities, these four school categories should be considered as major targets to make separation an initial priority.

Table 3- 6. Estimation of total waste and the breakdown from educational facilities

Category	Unit	Total number in Hue	General waste			Separated recyclables	Separated food residue	Total amount
			Residual amount	Recycling potential	Composting potential			
Day-care center	Facility	126	0.11	0.09	0.06	0	0	0.26
Kindergarten	Student	14,114	0.11	0.21	0.44	0.01	1.22	1.99
Primary school with food service	Student	22,057	0.13	0.22	0.34	0.03	0.78	1.50
Primary school without food service	Student	4,037	0.02	0.04	0.04	0	0	0.10
Secondary school	Student	35,390	0.31	0.34	0.16	0.06	0.17	1.04
College & University	Student	32,579	0.20	0.17	0.24	0.05	0.16	0.83
Private tutoring	Facility	55	0.01	0.02	0.02	0	0	0.04
Total (tons/day)			0.89	1.11	1.29	0.15	2.33	5.76
%			15.5%	19.3%	22.4%	2.6%	40.5%	100%

3.1.3.5 Interval estimation and Uncertainty analysis

The 95% CI of the total waste amount from 402 educational facilities was also estimated by Monte Carlo simulation (100,000 times) assuming normal distributions based on the means and standard



errors of the WGRs shown in Table 3-2. The results showed that the range for a 95% CI was 4.85–7.71 tons/day.The authors also examined the sensitivity as a percentage of the contribution from the WGR of each school category to the variance of the total waste amount. Figure 3-1 presents the results of Uncertainty analysison the total waste generated at schools. “SFA at primary school with food service” was identified as the category with the largest impact on the CI of the total waste amount (55%),

followed by “GW at primary school with food service” (16.8%), “GW at the secondary school” (8.2%), and “SFR at kindergarten” (5.9%). To improve the reliability of the total estimation, the authors should start by improving the data reliability at “Primary school with food service” by a further survey to increase the sample size and clarify the influencing factors on WGRs of SFR and GW.

Conclusions

1) This study aimed to provide a detailed description of the solid waste generation and composition from educational facilities in Hue, Vietnam. The authors surveyed 35 educational facilities for six school categories over seven consecutive days.
2) The WGRs by facility, student, classroom, staff member, and floor area were assessed by school category by three waste categories: general waste (GW), separated recyclables (SR), and separated food residue (SFR).
3) The mean differences of WGRs of the total waste among the school categories were assessed by ANOVA. There were significant differences in WGRs by all indicators among the six school categories.
4) GW was classified and measured by 10 physical categories and 77 sub-categories. Plastic, paper, and food waste were the dominant forms of waste in most school categories. “Composting potential in GW” accounted for 23.7%–57.2% and “Recycling potential in GW” accounted for 28.2%–53.9%.
5) The total waste generated from educational facilities in Hue was estimated to be 5.76 tons/day, of which 3.29 tons (57.2%) was GW, 0.15 tons (2.6%) was SR, and 2.33 tons (40.5%) was SFR. GW still contained 19.3% that could potentially be recycled and 22.4% that could potentially be composted in the total waste amount. The total disposal amount sent to the landfill could be reduced from 3.29 tons (57.2%) to 0.89 tons (15.5%).
6) To promote recycling and composting at educational facilities, the key findings can be summarized as follows:
    - Target waste items: According to the detailed breakdown of recycling and composting potential, plastic containers & packaging, paper containers & packaging, paper products, kitchen waste, and garden waste showed the highest contributions.
    - Target school categories: According to the estimated recycling and composting potential, “Secondary school,” “Primary school with food service,” “Kindergarten,” and

"College & University" contained the largest potential to recycle and compost within GW.

The abovementioned items and school categories should be considered as the major policy targets for separation with the highest priority.

7) The 95% CI of the total waste amount was estimated to be 4.85–7.71 tons/day. According to the Uncertainty analysis, the WGRs of the "Primary school with food service" category were identified as having the largest impact on the CI of the total waste amount.

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3.2 Solid waste generation fromhealth-care facilities

3.2.1 Introduction

Vietnam is one of the most densely inhabited country in the world, and its population growth rate is expected to be 1.054%. Approximately 30% of the country's residents currently live in the cities; its urbanization annual rate of change was 3%. According to statistics of the Ministry of Natural Resources and Environment, by 2008 Vietnam produced over 27.87 million tonnes of waste each year from various sources; of which, hazardous health-care waste accounted for only a small percentage (0.64%). The total amount (tonnes/year) of hazardous health-carewaste generated is increasing day by day and is estimated to be 300 thousand tonnes per year by 2050 (JICA, 2010). Therefore, health-care waste management in Vietnam has been given serious attention at different levels of government, as well as at the community level.At the national level, health-care waste management is underthe scope of the Ministry of Health, the MONRE, and the Ministryof Construction. At the local level, it is undertaken by theUrban Environmental Companies, which are directly under theProvincial People's Committees or the Department of Transportand Public Works or the Department of Construction or theDepartment of Natural Resources and Environment (DONRE).The central administrative bodies and respective departmentsof the provincial, district, and local levels have their own rolesand responsibilities for health-care waste management in theirjurisdictions. Other local agencies and organizations for healthcarewaste management also share responsibilities of management,such as collection at source, transportation and treatmentactivities.As health-care waste is recognized as a hazardous source forhuman health and environmental quality, the Government of Vietnamhas incorporated this issue into several development strategiesand environmental protection plans with a view to theboosting appropriate management and handling of this source.Several existing legal documents (strategies, development plans,and guidelines) have been issued by the government and relevantcentral ministries for developing and improving the health-carewaste management system. The development goals and expectedresults by target year 2015 (Decision 2149/2009/QD-TTg, and DecisionNo.1873/2009/QD-BYT) and 2020 (Decision 2149/2009/QDTTg,and Decision 30/2008/QD-TTg) have been introduced.

In 2009, there were 13,450 health-care facilities with more than232,925 beds (GSO, 2010), including 1002 general and specialtyhospitals, 682 regional clinics, 43 sanatoriums, 10,979 health-careservice units in villages and precincts, 710 health-care service unitsin offices and enterprises, and 34 other facilities.

In order to provide the scientific information that can to provide a detailed description of the

solid waste generation health-care facilities in Hue, Vietnam. The authors surveyed 32 target samples at 8 different categories according to "The system of economic branches of Vietnam, 2007", and analyzed differences by category. The authors conducted a survey on the waste collected by formal sectors, and also measured the amount of separated recyclables and food residue collected by informal sectors. This study was not cover the composition survey to avoid some medical waste that remaining in general waste. This study also conducted an interval estimation of the total waste in Hue, and aimed to clarify the reliability of collected data and improve future tasks through uncertainty analysis.

3.2.2 Results and discussion

3.2.2.1 Waste generation rates of health-care facilities

The waste generation rate was discussed on the following 3 business scale indicators; the number of facility, the number of bed, and the number of staff. Table 3-7 presented the averages and standard deviations (Ave ± SD) of waste generation rates by 3 different units; kg/facility/day, g/bed/day, and g/staff/day.

Among various categories of healthcare services, the waste generation rate (g/facility/day) of "National hospital" category was the highest (2767 kg/facility/day), followed by "other hospital" category (46.5 kg/facility/day). "Dental_family" was the smalles category for the generation rate by facility with the rate of 0.4 kg/facility/day. Among waste types, general waste accounted for the highest part, followed by food residues, and recyclable waste. (Hazardous healthcare waste was not covered in this study.)

Regarding the generation rate by bed *(kg/bed/day),* "National hospital" category was still having highest waste generation rate with 1.24 kg/bed/day.

Table 3- 7. Waste generation rate from health-care facilities in Hue

Category	N	General waste	Recyclable	Food residue	Total
WGR from health-care facilities (kg/facility/day)					
Dental_family	4	0.4±0.5	0±0	0±0	0.4±0.5
Dental_large	3	1±1.7	0±0	0±0	1±1.7
Clinic_family	2	1.5±1.5	0±0	0±0	1.5±1.5
Clinic_large	10	1±2.2	0.2±0.5	0.5±1.6	1.7±4.1
Health station	3	0.5±0.2	0±0	0±0	0.5±0.2
Hospital TW	1	2410±0	31.6±0	325.6±0	2767.2±0
Other hospital	7	41.9±26.8	0.8±1.7	3.8±7.1	46.5±34.1
Orthopedic and rehabilitation centers	2	4.6±1.8	0±0	0±0	4.6±1.8
WGR from health-care facilities (kg/bed/day)					
Dental_family	2	0.78±0.48	0±0	0±0	0.78±0.48
Dental_large	2	0.26±0.33	0±0	0±0	0.26±0.33
Clinic_family	1	0.26±0	0±0	0±0	0.26±0
Clinic_large	6	0.34±0.43	0.01±0.02	0.03±0.08	0.39±0.43
Health station	3	0.21±0.11	0±0	0±0	0.21±0.11
Hospital TW	1	1.08±0	0.01±0	0.15±0	1.24±0
Other hospital	7	0.68±0.53	0.01±0.04	0.04±0.07	0.73±0.52
Orthopedic and rehabilitation centers	1	0.21±0	0±0	0±0	0.21±0
WGR from health-care facilities (kg/staff/day)					
Dental_family	4	0.76±0.92	0±0	0±0	0.76±0.92
Dental_large	3	0.09±0.12	0±0	0±0	0.09±0.12
Clinic_family	2	1.33±1.76	0.01±0.01	0±0	1.34±1.77
Clinic_large	10	0.21±0.35	0.01±0.01	0.01±0.05	0.23±0.36
Health station	3	0.11±0.02	0±0	0±0	0.11±0.02
Hospital TW	1	1.05±0	0.01±0	0.14±0	1.21±0
Other hospital	7	0.47±0.16	0.01±0.03	0.04±0.07	0.52±0.17
Orthopedic and rehabilitation centers	2	0.13±0.03	0±0	0±0	0.13±0.03

As a reference, the waste generation rate by bed (kg/bed/day) for various levels of healthcare institutions in Vietnam surveyed by JICA(2010) was shown in Table 3-8.In comparison to this JICA survey result, the result of this survey wasrather lower, butthat was similar to the resultof Patil and Shedkar (2006); the waste generation rate of public hospital was reportedas 0.11 – 0.65 kg/bed/day.

Table 3- 8. Amount of general healthcare waste from various levels of hospital establishments

Categories	Total general healthcare waste generation (excluding hazardous healthcare waste)			
	Central hospital	Province	District hospital	Average
Hospital	0.97	0.88	0.73	0.86
Intensive care	1.08	1.27	1	1.12
Medical ward	0.64	0.47	0.45	0.52
Pediatrics	0.5	0.41	0.45	0.45
Surgical	1.01	0.87	0.73	0.87
Maternity	0.82	0.95	0.73	0.83
Ophthalmology/ Otolaryngology	0.66	0.68	0.34	0.56
Pala-clinical	0.11	0.1	0.08	0.10

Source: JICA (2010)

3.2.2.2 Total estimation of waste generation from health-care facility

Table 3-9 presents the estimation of total waste and the breakdown of the waste generated from health-care facilities. The total waste generated from health-care facilities in Hue was 4.38 tons/day, of which 3.94 tons (90%) was GW, 0.06 tons (1%) was SR, and 0.38 tons (9%) was SFR.

Table 3-9. Total estimated amount of waste from healthcare facilities (Unit: tons/day)

Categories	Total in Hue	Unit	General waste	Separated recyclable	Separated Food residue	Total waste amount
Dental_family	66	Staff	0.05	0	0	0.05
Dental_large	354	Staff	0.03	0	0	0.03
Clinic_family	364	Staff	0.48	0	0	0.49
Clinic_large	1155	Staff	0.24	0.01	0.02	0.26
Health station	101	Bed	0.02	0	0	0.02
Hospital TW	2239	Bed	2.41	0.03	0.33	2.77
Other hospital	1012	Bed	0.68	0.01	0.04	0.74
Orthopedic and rehabilitation centers	95	Bed	0.02	0	0	0.02
Total amount			3.94	0.06	0.38	4.38
Percentage (%)			90%	1%	9%	100%

3.2.2.3 Interval estimation and uncertainty analysis

The 95% CI of the total waste amount from health-care facilities was also estimated by Monte Carlo simulation (100,000 times) assuming normal distributions based on the means and standard errors of the WGRs. The results showed that the range for a 95% CI was 3.25 – 5.52 tons/day.The authors also examined the sensitivity as a percentage of the contribution from the WGR of health-care facility to the variance of the total waste amount.

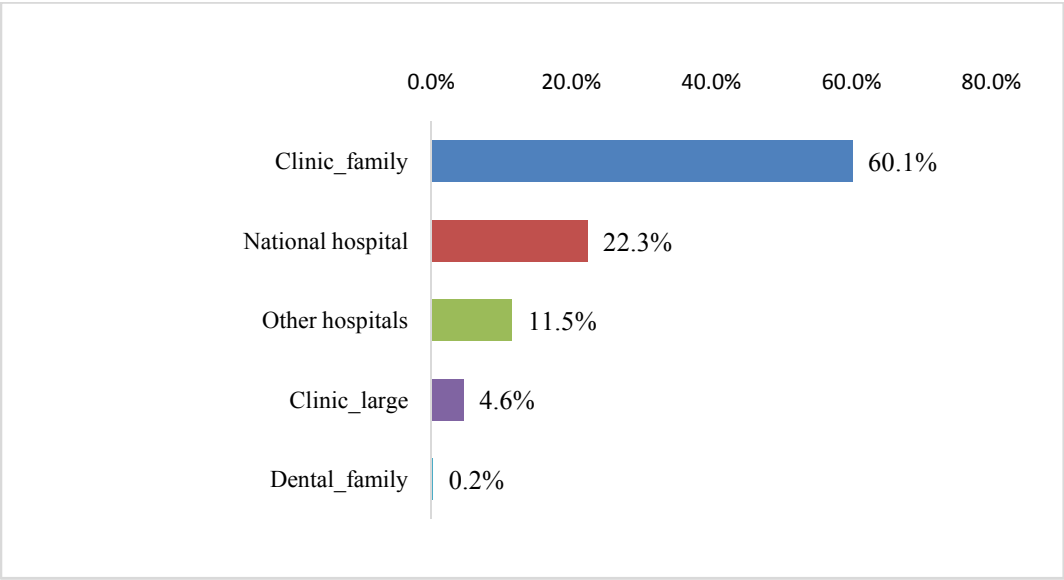


Figure 3-2 presents the results of Uncertainty analysison the total waste generated at health-care facilities. “Clinic_family” was identified as the category with the largest impact on the CI of the total waste amount (60.1%), followed by “National hospital” (22.3%), “Other hospital” (11.5%), and “Clinic_large” (4.6%). To improve the reliability of the total estimation, the authors should start by improving the data reliability at “Clinic_family” by a further survey to increase the sample size and clarify the influencing factors on WGRs.

3.3. Solid waste generation from Offices

The waste generation rate was estimated by the number of staff who was working at the Offices. Table 3-10 presented the waste generation rate and total estimated amount from the office by 11 categories.

Among 11 categories of office sector, the waste generation rate (g/staff/day) of "Other services" category generated the largest with the amount of 656 g/staff/day, followed by "Administrative Services and Assistant Services" with 293 g/staff/day. However, the contribution to total waste amount of "Financial, Banking and Insurance" was largest with 454 kg/day. Food residues weren't discharged for collection by informal sectors such as pig farmers.

The total waste generated from Office in Hue was 1410 kg/day, of which 1035 kg/day (73%) was GW, 0 201 (14%) was SR.

Table 3-10 Waste generation rate and total estimated waste amount from Offices

Category	Total staff	Waste generation rate (g/staff/day)			Total waste amount (kg/day)		
		General waste	Separated recyclable	Total waste amount	Genral waste	Separated Recyclable	Total amount
CP_Province/City	140	236	37	272	33	5	38
CP_Ward	822	51	16	67	42	13	55
Departments (City level)	1690	68	9	180	115	16	304
Transport and Warehouse	2726	25	1	26	68	3	70
Information and Communication	624	19	45	64	12	28	40
Financial, Banking and Insurance	3785	90	30	120	340	114	454
Professional practice, Science and Technology	1259	53	10	63	67	13	80
Administrative Services and Assistant Services	738	293	0	293	216	0	216
Artuctic, Recreational activities	170	148	51	200	25	9	34
Real-Estate Business	158	65	1	66	10	0	10
Other services	164	656	0	656	108	0	108
Total					1035	201	1410
%					73%	14%	100%

CHAPTER 4 SOLID WASTE GENERATION FROM OTHER SECTOR

4.1 Waste generation from household part at home-based business

4.1.1 Waste generation rate

Based on the survey at home-based business that presented in the section 2.3, the waste generation from household part also be considered. The table 4-1 showed the waste generation rate of household part by household size. The mean difference among 8 categories was found at General waste and total amount.

Table 4- 1. Waste generation rate from household part at home-based business

Household size	N	General waste	Recyclable	Food residue	Total amount
1 member	5	450±197	3±8	86±193	540±283
2 members	6	668±472	1±1	154±307	823±647
3 members	25	351±229	34±175	43±104	428±277
4 members	52	281±141	12±27	93±185	386±244
5 members	48	284±219	2±7	131±223	417±298
6 members	39	311±183	5±8	139±269	455±343
7 members	11	248±112	6±12	55±118	309±145
8 members	30	217±128	5±8	77±134	298±132
ANOVA		5.69***	0.82	0.92	3.52**

* $p<0.05$, ** $p<0.01$, ***$p<0.001$

4.1.2 Waste composition and potential

The figure 4-1 showed the waste composition of household part at home-based business. Food waste continues to be the largest component with 48%, followed by plastic (14%) and paper (13%). The figure 4-2 showed the composting and recycling potential from general waste, the composting potential accounted for 19.4% and the recycling potential accounted for 28.3%. The residue amount was only 22.3%

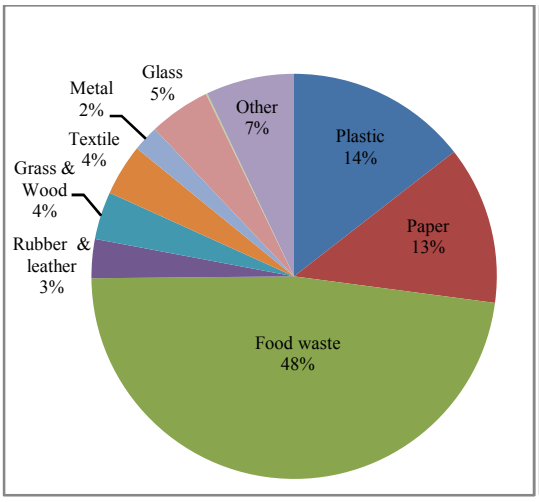


Figure 4- 1 . Waste composition of household_HB

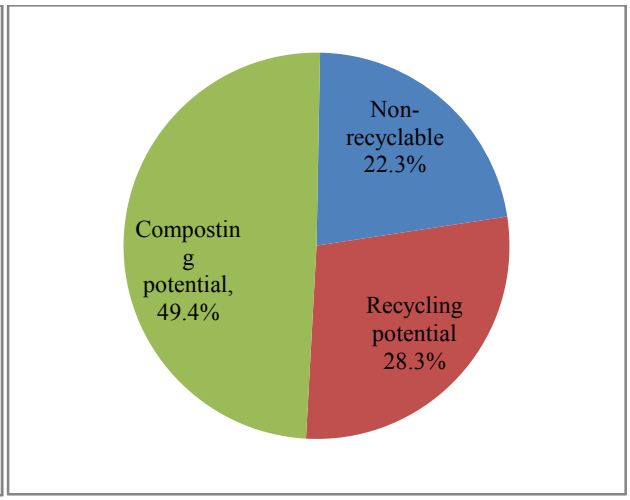


Figure 4- 2. Composting & Recycling Potential of general waste from household_HB

4.1.3 Total estimation of waste generation amount from household part at HBB

The table 4-2 showed the total estimation of waste generation amount by 5 components. The total generated amount from household part at household with business was 27.02 tons/day.

Table 4- 2. Total estimation of waste generation amount from household part at HBB

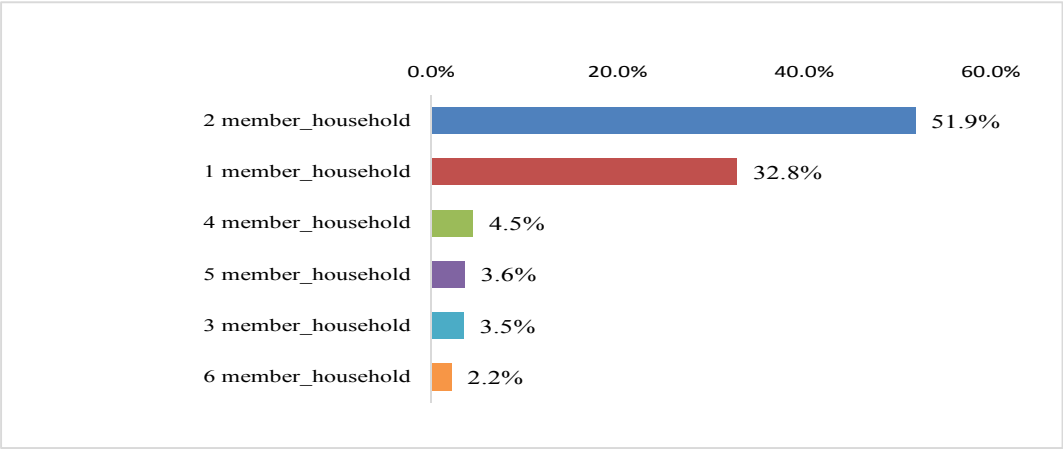
Household member	Total population	General Waste			Separated Recyclable	Separated Food residue	Total amount
		Residual amount	Recycling potential	Composting potential			
1 member	8061	0.81	1.03	1.79	0.03	0.70	4.36
2 members	9190	0.81	1.02	1.78	0.01	1.24	4.86
3 members	10389	0.58	0.73	1.28	0.28	0.34	3.21
4 members	16124	0.48	0.61	1.07	0.09	0.75	3.01
5 members	10737	0.48	0.60	1.05	0.02	1.05	3.21
6 members	6962	0.52	0.65	1.14	0.04	1.12	3.48
7 members	2355	0.45	0.57	0.99	0.05	0.44	2.49
8 members	2215	0.39	0.50	0.86	0.04	0.62	2.41
Total waste amount (tons)		**4.50**	**5.72**	**9.98**	**0.55**	**6.27**	**27.02**
%		*16.7%*	*21.2%*	*36.9%*	*2.0%*	*23.2%*	*100.0%*

4.1.4 Interval estimation and Uncertainty analysis

The 95% CI of the total waste amount from household part in HHB in Hue was also estimated by Monte Carlo simulation (100,000 times) assuming normal distributions based on the means and standard errors of the WGRs shown in Table 4-1 . The results showed that the range for a 95% CI was 23.2 –

30.2tons/day.

The authors also examined the sensitivity as a percentage of the contribution from the WGR of household part at HBB category to the variance of the total waste amount. Figure presents the results of



Uncertainty analysison the total waste generated at household part in HBB. “2 member_household” was identified as the category with the largest impact on the CI of the total waste amount (51.9%), followed by “1 member_household” (32.8%), “4 member_househol” (4.5%), and “5 member_household” (3.6%). To improve the reliability of the total estimation, the authors should start by improving the data reliability at “2 member_household” and “1 member_household” a further survey to increase the sample size and clarify the influencing factors on WGRs of SFR and GW.

4.2 Waste generation from household without business

The total waste generation from household without business was estimated based on the results of a study in Hue in 2010 (Yen et al, 2010) by the household size. The total waste amount generation from this part was 78.2 tons/day.

4.3 Waste generation from dormitory and street

The total waste amount in dormitory waste estimated by the total number of students who was staying at dormitory in Hue during the survey period, the total amount was 0.3 tons/day. Besides, based on the report of HEPCO, the street waste accounted for 15% of total collected amount from MSW in Hue, the total waste amount from street was estimated as 31.1 tons/day

CHAPTER 5 TOTAL ESTIMATION OF SOLID WASTE GENERATION AND ITS POTENTIAL FOR RECOVERY

5.1 Total waste generation from commercial and institutional sectors

The total waste generation (tons/day) from commercial and institutionalsectors (C&I sectors) in Hue city was calculated based on the waste generation rate (kg/business scale indicator/day) and the total number of each business scale indicator in Hue city, as introduced chapter 2 and 3.

Table 5-1 presented the estimated results of total waste generation amount and the breakdown from C&I sectors by six waste types such as: General waste (GW), Residue in GW, Recycling potential in GW, Separated recyclable, Composting potential in GW and Separatedfood residues. The waste generation by amount (tons/day) and percentage (%) by sub-categories of C&I sectors were calculated.

The total waste generation amount from C&I sectors were 106.2 tons/day, of which 63.4 tons (60%) was GW, 9.8 tons (9%) was SR, and 33 tons (31%) was SFR. The high percentage of SFR revealed that pig farmers played an important role in MSW systems at C&I sectors. Informal sector had recovering 40% of the total waste from C&I sectors. Although the C&I sectors achieved a certain level of recycling and separating of food residue, the GW still contained 11% that could be recycled and 27% that could be composted. Based on the comparison of the separated recyclable amount (9%) and the recycling potential (11%), it was suggested that the separated portion of recyclables was quite low, especially at "Restaurant"; the amount of recycling potential was three times larger than that of separated recyclable. The composting potential was more than one-third the GW amount. The result of this study suggested that the total disposal amount sent to a landfill could be reduced from 63.4 tons to 20.7 tons (19%) by recovering the recyclables and compostable parts within GW at C&I sectors.

Regarding the contribution from each category at C&I sectors, the results revealed that institutional sectors accounted only 12% of total amount while commercial sector was dominant with 88% of total amount. "Beverage &Restaurant" was identified as the largest generation source with 39.8 tons/day (38%), followed by"Home-based business" (24%) and "Traditional market" (16%).

Table 5- 1. Total waste generation from commercial and institutional sectors

Category	**GW (tons)**	Residue in GW		Recycling potential in GW		Separated Recyclable		Composting potential in GW		Separated Food Residues		Total Waste	
		tons	%	ton	%	ton	%	tons	%	tons	%	tons	%
Commercial sector	**54.8**	**15.7**	***15%***	**9.2**	***9%***	**8.1**	***8%***	**27.7**	***26%***	**30.2**	***28%***	**93.1**	***88%***
Hotel	4.0	2.2	*2%*	0.9	*1%*	0.5	*1%*	0.9	*1%*	2.6	*2%*	7.1	*7%*
Beverage&Restaurant	18.6	7.9	*7%*	3.4	*3%*	1.0	*1%*	7.3	*7%*	20.3	*19%*	39.8	*38%*
Traditional market	11.8	1.5	*1%*	0.9	*1%*	0.6	*1%*	9.4	*9%*	4.6	*4%*	17.0	*16%*
Super market	2.1	0.0	*0%*	0.0	*0%*	1.2	*1%*	0.0	*0%*	0.7	*1%*	4.0	*4%*
Home-based business	18.3	4.1	*4%*	4.0	*4%*	4.8	*4%*	10.2	*10%*	2.1	*2%*	25.2	*24%*
Institutional sector	**8.7**	**5.0**	***5%***	**2.0**	***2%***	**1.7**	***2%***	**1.5**	***1%***	**2.7**	***3%***	**13.1**	***12%***
Educational facilities	3.3	0.9	*1%*	1.1	*1%*	0.1	*0%*	1.3	*1%*	2.3	*2%*	5.7	*5%*
Hospital	3.9	3.9	*4%*		*0%*	0.1	*0%*		*0%*	0.4	*0%*	4.4	*4%*
Office	1.4	0.2	*0%*	0.9	*1%*	1.5	*1%*	0.2	*0%*		*0%*	3.0	*3%*
Total C&I sector	**63.4**	**20.7**	***19%***	**11.**	***11***	**9.8**	***9%***	**29.2**	***27%***	**33.0**	***31%***	**106.2**	***100%***

5.2 Total waste generation and discharge flow in Hue

By integrating the waste generation amount from the household part at home-based business category, household with business, dormitory and street waste with the C&I sector. The total waste generation amount and breakdown of total waste generation in Hue was described in the Figure 5-1.

The total waste generated in Hue was 244.2 tons/day, of which 39.2 tons (16.1%) were collected by pig farmers for feeding livestock and 10.4 tons (4.2%) were sold to the recycling market. The daily amount was collected by environmental company (HEPCO) in Hue was 194.7 tons. The composting potential accounted for 41% of total waste generation in Hue. The recycling potential accounted for 13.7%. The total disposal amount sent to the landfill site would be reduced from 79.7% to 25% of the total waste amount.

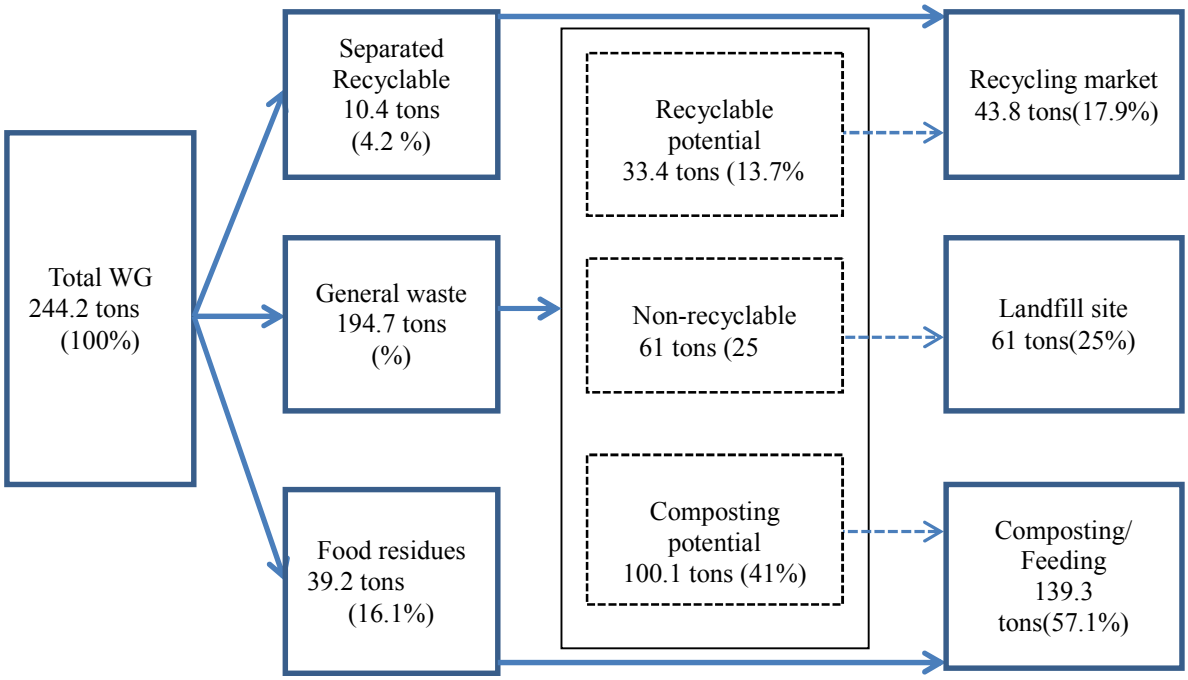


Figure 5- 1. Waste flow of total MSW in Hue city

5.3 Interval estimation and uncertainty analysis

The 95% confidence interval of total waste discharge amount by a Monte Carlo Simulation based on the means and standard errors of waste generation rates. Table presented the 95% confidence interval (95% CI) of waste generation amount (tons/day) in Hue city excluding street waste. The results showed that the range of 95% CI was 189 – 214 tons/day.

To estimate the impact of each waste generation rate affectingthe CI of total waste amount, a uncertainty analysis for sub-categories of commercial, institutional, and other sectors was conducted. Figure 5-2 and Figure 5-3 presented the results of sensitive analysis of total MSW in Hue city and from C&I sectors, respectively.

Table 5- 2. Interval estimation of total WGA in Hue in 2012

Categories	**95% CI of waste in 2012 (tons)**
Hotel	6.51-8.23
Restaurant	36.01-43.64
Home-based business	15.07-27.78
Traditional market	14.9-18.9
Educational facilities	4.85-7.71
Hospital	3.25-5.52
Office	0.95-1.85
Household with business_HH	23.2-30.2
Household without business	69.94-87.06
Total waste amount	189-214

*This table did not include the street waste

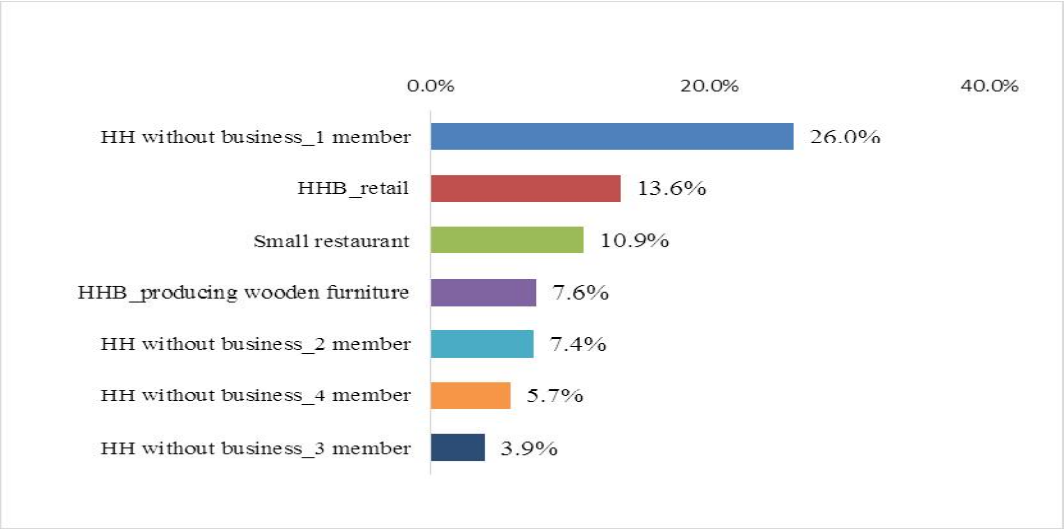


Figure 5- 2. Uncertainty analysis from MSW in Hue

The uncertainty analysis results of total waste generation from MSW in Hue showed that "HH without business_1 member"was identified as the category with the largest contribution (26%) to the variance of the total waste amount, followed by 'Home-based business_retail' (13.6%) and "Small restaurant" (10.9%). To improve the reliability of total estimation, the sample size should be increased.Further investigation must be undertaken to clarify the factors affecting waste generation rate in these categories.

5.4 Recycling and composting potential

Figure 5-4 and 5-5 presented the waste composting and recycling potential of total waste generation in Hue city; the potential for recycling or composting were defined based on the practical trading status of recycling market in Hue city. Regarding the recycling potential, "Container and packaging" (C&P) was dominant in comparing to other categories. Of which, plastic_C&P comprises 44%, paper_C&P accounted for 21%, follows by paper_product (12%), metal (8%).

As for composting potential, the component of this part contains mostly food waste with 94%, followed by garden waste and "Grass and wood_C&P"

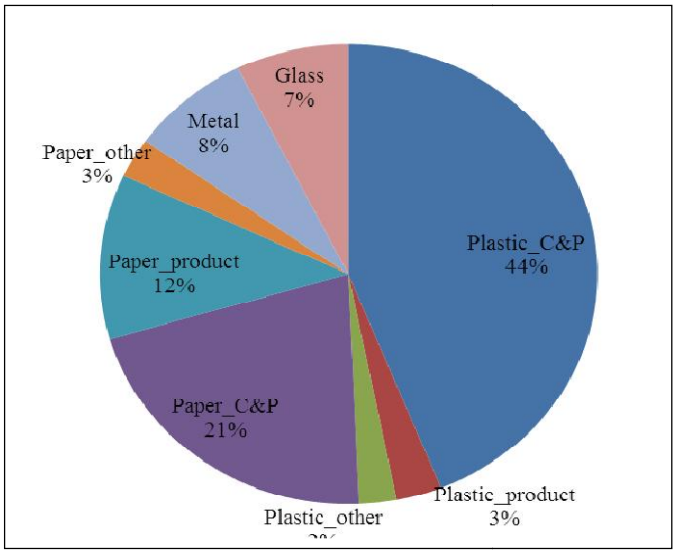


Figure 5- 3. Contribution of component in recycling potential

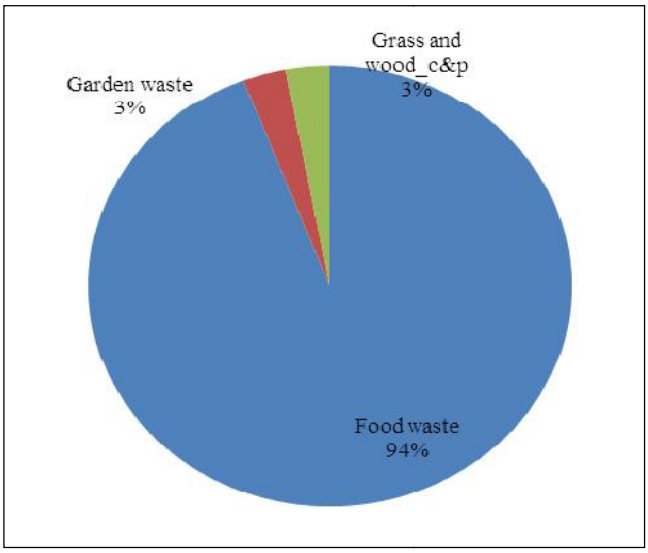


Figure 5- 4. Contribution of component in composting potential

5.1 Financial potential

Based on the data accumulated from recycling market that conducted by Hue University of science, the author estimated the total financial aspect from the recycling potential that remaining in GW. Table 5-3 clearly depicts how waste amount, after separating recycling and food residue for informal sectors can generate considerable profits of approximately 104.9 million vnd/day (about 5,000 us dollars/day). The revenue from each category also showed in that table.

Table 5- 3. Financial potential in general waste

Code	Categories	Price (vnd/kg)	Total amount (kg)	Total revenue (mill.vnd)	%
101	PET bottle	7733	700	5.5	5.2%
102	Other plastic bottle	7672	500	4.2	4.0%
103	Tray	5166	700	3.7	3.5%
104	Tube	5166	300	1.8	1.7%
105	Other shape of containers	5166	1300	6.8	6.4%
106	Shopping plastic bags	5040	4800	24.1	23.0%
107	Other plastic packaging	4433	1600	6.9	6.6%
108	Other containers and packaging	5166	600	3.1	3.0%
109	Plastic product	5166	700	3.7	3.5%
110	Other plastics	4433	600	2.6	2.5%
201	Carton	2613	900	2.2	2.1%
202	Containers	2613	2400	6.2	5.9%
203	Cardboard	2613	1000	2.5	2.4%
204	Packaging	2620	500	1.3	1.2%
205	Other containers and packaging	2620	400	1.1	1.1%
206	Newspapers/magazines /Advertising	2793	500	1.5	1.4%
207	Books	3560	25	0.1	0.1%
208	Notebooks	3560	500	1.7	1.6%
209	Photocopy paper/OA paper	3560	300	1.2	1.2%
210	Disposal paper products	3560	1100	4.1	3.9%
211	Other paper product	2620	300	0.7	0.7%
212	Other Paper	2620	700	1.8	1.7%
701	Containers	23567	200	5.4	5.1%
702	Other containers and packaging	23567	100	2.4	2.3%
703	Products and others	23567	75	0.3	0.3%
704	Steel_Containers	6410	500	2.9	2.8%
705	Steel_Other containers and packaging	6410	500	3.1	2.9%
706	Steel_Products and others	6410	500	2.9	2.8%
709	Other metals	3650	200	0.6	0.5%
802	Disposal bottle	1537	300	0.5	0.5%
803	Other containers	1537	100	0.2	0.2%
Total amount				104.9	100%

1$ ~ 20, 940 vnd in June 04,2012

CHAPTER 6 CONCLUSION AND RECOMMENDATION

6.1 Summary of key points

This dissertation consists of 6 sections, the contents of each section are shown as follows:

Section 1 introduces the research background, overview of solid waste management in Vietnam, the research area, and the scope as well as objectives of the study. The outline of whole study was also presented in this section.Section 2 and section 3 presents the detailed description of waste generation and characteristics from commercial and institutional sector in Hue city, respectively. Section 2 includes 4 sub-sections on hotels, restaurant and beverage sector, homebased business, traditional market and supermarket. Section 3 includes 3 sub-categories such as educational facilities, health-care facilities and offices. In each section, the literature review and methodology on sample selection, questionnaire, survey design and analytical procedure for study was described in detail.Regarding the results and discussion part, the waste generation rate and composition were discussed on differences categories by various business scale indicators. For example, in hotel sector, 6 categories such as: Guest-house, 1-star hotel, 2-star hotel, 3-star hotel, 4-star hotel and 5-star hotel were considered and the waste generation rate by number of bed, number of room, number of staff and floor area was also discussed. Besides, the mean difference among categories was also checked. Then the model on waste generation rate by number of room, number of staying guest, number of event guest was developed. Moreover, the potential for composting (food waste and garden waste), recycling (plastic and paper), reducing waste (food residues) and financial potential were identified. The interrelationships between the waste generation and business scale indicators were explored. Then the total waste generation and its potential on recycling and composting from each sector was shown and discussed. The 95% confidence interval (CI) and uncertainty analysis of total waste amount from each sector was also estimated.

In section 4, the waste generation and characteristic from other sector were presented. The waste generation from dormitory, household with business and household without business by house size also described. Besides, the author also estimated the total waste generation amount and confidential interval of total waste amount for these sectors.In the section 5, the total image of municipal solid waste generation in Hue city was shown. The contribution of each sector to total waste generation amount in Hue was also discussed. Additionally, the total recycling and composting potential, and residual food amount in general waste in Hue was also highlighted. The 95% CI of the total waste amount from municipal solid waste in Hue was also estimated by Monte Carlo simulation (100,000 times) assuming normal distributions based on the means and standard errors of the WGRs. The sensitivity as a

percentage of the contribution from the WGR of each category to the variance of the total waste amount was also examined. This section also showed the financial aspect that can recover from general waste amount in Hue.Finally, section 6 summarizes the main conclusions of the dissertation and shows the reasonable suggestions for improving and managing municipal solid waste in Vietnamese cities. Additionally, recommendations for future research and the possible development are represented.

The main achievements were shown as follows:

(1) The authors also estimated the total generated waste, the recycling and composting potential for 269 hotels in Hue. The total waste generation amount was 7.1 tons/day. In general waste, the recycling potential accounted for 13.1%, composting potential accounted for 30.5 %, and the remaining waste accounted for only 12.2%. The total disposal amount sent to the landfill site can be reduced from 55.8% to 12.2%.The results indicated that the total waste amount from hotel was mostly affected by the higher class hotel. In which, the waste generation by check-in guest had high influence (44.5%) on the total waste, followed by waste generation from room part in higher class (24.5%). The lower class had less impact to the total WGA of hotel.

(2) The total waste generation amount from food & beverage service sectors in Hue city, which was 39.85 ton/day. For general waste, the recycling potential, and compostable potential accounted for 3.44 ton/day (8.6%) and 7.86 ton/day (19.7%), respectively. The total amount of disposal waste delivered to landfill site can be reduced from 18.60 ton/day (46.7%) to 7.29 ton/day (18.3 %).The 95% confidential interval estimation of total waste generated from food and beverage service sectors in Hue City was 36.01 - 43.64 ton/day. The 95% CI of recycling potential and composting potential amount were 3.08 - 3.81 ton/day and 6.82 to 8.91 ton/day, respectively

(3) The total waste generated from Home-basebusinessin Hue was 25,151kg/day, of which 18,257 kg (73%) was GW, 4,767 kg (2.6%) was SR, and 2128 kg (8%) was SFR. GW still contained 21% that could potentially be recycled and 22% that could potentially be composted in the total waste amount. The total disposal amount sent to the landfill could be reduced from 18,257 kg7512 kg. The 95% CI of the total waste amount was estimated to be 15.07-27.78 tons/day. According to the Uncertainty analysis, the WGRs of the “Retail” category were identified as having the largest impact on the CI of the total waste amount.

(4) The total generated waste, the recycling and composting potential for 23 traditional markets in Hue. The total waste generated from market was 17.0 tons/day, of which 4.6 tons (27.1%) was collected by pig farmers for feeding livestock and 0.6 tons (3.6%) was sold to the recycling market. The composting potential accounted for 55.2% and the recycling potential accounted for 5.1% of total waste generation from traditional market in Hue. The total disposal amount sent to the landfill site would be reduced from 69.2% to 8.8% of the total. By Uncertainty analysis, '*Vegetable of first class market*' was identified as the category with the largest contribution to the variance of the total waste amount with subsequent *'Vegetable_vendor' and 'Fish of first class'*.

(5) The total waste generated from educational facilities in Hue was estimated to be 5.76 tons/day, of which 3.29 tons (57.2%) was GW, 0.15 tons (2.6%) was SR, and 2.33 tons (40.5%) was SFR. GW still contained 19.3% that could potentially be recycled and 22.4% that could potentially be composted in the total waste amount. The total disposal amount sent to the landfill could be reduced from 3.29 tons (57.2%) to 0.89 tons (15.5%).To promote recycling and composting at educational facilities, the key findings can be summarized as follows:

- Target waste items: According to the detailed breakdown of recycling and composting potential, plastic containers & packaging, paper containers & packaging, paper products, kitchen waste, and garden waste showed the highest contributions.
- Target school categories: According to the estimated recycling and composting potential, "Secondary school," "Primary school with food service," "Kindergarten," and "College & University" contained the largest potential to recycle and compost within GW.

The abovementioned items and school categories should be considered as the major policy targets for separation with the highest priority.

(6) The total waste generated from healthcare facilities was 4.4 tons/day, of which the general waste accounted for 90% and the amount recovery by informal sector was 10%. The total waste amount from the Offices, dormitory and street was 3 tons/day, 0.3 tons/day and 31.1 tons/day, respectively.

(7) The total waste generation amount from C&I sectors were 106.2 tons/day, accounted for 43.5% of total MSW in Hue. The total general waste amount from C&I sectors accounted for 32.5% of total general waste in Hue.

(8) The total waste generated in Hue was 244.2 tons/day, of which 39.2 tons (16.1%) were collected by pig farmers for feeding livestock and 10.4 tons (4.2%) were sold to the recycling market. The daily amount was collected by environmental company (HEPCO) in Hue was 194.7 tons. The composting potential accounted for 41% of total waste generation in Hue. The recycling potential accounted for 13.7%. The total disposal amount sent to the landfill site would be reduced from 79.7% to 25% of the total waste amount. The Uncertainty analysisresults of total waste generation from MSW in Hue showed that "HH without business_1 member"was identified as the category with the largest contribution (26%) to the variance of the total waste amount, followed by 'Home-based business_retail' (13.6%) and "Small restaurant" (10.9%).

(9) The recycling potential in general waste can generate considerable profits of approximately 104.9 million vnd/day (about 5,000 us dollars/day). According to Decree 122/2015/ND-CP regulating on the new region-based minimum wages, the above-mentioned revenue amount can pay for the 600 workers with the minimum wage is 3,500,000 vnd/month.

6.2. Recommendations

1) To promote recycling and composting at MSW in Hue city, the key findings can be summarized as follows:
   - Target waste items: According to the detailed breakdown of recycling and composting potential, plastic containers & packaging, paper containers & packaging, paper products, kitchen waste, and garden waste showed the highest contributions.
   - Target generation sources: According to the estimated recycling and composting potential, "Household without business" "Home-based business" "Restaurant" and "Traditional market" contained the largest potential to recycle and compost within general waste

The abovementioned items and generation source categories should be considered as the major policy targets for separation with the highest priority.

2) Based on the Uncertainty analysis, to improve the reliability of the total estimation, the author should start by improving the data reliability at "HH without business_1 member", 'Home-based

business_retail' (13.6%), "Small restaurant". To improve the reliability of total estimation, the sample size should be increased.Further investigation must be undertaken to clarify the factors affecting waste generation rate in these categories.

3) From the results of potential on recycling and composting and financial aspect, there is a huge potential for considerable improvement.

4) Waste pickers mayneed to be trained to be more organized and to have wider networksin order to keep the cost of operations to a minimum, and purchaserecyclables from businesses, academic institutions, as wellas individual households.

5) In addition to what government agencies and businesses cando, there is a lot which can be done by the teachers/academics inmodifying the behavior of our youth. Many schools and institutionsare adopting green initiatives, but it should be made compulsoryall the schools, as it leads to addiction/behavioral change. Theycan also be a role model in segregating waste to bring in thebehavioral change in the society. Sustainability and environmentalmanagement courses may be incorporated into curriculumthroughout different levels of school systems including highereducation.

APPENDICES

Appendix 1. Questionnaire survey on educational facilities

Appendix 2. Questionnaire survey on market

Code of questionnaire
Interviewer's name

Appendix 1 Questionnaire for Educational facilities

Responder's name:		Tel:
Name of Facility:	Category:	
Address:		

A. GENERAL INFORMATION

(Please answer all following information)

No.	Question	Answer
1	Number of total classes in the facility	……. *Classes*
2	Number of total classrooms	……. *Classrooms*
3	Number of total teachers, staff	…….. *People*
	(1) Fixed staff	……. *People*
	(2) Temporary staff	……. *People*
4	Teaching time [Please ask manager about the yearly schedule including holiday and vacation]	From ……. To …….. From ……. To ……..
5	Area	Building area: ……... Floor area: ……. Garden area: …….. Total area: …….
6	Other business or facilities	
	□ Canteen	*Business time: ……. to ……..* *Food service:* □ *Breakfast* □ *Lunch* □ *Dinners* *What kind of food: ……..* *……..* *……* *Number of tables:* *Number of chairs:* *Number of staff:* - *Full time:* - *Part time:* *Area: m^2* *Where they prepare/cook food:* Net-sales: ……
	□ Photocopy shop	*Business time: ……. to ……..* *Area: m^2* *Number of machines:* *Number of workers:*
	□ Dormitory (including dormitories for student and staff)	Student - *Number of rooms:* - *Number of residents:* Staff - *Number of rooms:* - *Number of residents:*
	□ Others, …….	
7	Waste collection fee	_____VND/month

B. What are the problems, difficulties, limitations which your facilities have met for waste management?

	Activity/process	Discription for problems, difficulties, limitation
1	Waste storage	(1) ..... (2) .....
2	Waste discharge	(1) ..... (2) .....
3	Recycling - *Waste pickers* - *Junk-buyers* - *Junk-shops* - *Pig farmers*	(1) ..... (2) .....
4	Waste collection service by HEPCO	(1) ..... (2) .....
5	Collection fee by HEPCO	(1) ..... (2) .....
6	Others	(1) ..... (2) .....

C. WASTE STORAGE, DISCHARGE AND RECYCLING **[Forstaff in charge of waste]**

D. **Does your facility manage to separate the following waste categories for storage?** "Manage to separate" means you clearly separate the category from general waste, store in designated place/equipments/containers, sell/give to specified collectors such as junk buyers/pig farmers, and manage the revenue as your facility's income if you get some.

☐ Food waste	☐ Recyclable	☐ Garden waste	☐ Other ( )

E. How and where do you keep the abovementioned categories?

Waste category	Type of container			Storage place
	Material & shape	Volume (L)	No. containers	
General waste	(1)			
	(2)			
	(3)			
Food/kitchen waste	(1)			
	(2)			
	(3)			
Recyclable waste	(1)			
	(2)			
	(3)			
Garden waste	(1)			

	(2)			
	(3)			
Other	(1)			
	(2)			
	(3)			

F. How many times and when do you usually discharge the abovementioned categories?

Waste category	How many times	When			Who collect
		1st time	2nd time	3rd time	
General waste	/ day				HEPCO
Food/kitchen waste	/ day				
Recyclable waste	/				
Garden waste	/				
Other	/				

G. How do you discharge the abovementioned categories?

Waste category	How do you discharge?	
	When do you transport waste to storage place	What kind of container do you transfer waste to collection vehicles or use for collectors
General waste	☐ *Before collection time, Time: …….:……* ☐ *During collection time*	☐ *Storage container* ☐ *Plastic bag* ☐ *Other, …….*
Food/kitchen waste	☐ *Before collection time Time: …….:……* ☐ *During collection time*	☐ *Storage container* ☐ *Plastic bag* ☐ *Other, …….*
Recyclable waste	☐ *Before collection time Time: …….:……* ☐ *During collection time*	☐ *Storage container* ☐ *Plastic bag* ☐ *Other, …….*
Garden waste	☐ *Before collection time Time: …….:……* ☐ *During collection time*	☐ *Storage container* ☐ *Plastic bag* ☐ *Other, …….*
Other	☐ *Before collection time Time: …….:……* ☐ *During collection time*	☐ *Storage container* ☐ *Plastic bag* ☐ *Other, …….*

H. Does your facility burn waste ? ☐ Yes ☐ No

If answer is YES, what kind of waste does you burn?

a. All wastes as general waste (mixed waste component)

b. Selection of some special components, Please describe which waste categories does you burn? And how much do you burn?

	Burned category	How much of each category does you burn?	
		Kg/time	*%*
1			
2			

c. ***How many times do you burn waste per day or per week ?***

1. General waste: *(1) …… per day* *(2) …… per week* *(3) …… per month*

2. Medical hazardous waste: *(1) …… per day* *(2) …… per week* *(3) …… per month*

I. What do you discharge with your recyclables?

- *Please identify (by ✓or ○) the recyclable*
- *Please identify the discharge methods (Discharge/keep for selling or reuse again/others) of each waste recyclable*

No.	Component	Items	Discharge methods of waste recyclables (✓)				
			Discharge into general waste (✓)	*Keep for reusing again*	*Keep for selling*		*Others (description)*
					Keep for selling (✓)	*Price (VND/kg)*	
1	**Paper**	*Newspaper*					
2.		*Cardboard/Boxes*					
3.		*Books, notebook*					
4.		*Bags/packaging*					
5.		*Wastepaper*					
6.		*Others, ……*					
1.	**Glass**	*Bottles/ containers*					
2.		*Products*					
3.		*Others, ……*					
1.	**Plastic**	*Bottles*					
2.		*Containers/foam box*					
3.		*Bags/packages*					
4.		*Products*					
5.		*Others, ……*					
1.	**Metal**	*Cans*					
2.		*Containers*					
3.		*Electric appliance*					
4.		*Home utensil*					
5.		*Others, …….*					

J. [For recyclables kept for selling in Q6] Do you get benefit from recyclables? How much per time or month?

☐ *YES* ☐ *NO*

If the answer is YES, ask the following question:

Benefit	*Facility 1: …….*	*……VND/ …….*
	Facility 2: …….	*……VND/ …….*
	Facility 3: …….	*……VND/ …….*
Others	……	

[Please ask manager/staff for getting information about sale record/receipt of recyclables]

K. How many categories do you have for food waste?

☐ *Only one category (mixing solid food and soup together)*
☐ *More than one sub-category,* *Description: ……..*

L. Do you get some revenue from food waste? If so, how much do you get per time or month?

☐ *Yes*	revenue	……*VND/* …….
☐ *No*	Reason	……

M. What are the problems, difficulties, limitations which your facilities have met for waste management?

	Activity/process	Discription for problems, difficulties, limitation
1	Waste storage	…… ……
2	Waste discharge	…… ……
3	Recycling - *Waste pickers* - *Junk-buyers* - *Junk-shops* - *Pig farmers*	…… ……
4	Waste collection service by HEPCO	……
5	Collection fee by HEPCO	…… ……
6	Others	(3) …… (4) …… (5) ……

Code of questionnaire
Interviewer's name

Appendix 2 Questionnaire for Kiosk in Market

Responder's name:		Tel:
Name of Kiosk:	Category:	
Address:		

N. GENERAL INFORMATION

(Please answer all following information)

No.	Question	Answer	
1	**Number of total staff /workers** (*in the case, there are more than 02 staff, please check carefully the working allocation among them: parallel working or one-by-one working in a day).*	……. *People*	
	(3) Fixed staff	……. *People*	
	(4) Temporary staff	……. *People*	
2	**Opening hours**		
	- In the case, kiosk sell at only one location	*From* ……. *to* …….. *From* ……. *to* ……..	
	- In the case, kiosk sell at more than one locations Location 1: …… Location 2: ……	 *Time:* ……. *to* …… *Time:* ……. *to* ……	
3	**Total area**		
	- In the case, kiosk sell at only one location	*Kiosk area:* m^2 *Storage area:* m^2	
	- In the case, kiosk sell at more than one locations Location 1: …… Location 2: ……	 *Kiosk area:* m^2 *Kiosk area:* m^2	
4	Where do the kiosk's workers take breakfast/lunch?	□ Buy food from other shops and eat at their kiosks □ Bring food from their own house and eat at their kiosks □ Eat the products/food which they sell □ Come back and take at their own house □ Others, ……..	
5	Peak/Bottom **days** in a **week**	Peak:	Bottom:
6	Peak/Bottom **days** in a **month**	Peak:	Bottom:
7	Peak/Bottom **months** in a **year**	Peak:	Bottom:
8	Waste collection fee	_____VND/month	

9. What items/sub-categories do the target kiosk sell? *Please indicate by cycle the relevant ID*

	Category	ID	Sub-category
1	Mobile retail or in-market-retail of **food**	1	Gạo (Rice)
2	Mobile retail or in-market-retail of **meat and meat products**	2	Thịt (Meat)
		3	Gà Vịt (Chicken & Duck)

		4	Trứng (Eggs)
3	Mobile retail or in-market-retail of **fish and fish products**	5	Cá (fish)
4	Mobile retail or in-market-retail of **vegetables**	6	Rau (Vegetable)
		7	Trầu cau (Betel and areca)
5	Mobile retail or in-market-retail of **fruits**	8	Trái cây (Fruits)
		9	Dừa (Coconut)
6	Mobile retail or in-market-retail of **other foodstuffs**	10	Gia vị (Spice)
		11	Tạp hóa (Grocery)
		12	Bánh kẹo
		13	Công nghệ phẩm (CNP)
		14	Bún (Fresh rice noodle)
7	Mobile retail or in-market-retail of **food stalls**	15	Hàng ăn (Food stalls)
8	Mobile retail or in-market-retail of **beverages**	16	Quán nước (Beverages)
9	Mobile retail or in-market-retail of **cigarettes, rustic tobacco**	17	Thuốc lá (cigarettes, rustic tobacco)
10	Mobile retail or in-market-retail of **textiles, apparel, footwear**	18	Vải (Textiles)
		19	Quần áo (apparel)
		20	Giầy dép (Footwear)
		21	Sửa giầy dép (Footwear repairing)
		22	Quần áo cũ (Second hand cloths)
11	Mobile retail or in-market-retail of **fresh flowers, ornamental plants**	23	Hoa (Flower)
12	Remainders of **other commodities** in market-retail	24	Dung cụ gia đình (Household's equipment)
		25	Nhang đèn (Incense & candle)
		26	Nón là (Palm-leaf conical hat)
		27	Sành sứ (Porcelain)
		28	Vàng (Gold)
		29	Thuốc (Medicine)
		30	Điện thoại (Mobile phone)
		31	Đồng hồ (Watch)
		32	Cắt tóc (Hair cutting)

10. <u>For small restaurant (kiosk sell food/beverage) inside the market</u>, Asking following questions:

- *Business time: ……. to ……..*
- *Food service:* ☐ *Breakfast* ☐ *Lunch* ☐ *Dinners*
- *What kind of food: ……, ……, ……, ……,*
- *Number of tables: …… units; Number of chairs: …… units*
- *Number of staff: Full time: …… people; Part time: …… people*
- *Area: …… m^2*
- *Where they prepare/cook food:*
  ……

O. WASTE STORAGE, DISCHARGE AND RECYCLING

1. Does your kiosk manage to separate the following waste categories for storage? "Manage to separate" means you clearly separate the category from general waste, store in designated place/equipments/containers, sell/give to specified collectors such as junk buyers/pig farmers, and manage the revenue as your kiosk's income if you get some.

☐ Food waste	☐ Recyclable	☐ Other ( )

2. How and where do you keep the abovementioned categories?

Waste category	Type of container			Storage place
	Material & shape	Volume (L)	No. containers	
General waste	(1)			
	(2)			
	(3)			
Food/kitchen waste	(1)			
	(2)			
	(3)			
Recyclable waste	(1)			
	(2)			
	(3)			
Other	(1)			
	(2)			
	(3)			

3. How many times and when do you usually discharge the abovementioned categories?

Waste category	How many times	When			Who collect
		1st time	2nd time	3rd time	
General waste	/ day				
Food/kitchen waste	/ day				
Recyclable waste	/				
Other	/				

4. How do you discharge the abovementioned categories?

Waste category	How do you discharge?	
	When do you transport waste to storage place	What kind of container do you transfer waste to public dustbin?
General waste	☐ *Before close time your kiosk, Time: …….:……* ☐ *During close time your kiosk*	☐ *Storage container* ☐ *Plastic bag* ☐ *Other,*

		……..
Food/kitchen waste	☐ *Before close time your kiosk, Time: …….:……* ☐ *During close time your kiosk*	☐ *Storage container* ☐ *Plastic bag* ☐ *Other, ……..*
Recyclable waste	☐ *Before close time your kiosk, Time: …….:……* ☐ *During close time your kiosk*	☐ *Storage container* ☐ *Plastic bag* ☐ *Other, ……..*
Other	☐ *Before close time your kiosk, Time: …….:……* ☐ *During close time your kiosk*	☐ *Storage container* ☐ *Plastic bag* ☐ *Other, ……..*

5. What do you discharge with your recyclables?

- *Please identify (by ✓or ○) the recyclable*
- *Please identify the discharge methods (Discharge/keep for selling or reusing again/others) of each waste recyclable*

No.	Component	Items	Discharge methods of waste recyclables (✓)				
			Discharge into general waste (✓)	*Keep for reusing again*	*Keep for selling*		*Others (description)*
					Keep for selling (✓)	*Price (VND/kg)*	
1	**Paper**	*Newspaper*					
2.		*Cardboard/Boxes*					
3.		*Books, notebook*					
4.		*Bags/packaging*					
5.		*Wastepaper*					
6.		*Others, ……*					
1.	**Glass**	*Bottles/ containers*					
2.		*Products*					
3.		*Others, ……*					
1.	**Plastic**	*Bottles*					
2.		*Containers/foam box*					
3.		*Bags/packages*					
4.		*Products*					
5.		*Others, ……*					
1.	**Metal**	*Cans*					
2.		*Containers*					
3.		*Electric appliance*					
4.		*Home utensil*					
5.		*Others, …….*					

6. [For recyclables kept for selling in Q5] Do you get benefit from recyclables? How much per time or month?

☐ *YES* ☐ *NO*

If the answer is YES, ask the following question:

Benefit	……*VND/* …….
Others	

[Please ask manager/staff for getting information about sale record/receipt of recyclables]

7. How many categories do you have for food waste?

☐ *Only one category (mixing solid food and soup together)*
☐ *More than one sub-category,* *Description:* ……..

8. Do you get some revenue from food waste? If so, how much do you get per time or month?

☐ *Yes*	revenue	……*VND/* …….
☐ *No*	Reason	……

9. What are the problems, difficulties, limitations which your facilities have met for waste management?

	Activity/process	Discription for problems, difficulties, limitation
1	Waste storage	.....
2	Waste discharge	.....
3	Recycling - *Waste pickers* - *Junk-buyers* - *Junk-shops* - *Pig farmers*	....
4	Waste collection service by Market managers	.....
5	Collection fee by Market managers	.....
6	Others	.....