3-1 Commercial and institutional solid waste generation and relevant factors: Case study in tourism city - Hue, Vietnam

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I. INTRODUCTION

1.1. Research background

To develop an effective solid waste management (SWM) strategy for a given region, it is important to know the amount of waste generated and the composition of the waste stream. The waste generation rate (kg/unit/day) is essential to estimate future waste generation and to evaluate the waste generation trend (Bandara et al., 2007). Data on waste composition is required for the planning of collection, transportation, and treatment of municipal solid waste (MSW). Reliable data is the foundation of effective integrated waste management system (Forbes et al., 2001). Furthermore, the evaluation on waste generation for disposal habit, changes and trends are indispensable (Beigl et al., 2008). However, it must be noted that cities in Vietnam lack reliable database on SWM.

Many studies have examined waste generation and physical waste composition for MSW or different sectors of MSW in Vietnam. Among them, Thanh et al. (2010) analyzed household (HH) solid waste to assess the waste generation rate and the detailed waste composition separated into 83 sub-categories in order to identify the potential for recyclables and mitigating greenhouse gas emissions; and developed predictive models for waste generation. Trung and Kumar (2005) assessed the resource use and management in the hotel industry in Vietnam; in which, the energy and water use, as well as the waste generated in the various hotel categories have been estimated. Byer et al. (2006) conducted surveys on waste generation rate and waste composition for households, hotels and markets to identify the possibility of composting of organic solid waste in Vietnam and Laos.

Annually, Vietnam publishes a report on the current status of environment situation focusing on the year's prominent issue. In 2004, SWM became the main topic. However, the report (Worldbank, 2004) presented the information on physical composition of MSW around Vietnam, and didn't introduce in-depth data of waste stream and various sources of MSW.

The rapid economic growth and expanding urbanization in cities in Vietnam have caused the increase of the waste generation and the diversification of waste composition. Commercial and institutional solid waste accounted for high proportion of total MSW, especially in tourism cities. Therefore, the evaluation and understanding for waste generation and characteristic from these sources are indispensable for the effective SWM planning.

1.2. Overview on research areas

In this study, Hue city was selected as the research area. Hue is located in the Central of Vietnam (see Figure 1); it was also the capital of Vietnam in the old times. Hue city is the capital city of Thua Thien Hue

Figure 1. Map of location of the target research area

province with an area of 83.3 km^2 and a population of 337,506 persons (by 31 December 2009) (GSO, 2010). Hue city has been known as one of World Heritage sites in Vietnam. Nowadays, Hue is becoming famous for visitors around the world.

The collected MSW amount in Hue city was approximately 210 tons/day, and the waste collection efficiency was estimated about 90–95%, collected by the Hue Urban Environment and Public Works State Company (HEPCO) (HEPCO, 2009). The trend of waste collection amount in a year of Hue city was presented in Figure 2.
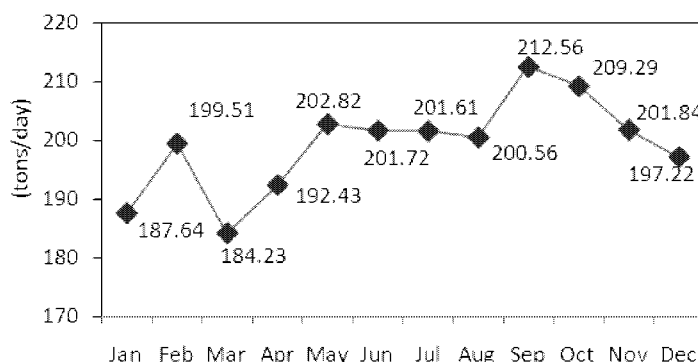

Figure 2. Average waste collection rate (tons/day) collected by HEPCO (2011)

II. OBJECTIVES OF STUDY and SCOPE OF STUDY

Objectives:

(1) To estimate and clarify the unit waste generation rate (kg/unit/day)

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

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

(4) To estimate the waste generation of each business category in Hue city by the Monte Carlo simulation of the estimated waste generation rates

Scope of study:

In this study, the target study was focused in two sectors of MSW, Institutional waste and commercial waste. The major components of commercial and institutional sectors were assessed and discussed in this study were presented in Table 1.

Table 1. Major components of commercial and institution sectors in this study

Component	Category
Institutional waste	• *Schools/University*
	• *Hospital/Healthcare*
	• *Office/Government office*
Commercial waste	▪ *Hotel*
	▪ *Restaurant*
	▪ *Market & Supermarket*
	▪ *Household with business*

III. METHODOLOGY

3.1. Sampling method

Generally, the sample selection in this study was mainly based on the total list according to the system of economic branches of Vietnam, which was accumulated by the statistical office of Hue city.

According to "*The System of Economic Branches of Vietnam*" (Decision No. 10/2007/QD-TTG dated January 23, 2007) issued by Prime Minister of the Government of Vietnam (VPM, 2007). This system 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.

Currently, when people register their business at Department of Planning and Investment, they must fill the code of the System of Economic Branches in the Application for Investment License. Depending on their business registration, the code will be level 4 or level 5.

The structure and components of *"The System of Economic Branches of Vietnam"* were summarized in Table 2. This table also presented the target categories in this study.

Table 2. The system of economic branches of Vietnam (VPM, 2007)

Level					BRANCH	Target category
1st	2nd	3rd	4th	5th		
A	1-3				*Agriculture, Forestry and Aquaculture*	
B	5-9				*Mining Minerals*	
C	10-33	88 branches, each branch coded by three numbers after those of the corresponding Level 2	242 branches, each branch coded by four numbers after those of the corresponding Level 3	437 branches, each branch coded by five numbers after those of the corresponding Level 4	*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*	School & 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		

According to *"The System of Economic Branches of Vietnam"*, the major components (main categories and sub-categories) of commercial and institutional sectors in this study were classified as well as possible, as presented in Table 3. This table also presented the total number in Hue city, sample size in this study, and sample selection method of each category and sub-category applied in this study.

Table 3. Target categories of commercial and institutional sectors and sample selection methods

Category	Sub-category	Total size	Sample size	Sample selection methods	Remarks
Institutional waste — Schools/Education service	(1) Kindergarten	49	9	Based on the total list, excluding sub-category (4). *The total list of each sub-category was prepared and sorted by the number of students. The target samples were selected systematically from the list.*	-
	(2) Primary education	37	5		
	(3) Secondary education	36	9		
	(4) Post-graduate education	8	2		
	(5) Other education services	181	6		
	(6) Education assistant services	0	0		
Institutional waste — Hospital/Healthcare services	(1) Hospitals	12	3	Random selection	-
	(2) Healthcare stations	27	3	*The total list of each sub-category was prepared and sorted by the number of beds. The target samples were selected systematically from the list.*	-
	(3) General and specialized medical establishments	256	6	*The total list of each sub-category was prepared and sorted by the number of staff. The target samples were selected systematically from the list.*	50% samples is family scale
	(4) Dental establishments	92	6		50% samples is medium scale
	(5) Standby [reserve] medical	5	1	Random selection	-
	(6) Orthopedic and rehabilitation centers	2	1	Random selection	-
Institutional waste — Offices	(1) Government offices — *Professional management services*	18	3	Random selection *(Departments/Bureaus/Institutions/Agencies)*	-
	— *People committee (PC)*	27+2	3+2	Random selection *(27 Wards' PC,2 City/Province's PC)*	
	(2) Other offices	365	32	Random selection from the total list	-
Commercial waste — Hotel	(1) Guest house	101	10	Based on the total list: *The total list of each sub-category was prepared and sorted by the number of beds. The target samples were selected systematically from the list.*	Total hotels in Hue also consist of: *45: Non-rated hotels have registered* *76: Non-rated hotels have not registered yet*
	(2) 1-star hotel	29	10		
	(3) 2-star hotel	18	7		
	(4) 3-star hotel	10	6		
	(5) 4-star hotel	7	5		
	(6) 5-star hotel	4	3		
Commercial waste — Restaurant	(1) Restaurant (large scale)	131	15	5 target zones were selected according to the urbanization level *(Thanh et al., 2010)* Based on the total list of each target zone: *The total list of each sub-category was prepared and sorted by the number of workers. The target samples were selected systematically from the list.*	68 restaurants in 5 zones
	(2) Family-restaurant and pub/bar — *1 worker* — *2 workers* — *3 workers* — *4 workers or more*	1068 836 212 190	30 22 7 6		Total number in 5 zones: — *1 worker: 565* — *2 workers: 425* — *3 workers: 114* — *4 workers or more: 92*
	(3) Beverage shops — *1 worker* — *2 workers* — *3 workers or more*	921 793 211	11 7 2	Sample size was decided according to the proportion by the number of workers in each zone.	Total number in 5 zones: — *1 worker: 564* — *2 workers: 416* — *3 workers or more: 149*
	(4) Vendor	NA	5	Random selection	1 sample for each zone
Commercial waste — Market and supermarket	(1) Market (kiosks in market)	460	64	Kiosks are classified into 12 categories and 31 sub-categories based on the *"The system of economic branches of Vietnam"* (level 5) The total list of each sub-category was prepared. The target samples were selected systematically from the list.	1st class market
	(2) Supermarket	8	1	Random selection	
Commercial waste — Household with business	(1) Manufacturing and Processing Industries (C)*	3247	45	5 target zones were selected according to the urbanization level *(Thanh et al., 2010)* Based on the total list of each target zone: *The total list of each sub-category was prepared and selected systematically from the list.* The sub-categories with less than 5 facilities were not surveyed (only 55 in total 85 sub-categories were considered and surveyed).	17 categories from 25 total categories in the 2nd level of the *"System of Economic Branches"*
	(2) Sale, repair of automobiles, motors, motorbikes etc. Wholesale and retail (G)*	7375	82		31 categories from 53 total categories in the combination both 4th and 5th levels of the *"System of Economic Branches"*

| | | (3) Other Services (Level 1 of the "*System of Economic Branches*": J, N, R, S, T)* | 2250 | 17 | | 7 categories in the 2nd level of the "*System of Economic Branches*" |

(*) Industrial code according Level 1 of the "*System of Economic Branches*" NA: Not available

3.2. Outline of survey

The target samples for each component of commercial and institutional sectors were conducted three surveys; a waste generation survey by actual measurement, a waste composition survey, and a questionnaire survey. All surveys were carried out simultaneously in rainy season (from September to December 2011). The outline of the research was presented in Figure 3.
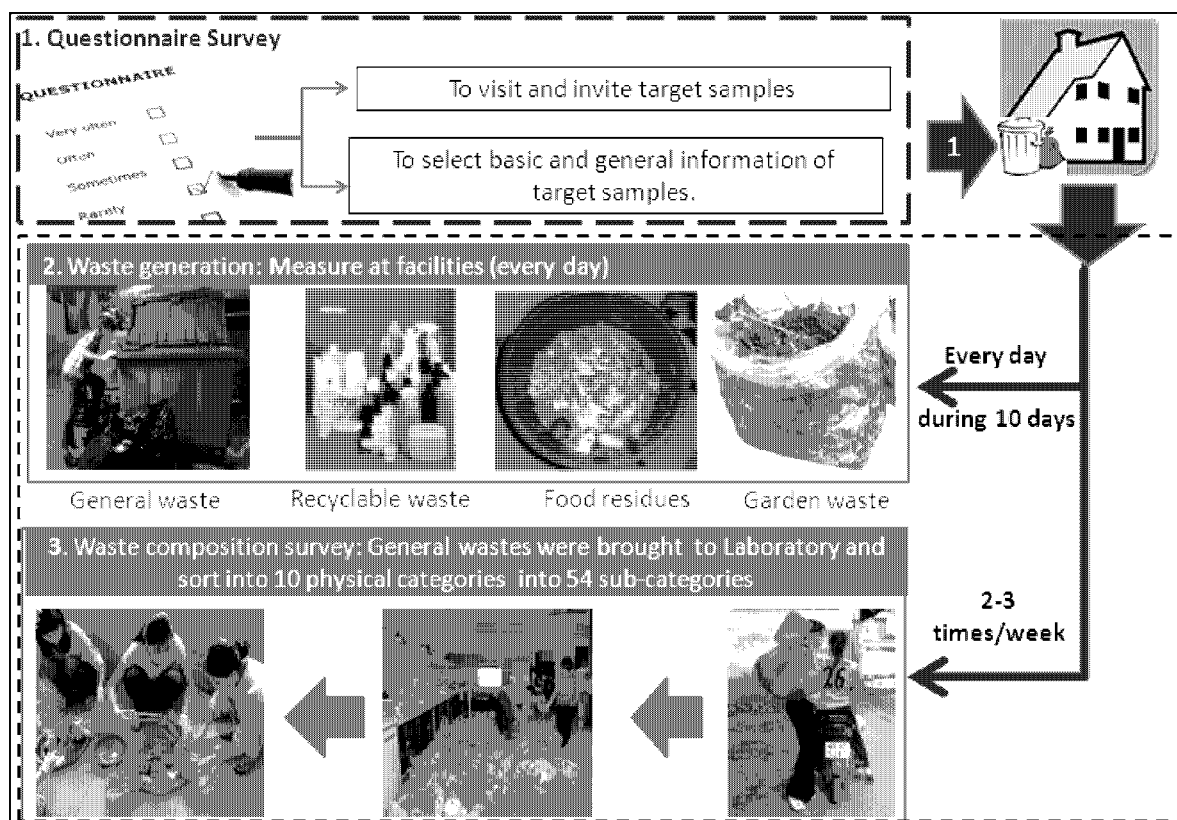
Figure 3. Flowchart of research proposal

3.2.1. *Questionnaire survey*

For recruiting target samples, a short questionnaire survey was conducted with the face-to-face interview to potential candidates that selected from the total sample list to collect basic and general information of their facilities. Moreover, this questionnaire also included information about the waste storage situation, waste discharge and collection habits, as well as the behavior for recycling activities. The purpose of this part is to understand the current status of waste management at target samples in order to design the measurement time and measurement method.

During the waste generation survey, a detailed questionnaire survey was designed and conducted to obtain the detailed information on relevant factors influencing waste generation such as business scale indicators and the current status of recycling activities.

3.2.2. *Waste generation survey*

A waste generation survey was conducted to acquire data on discharge amount of waste generated for 10 consecutive days. Of which, 3 first days spent for preparatory survey to make sure that the surveyors as well as relating people who take in charge of waste discharge/recycling and other relevant people can

147

understand well daily activities and schedule of the survey; then, 7 consecutive days of main survey was started.

The target samples were requested to keep and separate their waste into 4 categories; *"General waste,"* *"Recyclables,"* *"Food residues,"* and *"Garden waste."* The wastes was daily collected and measured by wet weight. These categories were defined as follows:

- *Recyclable*: waste items are kept for recycling or selling to informal sector or giving to somewhere/someone by target sample owner.
- *Food residues*: waste items are kept for pig (livestock) feeding which is usually collected by pig farmer.
- *Garden/yard waste*: waste items that generated from garden at target sample.
- *General waste*: all remaining waste items excepting abovementioned wastes. This waste generated from the target sample and daily discharged to waste collection service of HEPCO.

Actually, the scales of target samples were various and their storage and discharge methods were also different. Based on the current situation of each target sample, the measurement methods between large discharge sources and small discharge sources were designed different as follows:

For large discharge sources: Wastes are stored in their owner professional containers and discharged to the compacting waste trucks

- *"General waste"*, *"garden waste"*, and *"food residues"* were stored and discharged as usual. The surveyor visited and measured the weight of waste on site at the collection time of each waste (*"General waste" and "garden waste"* were collected by HEPCO's workers by the waste truck and *"food residues"* was collected by pig farmers). Each container was labeled and weighed; the void container's weight was also recorded.

- For *"recyclables"*, target samples were daily provided special "Green" plastic bags for storing their daily recyclables. The plastic bags were clearly marked indicator information, such as the waste type, date and measurement time; for example: "Recyclable, September 15th, 5:00 pm". After measurement, these plastic bags were tied up then given back to the target sample. Other plastic bags for next day were provided.

For small discharge sources: Wastes are stored in their owner temporary containers and discharged to the public dustbins or handcarts

The target samples were provided 3 different colored plastic bags for discharging waste every day, "Blue" bags for general waste, "Green" bags for recyclable, "White" bags for food residues. If they have garden, "Black" bags were provided. These plastic bags were clearly marked indicator information, such as the waste type, date and measurement time. Target samples were requested to discharge wastes/recyclables into the abovementioned specified bags. The surveyor visited and measured the weight of wastes (bags) on site at the collection time of each waste; the void bag's weight was also recorded. After measurement, "Green" plastic bags and "White" plastic bags were tied up then given back to the target sample. "Blue" and "Black" plastic bags were brought to discharge in the public dustbins by the surveyor.

During survey period, the surveyors negotiated with target respondents to make sure that all of general waste, food residues, recyclables, and garden waste were measured just before discharging general waste to HEPCO, selling recyclables to junk-buyers, and giving food residues to pig farmers.

3.2.3. Waste composition survey

In order to provide the information on waste composition data to support the development of the practical solid waste management system, this study was focused on the detailed composition of waste

generated from institutional and commercial sectors. A waste classification category list was prepared consisted of 10 physical categories and 54 sub-categories. This category list was designed and developed based on the relative shares of recyclable and compostable wastes, their usage function and purpose, discharge source and hazardous waste; referred by the previous study (Thanh *et al.*, 2010). The description of waste classification categories was illustrated in Table 4.

During the waste generation survey, a waste composition survey was conducted. *"General waste"* of the representative samples was collected and transported to the laboratory after measuring the weight on site. The collected waste was classified into 10 physical categories and 54 sub-categories by digital scale measuring a minimum of one gram (g).

3.3. Total waste generation   estimation

Total waste generation (kg/day) of commercial, institutional, and residential sectors was calculated based on following equation.

$$\text{Total waste generation (kg/day)} = \Sigma X_i * N_i$$

X_i: Waste generation rate (kg/ business scale indicator /day) of business category i

N_i: Total number of business scale indicator of business category i

i: Business category (business scale indicator): *School (No. classes, No. students, No. classroom), Healthcare service (No. patients, No. workers, No. beds), Office (No. rooms, No. workers, area (m²), Hotel (No. rooms, No. beds, No. guests), Restaurant (No. workers, No. chairs, No. tables), Household with business (No. workers), Household (population)*

For each the waste generation rate of categories and sub-categories of commercial, institutional, and residential sectors by different business scale indicators, a different calculation model was developed, so as to look for the model which showed the best result (narrow range of 95% confidence interval) was selected for calculate total waste generation in Hue city.

As a validation for the unit waste generation rates, the author estimated the 95% confidence interval of total waste discharge amount in Hue city by a *Monte Carlo Simulation* based on the means and standard errors.

3.4. Analytical procedure

This study mainly focused on estimating the waste generation rate by 4 categories: *general waste, food residues, recyclable, and garden waste* and waste composition with 10 physical categories and 54 sub-categories. The waste generation rate was calculated in various units *(kg/unit/day)* by business scale indicators for categories and sub-categories of commercial and institutional sectors. Moreover, the correlations between the waste generation rates and relevant factors/business scale indicators (e.g., number of staff, number of room, number of bed for hotel sector) were analyzed by ANOVA and Pearson correlation analysis by the statistical software (SPSS).

Table 4. Classification categories of solid waste and recycling potential

Category		Code	Sub-category
1. Plastic	*Container*	*101*	PET bottle
		102	Other plastic bottle
		103	Tray
		104	Tube
		105	Other shape
	Packaging	*106*	Shopping plastic bags
		107	Other plastic packaging
		108	Other container and packaging
	Plastic product	*109*	Plastic product
	Other plastics	*110*	Other plastics
2. Paper	*Container*	*201*	Carton (beverage and food)
		202	Container
		203	Cardboard
	Packaging	*204*	Packaging
		205	Other container and packaging
	Product	*206*	Newspapers/magazines /Advertising
		207	Books
		208	Notebooks
		209	Photocopy paper/OA paper
		210	Disposal paper products/Diapers
		211	Other paper product
	Other Paper	*212*	Other Paper
3. Kitchen waste *(food waste)*	*Compostable*	*301*	Kitchen waste (food waste)
		301a	Coffee and tea residues
		301b	A bunch of banana/coconut
	Non-compostable	*302*	Hard bones of animal or shell
4. Rubber and leather		*401*	Rubber and leather
5. Grass and wood	*Garden waste*	*501*	Garden waste
		501a	Flower
	Containers &	*502*	Container & packaging
	Wooden product	*503*	Wooden product
	Others	*504*	Other Grass and wood
6. Textile		*601*	Textile
7. Metal	*Aluminium*	*701*	Containers
		701a	Other or apart of container and packaging
		702	Products
		703	Other aluminium
	Steel	*704*	Containers
		705	Products
		706	Other steel
	Stainless	*707*	Products
	Lead	*708*	Products
	Other metals	*709*	Other metal
		710	Electrical Appliance
8. Glass	*Container*	*801*	Returnable bottle
		802	Disposal bottle
		803	Other container
	Product	*804*	Product
	Others	*805*	Others
9. Ceramic	*Containers*	*901*	Containers
	Products	*902*	Products
	Other ceramic	*903*	Other ceramic
10. Miscellaneous		*1001*	Combustibles
		1002	Other liquids
		1003	Incombustibles (Ash)
		1004	Others

IV. RESULT AND DISCUSSION

4.1. Waste generation rate

This study estimated and discussed the waste generation rate *(kg/unit/day)* for commercial and institutional sectors in Hue city, the average and standard deviation (Ave ± SD) of waste generation rate by the category of the commercial and institutional sectors were summarized. The waste generation rate was separately measured and calculated by 4 waste types; general waste, recyclable waste, food residues, and garden waste. The waste generation rate (g/unit/day) was calculated by dividing the waste generation amount per day (g/day) by business scale indicators such as the number of workers, the number of beds. These estimations and contents are indispensable basic data for the rational planning on waste management and 3Rs promotion.

4.1.1. Institutional waste

4.1.1.1. School, university, and education services

The waste generation rate was calculated by the following 3 business scale indicators; number of class, number of pupils (students), and number of classrooms. The Table 5 presented the average and standard deviation (Ave ± SD) of waste generation rate by 3 different units: *g/class/day, g/pupil (student)/day, and g/classroom/day*.

Each category of this sector was separately measured and estimated by two sources: canteen and class. Regarding waste from class activities, "Kindergarten" was identified as the highest generation category for the unit (g/class/day and g/classroom/day), while the generation rate (g/pupil/day) of "other education (baby-keeping house)" category was the highest. Regarding waste generated from canteen activities, "Kindergarten" category generated the highest waste amount were for all 3 units, followed by "Primary education" category. These results may reflect reality that Kindergarten and Primary education facilities have food services for students at breakfast and lunch time in their campus. Moreover, Kindergartens always cook and serve food for their students; this might be the reason that waste generation from these sources is higher than that of other education services.

Table 5 presented the ANOVA results, for waste generated canteen activities, the significant average difference for general waste, food residues and total waste was found for all 3 units. While, only a significant average difference ($p<0.05$) was found on general waste for the unit (g/pupil/day).

4.1.1.2. Healthcare services

The waste generation rate was discussed by the following 3 business scale indicators; number of patient, number of workers, and number of beds. The Table 5 presented the average and standard deviation (Ave ± SD) of waste generation rate by 3 different units: *g/patient/day, g/worker/day, and g/bed/day*.

Among various categories of healthcare services, the waste generation rate (g/patient/day) of "hospital" category was the highest, followed by "dental establishment" category. While "dental establishment" was the highest category for the generation rate by worker (g/worker/day), followed by "hospital." Among waste proportions, general waste accounted for the highest generation part, followed by food residues, garden waste, and recyclable waste. Hazardous healthcare waste was not covered in this study.

Regarding to the generation rate by bed *(g/bed/day)*, there are no result in the *"Dental establishments"* and *"Standby medical activities"* categories. Because these categories only provide checking health service and their opening time is mostly 8 hours per day.

Table 5 presented the ANOVA results, the significant average difference was found for garden waste (g/patient/day) and general waste (g/bed/day).

4.1.1.3. Offices

The waste generation rate was estimated by the following 3 business scale indicators; number of rooms, number of workers, and area (m^2). Table 5 presented the average and standard deviation (Ave ± SD) of waste generation rate by 3 different units: *g/room/day, g/worker/day, and g/m²/day*.

Among three categories of office sector, the waste generation rate (g/unit/day) of "professional management services" category was smaller than that of others; while "other offices" category was the highest in the waste generation rates by staff (g/worker/day) and area (g/m²/day). Among 4 waste types, recyclable waste accounted for the highest part, followed by general waste and garden waste. Food residues weren't discharged for collection by users such as pig farmers.

The significant average difference ($p < 0.01$) of ANOVA was only found for garden waste (g/room/day) and garden waste (g/worker/day).

4.1.2. Commercial waste

4.1.2.1. Hotel waste generation

The waste generation rate was discussed by the following 3 business scale indicators; number of rooms, number of beds, and number of workers. Table 5 presented the average and standard deviation (Ave ± SD) of waste generation rate by 3 different units: *kg/room/day, kg/bed/day,* and *kg/guest/day* for 6 scales of hotel sector.

Among the hotel categories, the waste generation rate *(kg/unit/day)* of "5-star hotel" category was larger than those of others; while "guesthouse" was the smallest in the most cases. Among 4 waste types, general waste accounted for the highest part, followed by food residues, recyclable, and garden waste.

For food residues, waste generation rates of food residues for "guest house", "1-star hotel", and "2-star hotel" were rather lower than that of three remaining categories: "3-star hotel", "4-star hotel" and "5-star hotel". This result was correct with the current situation, Almost "3-star hotel", "4- star hotel" and "5-star hotel" have restaurant and coffee shop/bar that usually serve food and drink for breakfast, lunch and dinner.

Table 5 was also presented the ANOVA results among 6 categories, the strong significant average differences ($p < 0.001$) were existed among 6 categories for the *total waste* in four different units: kg/bed/day, kg/room/day, kg/guest/day, kg/day. Moreover, the strong significant average differences according to business scale ($p < 0.001$ and $p < 0.01$) were also found for other waste types, general waste, recyclables, food residues, and garden waste.

4.1.2.2. Restaurant waste generation

The waste generation rate was discussed by the following 3 business scale indicators; number of workers, number of chairs, and number of tables. Table 5 presented the average and standard deviation (Ave ± SD) of waste generation rate by 3 different units: *kg/worker/day, g/chair/day,* and *g/table/day* for 9 scales of restaurant sector. Among the restaurant categories, the waste generation rate *(kg/unit/day)* of "vendor" category was smaller than those of others, followed by "beverage shops" category; while "restaurants" (large and family scale) was the highest in most cases. The waste generation rate *(kg/worker/day)* of "1-worker restaurant" category was the highest generation rate, while "3-workers restaurant" was the highest for the generation rates by table *(g/table/day)* and chair *(g/chair/day)*. Among 4 waste types, food residues accounted for the highest part, followed by general waste, recyclable, and garden waste.

Table 5 was also presented the ANOVA results among 9 categories, regarding the waste generation rate (kg/worker/day), the significant average differences was found for recyclables ($p < 0.05$) and food residues ($p < 0.001$); besides, regarding the waste generation rate (kg/chair/day), the significant average differences was only found for total waste ($p < 0.05$); while, the waste generation rate (kg/table/day), the significant average differences was found for food residues ($p < 0.05$) and total waste ($p < 0.05$).

Table 5. Waste generation rate (g/unit/day) of commercial and institutional sectors by business scale indicators

INSTITUTION WASTE — Schools/Education service (units: Group A = g/class/day; Group B = g/pupil/day; Group C = g/classroom/day)

CATEGORY	General	Recyclable	Food residues (g/class/day)	Garden	Total	General	Recyclable	Food residues (g/pupil/day)	Garden	Total	General	Recyclable	Food residues (g/classroom/day)	Garden	Total
(1) Kindergarten- Classes	1152.53±925.88	16.09±31.33	0	473.8±764.86	1559.04±911.98	31.04±22.14	0.46±0.94	0	13.48±23.53	42.61±22.88	1114.57±935.57	15.01±30.89	0	460.46±767.71	1506.67±928.56
Kindergarten- Canteen	432.33±220.83	20.6±35.18	3416.74±1357.53	0	3953.04±1446.9	12.01±4.84	0.55±0.95	96.21±37.16	0	111.14±37.85	400.73±149.64	18±31.12	3255.02±1267.5	0	3757.12±1289.01
(2) Primary education - Classes	861.67±184.57	0	0	119.14±202.17	980.82±124.45	25.61±3.01	0	0	5.01±8.97	30.62±11.3	842.9±162.36	0	0	136.63±236.88	979.53±237.65
Primary education - Canteen	112.18±66.65	0	1537.02±635.06	0	1649.2±588.62	3.21±1.22	0	51.81±28.73	0	55.03±27.54	114.69±62.9	0	1634.23±702.62	0	1748.91±647.99
(3) Secondary education - Classes	475.57±205.31	16.1±47.42	0	685.45±486.59	1177.12±583.43	12.66±5.86	0.39±1.13	0	18.35±15.7	31.39±19.41	592.01±269.84	19.4±57.52	0	888.43±701.51	1499.84±855.11
Secondary education - Canteen	126.82±48.33	18.46±22.68	117.35±133.07	0	262.62±180.03	2.88±1.04	0.42±0.52	2.69±3.04	0	5.99±4.09	182.5±121.58	21.56±21.66	154.22±180.06	0	358.28±292.03
(4) Post-graduate education-Classes	488.24±122.17	50.96±25.73	0	474.33±670.81	1013.53±818.71	7.3±2.62	0.7±0.06	0	4.5±6.36	12.5±3.67	568.03±317.5	52.98±16.46	0	283.57±401.02	904.59±67.06
Post-graduate education- Canteen	212.24±52.33	31.24±3.09	291.48±21.15	0	534.96±34.27	3.67±2.84	0.52±0.34	4.6±2.4	-	8.79±5.58	298.16±273.51	41.65±34.33	364.28±256.1	0	704.09±563.94
(5) Other education															
- Private teaching classes	21.06±1.78	0	0	0	21.06±1.78	2.58±0.04	0	0	0	2.58±0.04	138.75±56.21	0	0	0	138.75±56.21
- Baby-keeping house	1050.96±486.58	0.766	1592.27±1797.64	1.07	2643.23±1318.2	79.31±63.23	3.26	143.14±129.74	8.29	222.46±153.95	780.48±661.44	0.641	796.13±898.82	0	1576.62±451.3
ANOVA (F) [Among Classes of sub-categories]	2.662	0.766	15.489***	5.137*	2.433	3.525*	3.26	15.131***	8.29	2.452	1.609	0.641	14.943***	1.513	1.706
ANOVA (F) [Among Canteens of sub-categories]	5.665**	0.638	15.489***	3.487**	16.337***	10.090**	0.453	15.131***	3.550**	17.956***	3.841*	1.077	14.943***	-	15.986***

INSTITUTION WASTE — Healthcare services (units: Group A = g/patient/day; Group B = g/bed/day; Group C = g/bed/day)

CATEGORY	General	Recyclable	Food residues (g/patient/day)	Garden	Total	General	Recyclable	Food residues (g/bed/day)	Garden	Total	General	Recyclable	Food residues (g/bed/day)	Garden	Total
(1) Hospitals	448.16±565.2	40.83±55.98	211.72±423.43	88.19±102.73	788.89±1036.53	188.29±112.64	30.53±55.77	38.52±77.03	70.63±122.65	327.96±160.19	186.51±109.27	31.41±58.67	30.04±60.09	79.17±143.62	327.13±155.99
(2) Healthcare stations	91.37±143.24	0	0	20.73±26.67	112.09±126.91	99.78±57.02	0	0	181.66±255.37	281.43±241.22	178.67±207.28	0	0	22.29±31.52	200.95±175.76
(3) General/specialized medical establishments	96.22±100.72	13.31±26.62	44.09±88.17	0	153.62±211.07	183.47±147.76	17.45±34.89	57.79±115.59	0	258.71±263.54	374.05±300.9	14.83±29.66	49.13±98.25	0	438.01±296.23
(4) Dental establishments	570.9±517.06	0	0	0	570.9±517.06	621.66±413.17	0	0	0	621.66±413.17	621.66±413.17	0	0	-	621.66±413.17
(5) Standby [reserve] medical activities	65.93	0	0	24.25	90.18	87.68	0	0	32.25	119.94					
(6) Orthopedic and rehabilitation centers	251.51	14	162.05	292.29	719.84	57.72	3.21	37.19	67.08	165.21	50.3	2.8	32.41	58.46	143.97
ANOVA (F)	0.838	0.737	0.447	5.137*	0.703	2.551	0.397	0.329	0.807	0.952	7.578**	0.327	0.248	0.507	6.084

INSTITUTION WASTE — Offices (units: Group A = g/room/day; Group B = g/worker/day; Group C = g/m²/day)

CATEGORY	General	Recyclable	Food residues (g/room/day)	Garden	Total	General	Recyclable	Food residues (g/worker/day)	Garden	Total	General	Recyclable	Food residues (g/m²/day)	Garden	Total
(1) Government offices															
- Professional management services	168.29±166.52	9.58±16.59		154.45±131.43	332.33±233.37	35.34±43.63	1.17±2.02		28.98±24.58	65.49±61.51	1.51±1.94	0.06±0.1		1.14±1.01	2.7±2.74
- People committee (PC)	280.97±58.2	370.99±197.54		960.49±678.44	1612.44±471.41	39.32±17.6	45.76±32.01		87.21±14.33	172.29±45.84	1.86±0.23	2.66±0.24		3.74±0.39	8.26±0.2
(2) Other offices (10 detailed sub-categories)	250.22±194.77	509.35±781.28		89.71±158.12	849.28±1035.31	12.67±39.53	12.67±316.34		9.6±17.07	273.33±355.38	8.14±7.49	10.61±17.33		0.62±1.05	19.37±23.77
ANOVA (F) [Among 13 sub-categories]	1.259	1.622	2.910**	3.487**	1.622	1.134	1.901	11.698***	3.550**	1.727	0.888	0.818		1.208	0.594

COMMERCIAL WASTE — Hotel (units: Group A = kg/room/day; Group B = kg/bed/day; Group C = kg/guest/day)

CATEGORY	General	Recyclable	Food residues (kg/room/day)	Garden	Total	General	Recyclable	Food residues (kg/bed/day)	Garden	Total	General	Recyclable	Food residues (kg/guest/day)	Garden	Total
(1) Guest house	0.19±0.11	0.02±0.01	0.09±0.2	0.01±0.03	0.3±0.24	0.13±0.08	0.01±0.01	0.06±0.13	0.01±0.02	0.21±0.16	0.39±0.29	0.08±0.11	0.07±0.14	0.02±0.06	0.55±0.4
(2) 1-star hotel	0.31±0.15	0.03±0.02	0.07±0.12	0.01±0.04	0.42±0.22	0.18±0.09	0.02±0.01	0.04±0.07	0.01±0.03	0.25±0.13	0.59±0.55	0.05±0.08	0.08±0.21	0	0.75±0.66
(3) 2-star hotel	0.29±0.31	0.02±0.02	0.12±0.16	0	0.42±0.4	0.17±0.17	0.01±0.01	0.07±0.09	0	0.24±0.22	0.82±0.85	0.05±0.08	0.14±0.2	0	1.01±1
(4) 3-star hotel	0.55±0.37	0.06±0.05	0.29±0.07	0	0.9±0.4	0.29±0.18	0.03±0.03	0.16±0.04	0	0.48±0.19	1.43±1.29	0.19±0.28	1.01±1.5	0	2.63±2.63
(5) 4-star hotel	0.65±0.45	0.06±0.04	0.42±0.26	0.01±0.03	1.12±0.73	0.45±0.19	0.04±0.03	0.31±0.12	0.01±0.02	0.82±0.31	1.18±1.21	0.22±0.58	0.85±0.85	0.03±0.12	2.28±2
(6) 5-star hotel	0.79±0.24	0.1±0.07	0.51±0.02	0.11±0.17	1.5±0.25	0.58±0.25	0.07±0.06	0.37±0.03	0.08±0.12	1.1±0.31	1.73±1.05	0.21±0.18	1.13±0.42	0.08±0.19	3.15±1.38
ANOVA (F)	3.993**	3.979**	6.971***	2.619*	7.8004***	7.225***	4.968**	11.698***	2.496**	15.01***	7.207**	2.611*	10.257***	3.372**	11.529***

COMMERCIAL WASTE — Restaurant (units: Group A = kg/worker/day; Group B = g/chair/day; Group C = g/table/day)

CATEGORY	General	Recyclable	Food residues (kg/worker/day)	Garden	Total	General	Recyclable	Food residues (g/chair/day)	Garden	Total	General	Recyclable	Food residues (g/table/day)	Garden	Total
(1) Restaurant (large scale)	1.41±0.82	0.15±0.18	1.86±1.59	0	3.42±2.32	134.5±65.55	10.49±9.29	174.26±123.13	0.52±1.54	319.76±175.8	611.5±311.02	61.49±93.92	795.65±598.81	2.85±8.91	1502.38±874.94
(2) Family-restaurant and pub/bar															
- 1 worker	2.75±2.1	0.05±0.12	4.44±4.24	0	7.25±5.68	160.38±104.88	3.02±8.02	232.59±165.93	0	395.98±231.15	586.3±439.4	12.06±32.09	883.67±862.75	0	1482.04±973.35
- 2 workers	1.51±0.77	0.08±0.12	3.08±2.46	0.05±0.16	4.72±2.75	132.31±71.46	4.57±6.42	222.71±189.47	3.58±10.52	363.16±227.17	568.37±337.3	18.08±25.39	996.51±860.55	14.68±42.38	1597.64±992.37
- 3 workers	1.74±1.04	0.05±0.09	3.87±4.88	0	5.66±5.55	169.17±123.9	3.28±6.56	459.65±657.56	0.52±1.57	632.63±770.47	675.99±494.86	15.58±32.58	1796.34±2628.07	1.84±5.51	2489.74±3071.9
- 4 or more than 4 workers	2.1±2.22	0.22±0.54	2.4±2.22	0.01±0.03	4.73±4.18	210.42±161.32	4.64±7.06	317.99±377.27	0	533.05±371.61	829.28±657.46	18.58±28.24	1251.35±1520.08	0	2099.21±1520.67
(3) Beverage shops															
- 1 worker	2.08±0.93	0.01±0.01	0	0.01±0.04	2.01±0.94	101.04±52.27	0.32±0.28	0	0.09±0.94	101.36±52.34	330.9±131.1	1.14±1.05	0	0.02±0.06	332.04±131.28
- 2 workers	1.7±1.4	0.07±0.1	0	0.13±0.32	1.9±1.51	76.16±38.86	2.47±3.17	0	9.76±26.46	88.39±54.35	278.62±133.64	8.84±11.41	0	38.48±106.04	325.94±204.55
- 3 or more than 3 workers	1.95±1.88	0.79±1.36	0	0.1±0.13	2.85±2.04	126.32±44.77	8.91±11.76	0	1.87±3.23	137.09±45.75	504.74±204.17	28.21±34.53	0	7.46±12.93	540.42±194.33
(4) Vendor	1.52±1.06	0.02±0.03	0.33±0.05	0	1.87±1.04	0.09	0.03	0	0.14	0.09	63	2.18	0	0	15.75
ANOVA (F)	0.913	2.106*	2.910**	2.619*	2.023	1.566	1.586	2.121	0.831	2.330*	1.599	1.694	2.278*	0.849	2.460*

COMMERCIAL WASTE — Market and supermarket (units: Group A = kg/kiosk/day; Group B = g/m²/day; Group C = g/m²/hour)

CATEGORY	General	Recyclable	Food residues (kg/kiosk/day)	Garden	Total	General	Recyclable	Food residues (g/m²/day)	Garden	Total	General	Recyclable	Food residues (g/m²/hour)	Garden	Total
(1) Market (kiosk in market)															
- Food (rice, cereal, etc.)	1.58±1.72	0.43±0.18	0	0	2.01±1.53	0.84±0.87	0.24±0.12	0	0.01±0.02	1.08±0.75	143.7±155.98	22.07±11.31	0	0.02±0.06	98.16±68.17
- Meat and meat products	0.4±0.09	0.05±0.08	5.21	0	3.05±3.64	0.57±0.41	0.06±0.12	0	0	2.36±4.12	39.42±16.62	9.39±13.29	289.31±409.15	0	344.37±431.06
- Fish and fish products	0.29±0.31	0	1.57±1.12	0	1.85±0.96	0.33±0.34	0	0	0	1.86±1.11	39.68±48.74	0	165.21±164.48	0	201.68±153.12
- Vegetables	4.21±1.16	0	0	0	4.21±1.16	2.85	0	0	0	2.85	480.86±117.47	0	0	0	265.78±266.42
- Fruits	11.2±4.65	3.53±3.6	0	0	14.73±8.25	4.35±0.41	1.05±1.59	0	0	5.41±2.41	1135.52±262.54	111.52±70.97	0	0	551.92±95.95
- Other foodstuffs	0.22±0.1	0	0	0	0.22±0.1	0.17±0.02	0	0	0	0.17±0.03	18.31±7.71	0	0	0	10.4±6.71
- Food stalls	1.29±1.62	0.1±0.23	5.84±3.6	0.13±0.32	7.23±4.84	0.77±0.96	0.06±0.14	3.47±2.14	0	4.3±2.88	150.61±122.4	10.15±22.7	523.57±251.07	38.48±106.04	623.37±250.65
- Beverages	0.35	0	0	0	0.35	0.09	0.03	0	0	0.09	63	2.18	0	0	15.75
- Cigarettes, rustic tobacco	0.19	0.03	0	0	0.22	0.14	0	0	0	0.17	16.21	0.21	0	0	14.46
- Textiles, apparel, footwear	0.68±0.19	0.01	0	0	0.68±0.19	0.32±0.03	0.03	0	0	0.32±0.03	52.64±12.23	0	0	0	24.15±3.47
- Fresh flowers, ornamental plants	20.82±19.33	0	0	0.1±0.13	20.82±19.33	5.30±2.62	0	0	1.87±3.23	5.30±2.62	1530±1320	0	0	7.46±12.93	1530±1320
- Other commodities	0.33±0.14	0.01±0.01	0	0	0.34±0.14	0.12±0.07	0	0	0	0.12±0.07	28.23±13.57	0.22±0.26	0	0	9.9±5.49
(2) Supermarket	12.34±4	9.15	20.15±4.43	1.059	41.64±3.46	0.25±0.08	0.18	2.121	0.831	0.83±0.07	20.733***	4.778***	1.685	2.278*	3.078**
ANOVA (F)	1.637*	1.590*	1.455		3.059***	3.694**	2.817***	1.22		2.739**					2.460*

HH with business (Business source: g/worker/day; Household source: g/capita/day; Garden source: calculated in two aspects — g/household member/day; g/worker/day)

CATEGORY	General	Recyclable	Food residues	Garden	Total	General	Recyclable	Food residues	Garden	Total	General	Recyclable	Garden
(1) Manufacturing Industries (C)	715.23±1007.75	910.22±1197.22	283.52±426.02	349.09±189.54	1908.97±1598.62	259.73±141.98	193.58±86.03	87.39±93.51		350.03±570.87	1.97±2.29	3.03±10.58	14.75±11.15
(2) Sale, repair of automobiles etc.	294.49±422.15	55.54±153.68	0	223.15±138.81	350.03±570.87	193.58±86.03	27.65±82.45	27.65±82.45		456.03±337.89	1.91±8.14	1.21±4.23	
Wholesale and retail (G)	321.27±246.68	128.53±190.5	6.23±9.52	309.83±184.9	456.03±337.89	230.66±128.21	71.68±103.62	71.68±103.62			7.49±12.69	13±20.99	29.08±46.91
(3) Other Services (level 1:J,N,R,S,T)	166.61±186.77	38.44±38.71	111.4±298.92	281.82±136.02	316.45±450.94	209.91±116.52	67.91±108.72	67.91±108.72			4±5.2	0.29±0.4	0.86±1.21
ANOVA (F) [Among 55 sub-categories]	1.637*	1.590*	1.454	1.545*	3.059***	1.043	0.661	1.545*			0.661	1.494*	1.596*

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

4.1.2.3. Market and supermarket waste generation

Kiosks in market were classified into 12 categories. The waste generation rate was calculated by the following 3 business scale indicators; number of kiosks, area (m^2), and business time (hours). Table 5 presented the average and standard deviation (Ave ± SD) of waste generation rate by 3 different units: *kg/kiosk/day, kg/m^2/day*, and *g/m^2/hour*. The waste generation rate of supermarket was considered by 2 following business scale indicators: *g/m^2/day* and *kg/worker/day*.

Regarding the waste generation rate for each kiosk (kg/kiosk/day), among 12 business categories, "fresh-flower" category accounted for the highest waste generation rate (20.82 kg/day), followed by "fruits" category (14.73 kg/day), "food stall" category (7.23 kg/day), "vegetables" category (4.21 kg/day), respectively. While "other foodstuff" category and "Cigarettes, rustic tobacco" category were identified as the lowest generation rate (similar generation rate, 0.22 kg/kiosk/day). Food residue was only found in "Meat and meat product" category, "fish and fish product" category, and "food stall" category.

For all 3 units, the ANOVA results showed that significant average difference was found for general waste, recyclable and food residue and total waste.

4.1.2.4. Household with business

Households with business facilities were classified in four types of business: manufacturing industries, sale/repair of automobiles, wholesale/retail, and other services. The waste generation rate of business facilities was calculated by *g/worker/day*, and the waste generation rate of household was separately estimated by *g/capita/day*. Besides, garden waste was calculated by 2 indicators for households and business scales.

For waste generated from business activities, the ANOVA results showed significant average difference for general waste ($p<0.05$), recyclable ($p<0.05$) and total waste ($p<0.001$). The significant average difference was only found for total waste ($p<0.05$) generated from household activities. The ANOVA results also showed the significant average difference on garden waste ($p<0.05$) at both calculation cases: household activities and business activities

4.2. Waste composition

The waste composition (average proportion percentage and weight) of commercial and institutional wastes by 10 physical categories and 54 sub-categories were also estimated and discussed. Table 6 and Table 7 presented the waste composition by different business scales (in both weight and percentage).

4.2.1. Institutional waste

4.2.1.1. Waste composition of School, university, and education services

The waste composition of *School, university, and education services* by different business scales (in weight and percentage) was presented in Table 6 and Table 7. The waste compositions of education service were calculated by 5 categories of education service and garden waste. Food waste accounted for the largest part in the total general waste, followed by paper and plastic (excluding "post-graduate education" category). Regarding "post-graduate education" category, miscellaneous accounted for the largest part in the total general waste, followed by plastic, food waste, grass and wood, and paper.

4.2.1.2. Office

Paper and food waste accounted for the largest parts, followed by plastic, miscellaneous, grass and wood, metals, textile, rubber and leather, ceramic, and glass. The large generation rate of food waste was partly caused by the discharge from residents (security staff, drivers) living in the office. Paper and plastic have high potential for recycling and reducing of total waste generated from these sources.

4.2.2. Commercial waste
4.2.2.1. Hotel waste composition

Table 6 and Table 7 presented the Hotel waste composition by different business scales (in weight and percentage) of *general waste and recyclables*. Food waste accounted for the largest part in the total general waste and recyclable waste, followed by plastic and paper (excluding "guest house" category). These large components have high potential for recycling and reducing by composting and recycling options for paper and plastic waste.

Table 6. Waste composition (in percentage, %) of commercial and institutional sectors

Category		Sub-category	Plastic	Paper	Food waste	Rubber & leather	Grass & wood	Textile	Metal	Glass	Ceramic	Miscella-neous	Total	Boundary
Institutional waste	Schools/Education service	(1) Kindergarten	14.63	19.72	50.18	1.45	3.98	1.65	0.64	0.14	0.87	6.74	100	General waste (class and canteen)
		(2) Primary education	21.74	23.77	22.81	0.60	7.50	6.86	0.13	0.12	3.99	12.48	100	
		(3) Secondary education	22.74	28.76	31.90	0.17	8.21	0.53	0.32	1.14	0.46	5.77	100	
		(4) Post-graduate education	27.42	11.64	15.50	0.21	13.32	1.83	0.51	-	-	29.58	100	
		(5) Other education services												
		- Private teaching classes	8.49	6.11	38.76	0.06	39.97	0.34	1.69	0.43	-	4.15	100	
		- Baby-keeping house	21.81	38.32	26.30	0.05	7.89	0.03	0.22	-	-	5.38	100	
		Garden of school	1.38	6.39	0.24	0.06	90.71	0.73	0.03	-	-	0.45	100	
	Hospital/Healthcare services		-	-	-	-	-	-	-	-	-	-	-	
	Offices	(1) Government offices	15.66	38.57	31.39	0.58	4.69	0.78	1.90	0.18	0.14	6.13	100	General waste
		- *Professional management*	11.56	43.67	30.80	0.23	9.73	0.55	0.52	-	-	2.94	100	
		- *People committee (PC)*	14.07	35.61	39.45	0.01	0.20	0.26	1.75	-	-	8.64	100	
		(2) Other offices	21.34	36.42	23.90	1.49	4.12	1.53	3.42	0.54	0.42	6.80	100	
Commercial waste	Hotel	(1) Guest house	11.52	10.24	28.80	0.03	3.73	0.04	1.70	31.90	0.01	12.05	100	General waste and recyclable waste
		(2) 1-star hotel	28.29	23.39	28.75	0.14	10.29	0.05	3.01	-	-	6.09	100	
		(3) 2-star hotel	25.15	8.99	52.15	0.05	2.92	0.85	0.42	-	-	9.46	100	
		(4) 3-star hotel	9.48	9.69	63.11	0.77	7.56	1.17	2.74	-	-	5.48	100	
		(5) 4-star hotel	13.86	18.93	47.37	0.38	3.64	1.77	1.67	3.52	0.01	8.86	100	
		(6) 5-star hotel	15.52	13.84	55.81	0.09	1.46	2.89	1.50	3.77	0.18	4.95	100	
	Restaurant	(1) Restaurant (large scale)	12.80	9.04	57.63	0.08	4.69	2.82	1.18	0.99	0.17	10.61	100	General waste
		(2) Family-restaurant and pub/bar												
		- 1 worker	10.65	11.86	60.16	0.04	4.46	0.67	2.12	0.19	0.52	9.33	100	
		- 2 workers	11.39	6.35	53.99	0.02	9.39	1.55	1.30	0.10	0.48	15.42	100	
		- 3 workers	8.44	10.25	34.08	0.08	18.00	1.27	0.31	1.72	-	25.86	100	
		- 4 or more than 4 workers	13.18	10.02	56.85	0.04	4.19	1.30	2.39	0.35	0.53	11.14	100	
		(3) Beverage shops												
		- 1 worker	7.69	9.82	45.01	0.02	11.79	-	3.54	-	-	22.13	100	
		- 2 workers	5.97	7.14	79.86	0.04	1.04	0.57	1.63	0.11	0.13	3.51	100	
		- 3 or more than 3 workers	2.78	3.03	87.02	0.01	2.51	0.04	0.16	0.00	-	4.46	100	
		(4) Vendor	12.90	-	76.10	-	10.16	-	-	-	-	0.84	100	
	Market and supermarket	(1) Market (kiosk in market)	18.19	10.50	51.76	0.67	13.13	0.28	0.19	0.40	0.20	4.68	100	General waste
		- *Food (rice, cereal, etc.)*	2.65	0.94	71.33	0.17	-	-	-	-	-	24.91	100	
		- *Meat and meat products*	26.11	15.62	55.88	0.09	-	-	-	2.29	-	-	100	
		- *Fish and fish products*	4.74	-	95.04	-	-	-	-	-	-	0.22	100	
		- *Vegetables*	4.80	0.69	91.15	-	3.07	-	-	-	-	0.29	100	
		- *Fruits*	8.51	14.48	62.02	0.03	0.19	-	-	-	-	14.76	100	
		- *Other foodstuffs*	55.14	27.09	14.94	0.15	2.19	0.25	-	-	-	0.25	100	
		- *Food stalls*	3.67	2.98	46.61	0.03	38.45	0.02	0.03	0.43	-	7.77	100	
		- *Beverages*	-	-	-	-	-	-	-	-	-	-	-	
		- *Cigarettes, rustic*	19.87	4.10	66.56	0.95	7.26	-	1.26	-	-	-	100	
		- *Textiles, apparel,*	51.46	15.79	22.53	4.92	2.75	2.19	0.24	-	-	0.11	100	
		- *Fresh flowers,*	6.90	4.32	5.34	0.10	83.22		0.09	-	-	0.03	100	
		- *Other commodities*	16.27	29.49	37.94	0.93	7.28	0.62	0.41	1.69	2.23	3.14	100	
		(2) Supermarket	23.58	22.15	42.42	0.08	1.77	3.48	1.06	-	-	5.48	100	General waste
	Household with business	(1) Manufacturing Industries (C)	20.88	8.21	37.13	2.63	7.64	16.84	4.15	0.31	-	2.20	100	General waste of business facilities
		(2) Sale, repair of automobiles, etc.	17.39	25.43	18.84	20.21	0.48	10.54	1.84	-	-	5.29	100	
		Wholesale and retail (G)	20.32	11.37	48.52	0.54	10.99	3.27	0.69	2.51	0.46	1.32	100	
		(3) Other Services	17.30	13.32	40.70	6.53	1.76	0.45	2.74	1.87	0.92	14.41	100	

Table 7. Waste composition (in weight, g/day) of commercial and institutional sectors

Category		Sub-category	Plastic	Paper	Food waste	Rubber & leather	Grass & wood	Textile	Metal	Glass	Ceramic	Miscellaneous	Total	Boundary
Institutional waste	Schools/Education service	(1) Kindergarten	1.576	2.124	5.406	0.156	0.429	0.178	0.069	0.015	0.094	0.726	10.771	General waste (class and canteen)
		(2) Primary education	1.732	1.893	1.817	0.048	0.598	0.546	0.010	0.009	0.318	0.994	7.965	
		(3) Secondary education	3.077	3.892	4.316	0.023	1.111	0.072	0.044	0.154	0.062	0.780	13.531	
		(4) Post-graduate education	10.637	4.514	6.014	0.080	5.166	0.710	0.199	-	-	11.476	38.796	
		(5) Other education services												
		- Private teaching classes	0.550	0.967	0.664	0.001	0.199	0.001	0.006	-	-	0.136	2.523	
		- Baby-keeping house	0.105	0.076	0.480	0.001	0.495	0.004	0.021	0.005	-	0.051	1.239	
		Garden of school	0.264	1.219	0.045	0.012	17.289	0.140	0.005	-	-	0.086	19.059	
	Hospital/Healthcare services													
	Offices	(1) Government offices	0.101	0.322	0.248	0.001	0.024	0.002	0.014	-	-	0.068	0.779	General waste
		- *Professional management*	0.057	0.217	0.153	0.001	0.048	0.003	0.003	-	-	0.015	0.497	
		- *People committee (PC)*	0.139	0.416	0.333	0.000	0.003	0.001	0.023	-	-	0.116	1.032	
		(2) Other offices	0.143	0.205	0.204	0.009	0.052	0.009	0.006	0.013	0.005	0.063	0.709	
		Garden waste	0.091	0.108	0.169	0.010	0.460	0.030	0.008	0.012	-	0.203	1.090	
Commercial waste	Hotel	(1) Guest house	0.362	0.321	0.904	0.001	0.117	0.001	0.053	1.001	0.000	0.378	3.138	General waste and recyclable waste
		(2) 1-star hotel	0.633	0.524	0.644	0.003	0.230	0.001	0.067	-	-	0.136	2.239	
		(3) 2-star hotel	0.808	0.289	1.676	0.002	0.094	0.027	0.014	-	-	0.304	3.213	
		(4) 3-star hotel	1.572	1.607	10.466	0.127	1.253	0.194	0.455	-	-	0.909	16.583	
		(5) 4-star hotel	4.935	6.738	16.862	0.134	1.295	0.629	0.595	1.251	0.004	3.152	35.595	
		(6) 5-star hotel	16.349	14.580	58.804	0.098	1.539	3.041	1.584	3.970	0.185	5.217	105.367	
	Restaurant	(1) Restaurant (large scale)	1.826	1.289	8.218	0.012	0.669	0.402	0.169	0.141	0.024	1.513	14.262	General waste
		(2) Family-restaurant and pub/bar												
		- 1 worker	0.242	0.270	1.370	0.001	0.102	0.015	0.048	0.004	0.012	0.212	2.277	
		- 2 workers	0.425	0.237	2.017	0.001	0.351	0.058	0.049	0.004	0.018	0.576	3.735	
		- 3 workers	0.431	0.524	1.742	0.004	0.920	0.065	0.016	0.088	-	1.322	5.112	
		- 4 or more than 4 workers	1.035	0.787	4.466	0.003	0.329	0.102	0.188	0.028	0.042	0.876	7.856	
		(3) Beverage shops												
		- 1 worker	0.343	0.438	2.007	0.001	0.526	-	0.158	-	-	0.987	4.459	
		- 2 workers	0.167	0.200	2.233	0.001	0.029	0.016	0.046	0.003	0.004	0.098	2.796	
		- 3 or more than 3 workers	0.125	0.135	3.897	0.000	0.112	0.002	0.007	0.000	-	0.200	4.478	
		(4) Vendor	0.280	-	1.652	-	0.221	-	-	-	-	0.018	2.171	
	Market and supermarket	(1) Market (kiosk in market)												General waste
		- *Food (rice, cereal, etc.)*	0.040	0.014	1.085	0.003	-	0.000	-	-	-	0.379	1.521	
		- *Meat and meat products*	0.197	0.118	0.422	0.001	-	-	-	0.017	-	-	0.756	
		- *Fish and fish products*	0.002	-	0.044	-	-	-	-	-	-	0.000	0.046	
		- *Vegetables*	0.284	0.042	3.861	0.000	0.104	-	-	-	-	0.011	4.302	
		- *Fruits*	0.241	0.411	1.759	0.001	0.006	-	-	-	-	0.419	2.836	
		- *Other foodstuffs*	0.066	0.036	0.022	0.000	0.003	0.000	-	-	-	0.000	0.128	
		- *Food stalls*	0.086	0.070	1.095	0.001	0.903	0.001	0.001	0.010	-	0.183	2.350	
		- *Beverages*	-	-	-	-	-	-	-	-	-	-	-	
		- *Cigarettes, rustic*	0.063	0.013	0.211	0.003	0.023	-	0.004	-	-	-	0.317	
		- *Textiles, apparel,*	0.191	0.061	0.061	0.021	0.007	0.006	0.001	-	-	0.000	0.348	
		- *Fresh flowers,*	0.179	0.112	0.139	0.003	2.161	-	0.002	-	-	0.001	2.596	
		- *Other commodities*	0.052	0.151	0.104	0.003	0.024	0.003	0.002	0.005	0.004	0.013	0.363	
		(2) Supermarket	1.556	0.472	10.657	0.002	0.243	0.048	0.019	-	-	0.916	13.913	General waste
	Household with business	(1) Manufacturing Industries (C)	0.109	0.043	0.194	0.014	0.040	0.088	0.022	0.002	-	0.011	0.521	General waste of business facilities
		(2) Sale, repair of automobiles, etc.	0.118	0.256	0.188	0.018	0.004	0.106	0.016	-	-	0.043	0.749	
		Wholesale and retail (G)	0.137	0.077	0.327	0.004	0.074	0.022	0.005	0.017	0.003	0.009	0.674	
		(3) Other Services	0.060	0.046	0.142	0.023	0.006	0.002	0.010	0.007	0.003	0.050	0.349	

4.2.2.2. Restaurant waste composition

The restaurant waste composition by different business scales (in weight and percentage) was presented in Table 6 and Table 7. Food waste accounted for high proportion in total general waste (more than 50%), especially more than 75% in "beverage" and "vendor" categories. Paper and plastic were the second largest components. However, miscellaneous accounted for large part in "restaurants" (for large scale and family

scale); the possible reason was the fossil coal used for cooking in these restaurants; this coal caused large discharge amount by coal ash with high density.

4.2.2.3. Market and supermarket waste composition

Table 6 and Table 7 presented the waste composition of kiosks in market by 12 business categories (in weight and percentage). The waste composition of various kiosks in market is rather different depended on the characteristic of each business category. The average composition of supermarket showed that food waste accounted for the largest part in the total general waste, followed by paper, plastic, grass and wood.

4.2.2.4. Waste composition of Household with business

The waste compositions in various business categories of households with business sector were considered by 4 types of business: manufacturing industries, sale/repair of automobiles, wholesale/retail, and other services; the physical composition varied greatly among four types as presented in Table 6 and Table 7.

The results showed that food waste accounted for the largest part comparing to other physical categories, except "sale/repair of automobiles" category. For "sale/repair of automobiles" category, paper accounted for the highest generation rate, followed by rubber and leather, food waste, and plastic.

Table 8. Correlation analysis of waste generation (kg/day) and relevant factors$^{(\star)}$

Category		Sub-category	General	Recyclable	Food	Garden	Total
Institutional waste	Schools/ University/ Education service	(1) School/class/office					
		Number of Students/pupils	0.738***	0.655**		-	0.746***
		Number of Class	0.754***	0.612**		0.567**	0.746***
		Number of Classrooms	0.706***	0.619**		-	0.758***
		(2) Canteen (food stall)					
		Number of Students/pupils	0.603**	0.652**	-		-
		Number of Class	0.699**	0.742***	-		-
		Number of Classrooms	0.517*	0.669**	-		-
	Healthcare	Number of beds	0.988***	-	-	-	0.969***
		Number of workers	0.986***	-	-	-	0.964***
		Number of patients	0.983***	-	-	-	0.957***
	Offices	Number of rooms	0.441**	-		-	-
		Number of workers	0.526***	-		0.496**	0.420**
		Land area (m^2)	0.395*	-		0.647***	0.487**
		Floor area (m^2)	0.744***	-		0.977***	0.798***
		Garden area (m^2)	0.863***	-		0.955***	0.786**
Commercial waste	Hotel	Number of workers	0.907***	0.752***	0.913***	0.485**	0.916***
		Floor area (m^2)	0.441*	0.622**	0.585**	0.264	0.522*
		Number of rooms	0.803***	0.670***	0.855***	0.418**	0.834***
		Number of beds	0.911***	0.678***	0.931***	0.441**	0.923***
		Number of guest	0.673***	0.384***	0.693***		0.713***
		Net-sales	0.772***	0.536***	0.682***	-	0.775***
	Restaurant	Number of total workers	0.645***	0.283**	0.479***	-	0.668***
		Number of tables	0.817***	0.222*	0.266*	0.318**	0.612***
		Number of chairs	0.816***	0.242*	0.293**	0.299**	0.651***
		Market and supermarket	NA	NA	NA	NA	NA
	HH with business	(1) Business facilities					
		Number of workers	0.386***	-	-	-	0.375***
		(2) Household					
		Household size	0.308***	-	-	0.173*	0.204*

$^{(\star)}$ *Correlation analysis using Pearson correlation (2-tailed)*   **p<0.05*   ***p<0.01*   ****p<0.001*   *NA: Not available*

4.3. Relevant factors influencing waste generation

The authors analyzed the correlations between the generation rates and the relevant factors such as business scale indicators, household size, and net-sales by correlation analysis using *Pearson correlation*. The analyses were implemented by 4 waste types and total: general waste, recyclable waste, food residues, garden waste, and total waste. The results of correlation analyses were presented in Table 8. The positive significant correlations were found in many sub-categories of the commercial and institutional sectors to relevant factors. Among 5 segments of waste type, the authors found numerous significant correlations in the waste generation rate for general waste and total waste, followed by recyclable waste, garden waste, and food residues.

The results from this analysis could determine which factors were significantly affected to the waste generation amount (kg/day). It is initial step to find the dominant factors for each waste generation source in order to make the accurate estimations of current status and future total waste generation.

4.4. Estimation of waste generation from commercial, institutional, and residential sectors

6.3.1. Waste generation and discharge flow

The total waste generation (tons/day) from commercial, institutional, and residential 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 in section 4.3. Unfortunately, Market and supermarket sectors were not involved in this calculation because of missing information and database.

Table 9 presented the estimation results of total waste generated from commercial, institutional, and residential sectors by four waste types, *General waste, Recyclable waste, Food residues,* and *Garden waste.* The distributions of waste generation (both amount (tons/day) and percentage (%)) among sub-categories of commercial, institutional, and residential sectors (categories) as well as among waste types in total wastes were

Figure 4. Preliminary calculation of waste generation flow in Hue city

calculated. Among 4 waste types, *General waste* accounted for the highest part (78.55%), followed by *Food residues* (14.83%), *Recyclable* (5.43%), and *Garden waste* (1.19%). Among sub-categories of commercial, institutional, and residential sectors, *Residential waste* (household without business) accounted for the largest proportion (44.11%), followed by *Household with business* (25.72%), *Restaurant* (21.42%), *School* (3.77%), *Hotel* (3.32%), *Hospital* (1.16%), and *office* (0.49%).

This table also presented the *business scale indicator* used for estimating total waste generation of each sub-category. Based on this calculation, it was assumed that waste collection efficiency was 90% by population, the daily waste collection amounts by HEPCO was 118.83 tons/day (including general waste and garden waste); recycling rates of *Recyclables* which were stored and sold to junk-buyers by owners and *Food residues* which were stored and given to pig farms were 8.99 tons/day and 24.55 tons/day, respectively.
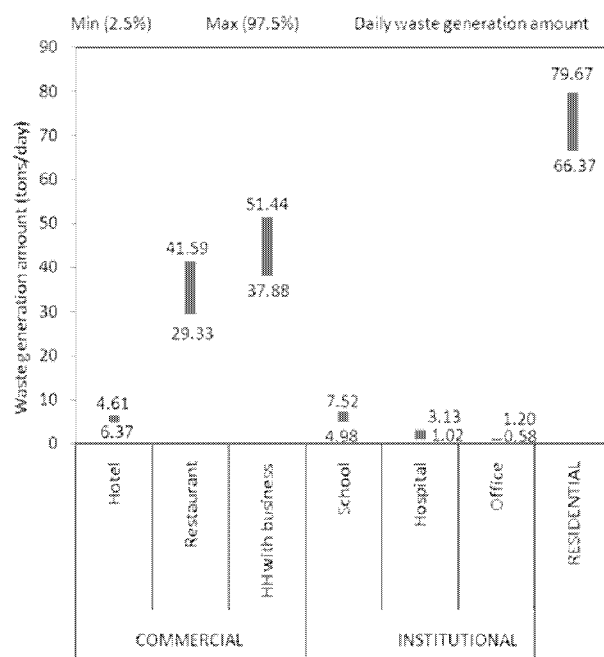
Table 9. Estimation of waste generation from commercial, institutional, and residential sectors

CATEGORY	SUB-CATEGORY	Business scale indicator	General waste tons/day	General waste %	Recyclable waste tons/day	Recyclable waste %	Food residues tons/day	Food residues %	Garden waste tons/day	Garden waste %	Total tons/day	Total %
COMMERCIAL	HOTEL	No. bed	3.32	2.55	0.34	3.78	1.70	6.93	0.13	6.82	5.49	3.32
	RESTAURANT	No. staff	16.62	12.78	1.39	15.42	17.07	69.53	0.39	19.80	35.47	21.42
	HH with business	No. facilities	33.07	25.43	6.80	75.67	2.72	11.07	-	-	42.59	25.72
INSTITUTIONAL	School	No. students**	2.43	1.87	0.08	0.84	2.72	11.08	1.02	51.65	6.24	3.77
	Hospital	No. facilities*	1.15	0.89	0.17	1.85	0.34	1.39	0.27	13.58	1.93	1.16
	Office	No. facilities	0.44	0.34	0.22	2.43	-	-	0.16	8.15	0.82	0.49
RESIDENTIAL	HH without business	Population	73.03	56.15							73.03	44.11
TOTAL			130.06	100	8.99	100	24.55	100	1.97	100	165.57	100.00
Percentage (%) among major components				78.55		5.43		14.83		1.19		100

General Hospital was calculated by No. beds   ** *Other educations were calculated by No. facilities*   *HH: Household*

As a validation for the unit waste generation rates and this estimation approach, the author estimated the 95% confidence interval of *Total waste* discharge amount by a *Monte Carlo Simulation* based on the means and standard errors. Figure 4 presented the waste generation amount (tons/day) by 95% confidence interval (95% CI) for commercial, institutional, and residential sectors in Hue city. The results showed that the wide range of 95% CI was found for sub-categories: *Household with business, Restaurant, and household without business*. These were significant signals for bad results of estimation; therefore, the 95% CI of total waste in Hue was very wide (144.77 – 190.92 tons/day). To improve the estimation results, a sensitive analysis for sub-categories of commercial, institutional, and residential sectors which had wide-range of 95%CI for finding the impact factors influencing final estimation results was calculated. For examples, Figure 5 presented the sensitive analysis for restaurant sector; *"Family-restaurant and pub/bar_1 worker"* sub-category was identified as the most component influencing total estimation result of restaurant sector, followed by *"Beverage shops_3 or more than 3 workers"*, *"Family-restaurant and pub/bar_3 workers"*, etc. These components will be concentrated and improved for next surveys.
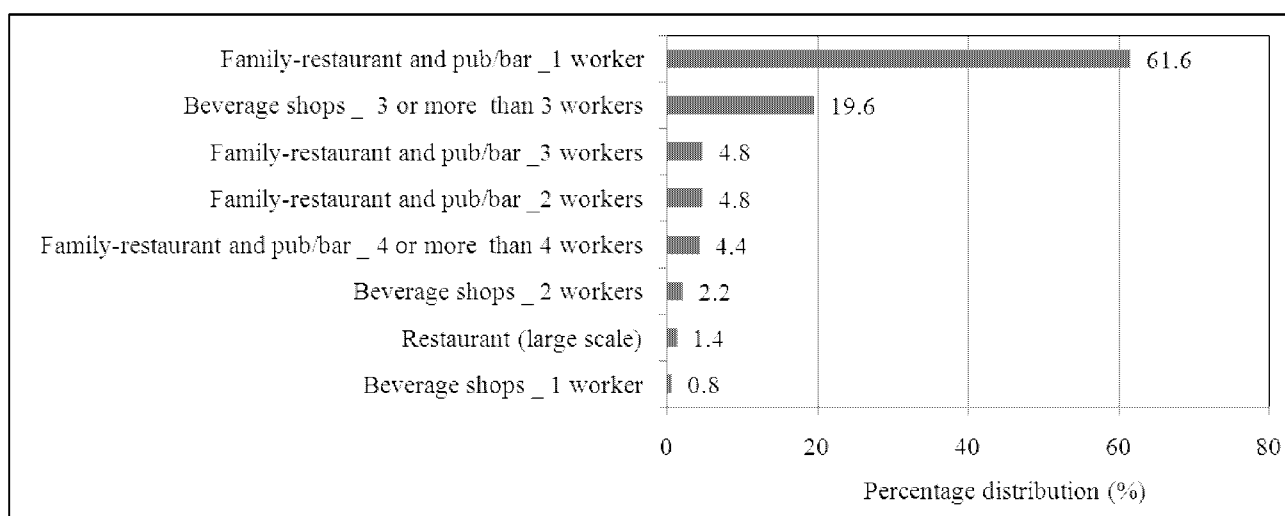
Figure 5. Sensitive analysis of sub-categories of restaurant sector
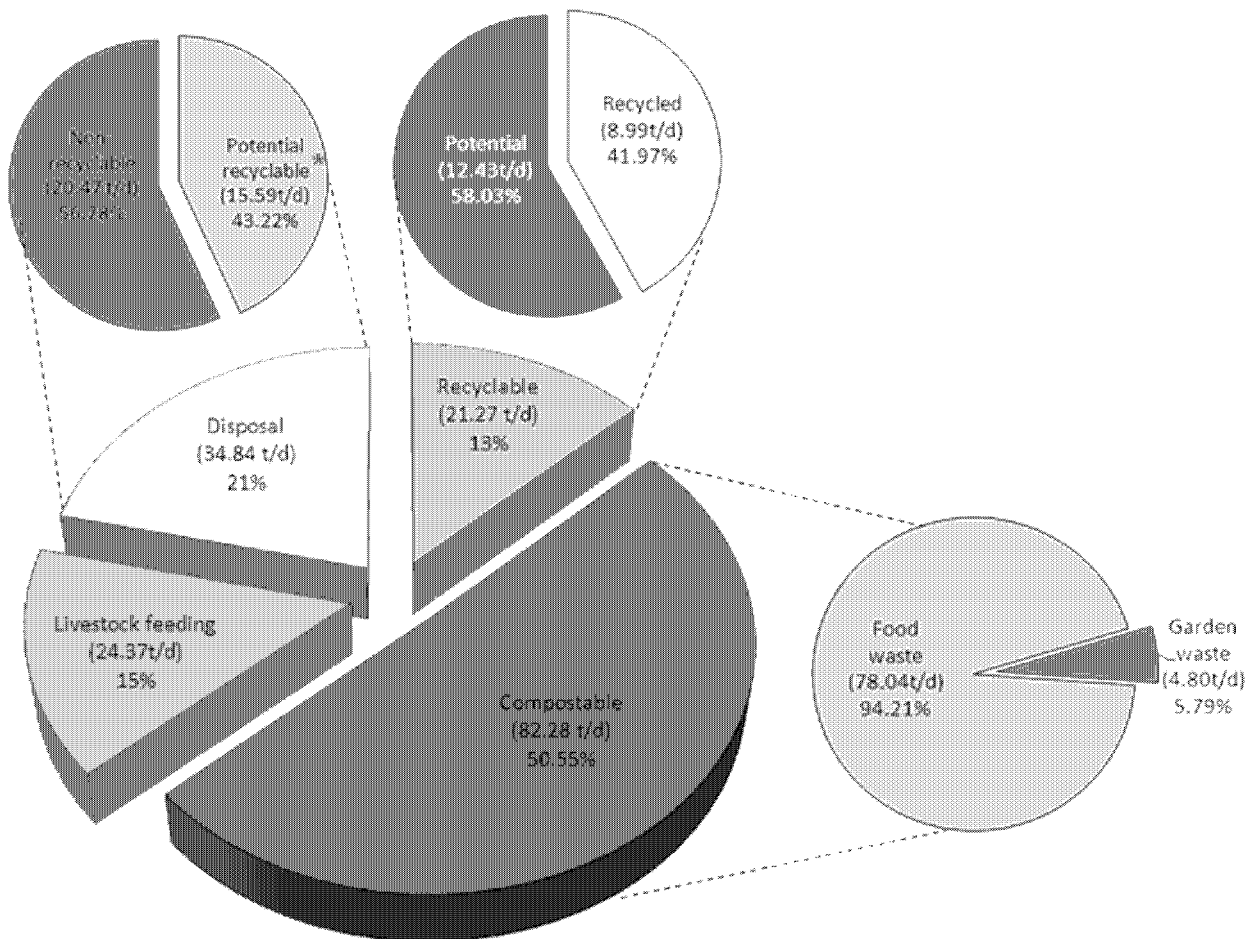
6.3.2. Recyclable potential

Figure 6 presented the waste composition distribution and recyclable potential of total waste generation in Hue city; potential materials for recycling or composting were defined based on the practical operation of recycling market in Hue city. The results showed that compostable wastes accounted for large percentage (50.25%) of total waste generation, of which more than 94% generated from food waste and remaining part from garden waste. Food residues for livestock feeding accounted for 15% of total waste generation recycled by pig farmers; this plays an important role for reducing total daily waste generation amount as well as mitigating negative effects of this source to environmental quality and natural resource conservation.

Recyclable materials also accounted for high percentage (13%) of total waste generation; of which recycled

materials which had kept and recycled by discharger owner took 41.97% and the remaining (58.03%) was high potential recyclables which may be recycled by waste pickers, waste collectors, junk-buyers, scavengers, etc.

Disposal waste part accounted 21% of total waste generation; however, 43.22% of this part was the existing potential materials for recycling, which have theoretical recyclable potential, depend on recycling market (e.g., shopping plastic bags, glass bottle, and plastic tray).

Materials which have theoretical recyclable potential, depend on recycling market (e.g., shopping plastic bags, glass bottle, plastic tray)

Figure 6. Waste composition distribution and recyclable potential

V. CONCLUSION AND RECOMMENDATION

The major focus of this study was to estimate the generation and characteristic of waste generated from the commercial and institutional sectors in a tourism city—Hue city at central of Vietnam. The main achievements were shown as follows:

- The waste generation rate *(kg/unit/day)* was calculated and discussed by various business scale indicators.

- Waste compositions were classified in 10 physical categories and 54 sub-categories. The high potential of compostable components (food waste and garden waste), recyclables materials (plastic and paper), and reducible wastes (food residues) in commercial and institutional sectors were identified.

- The interrelationships between the waste generation and business scale indicators were explored. This is the first step for developing predictive models and planning waste management system.

- By the Monte Carlo simulation, the interval estimation for total waste generation in Hue was simulated and estimated. Through the sensitive analysis, the components with high contribution to the result variation were clarified; these will be considered and improved for next surveys and researches.

This is the first step for developing predictive models and total estimation of waste flow for a given city. Further studies are necessary in consideration of a deep and wide analysis of relevant factors and levels as well as abilities to practical applications. 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 integrated solid waste management.

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