Household consumption change and household waste generation from household activities in Asian countries

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1. Research Background

Global warming and other environmental issues have necessitated changes in consumption behavior[1]. Taking into account that a household is the final consumer of society and household consumption expenditure of Japan in 2011 accounts for 59% of the GDP[2], it is evident that the consumption behavior in the household sector has a significant impact on the entire society. However, existing research on comprehensive environment sustainability barely analyzes or identifies household consumption behavior in detail for examining influences on environmental load generation. This is mainly because the detailed data required for such analysis are available only in developed countries, which has resulted in limited analysis in relation to data availability. In order to establish a sustainable society in the future, developing countries need to find a new way of sustainable development rather than following the development trail of developed countries. In quantitatively identifying a desirable social establishment, the relationship between consumption behavior and related environmental load generation must be ascertained in an explicit manner; for this purpose, a model that allows us to analyze sustainable consumption behavior must be developed. In considering future environment sustainability, the Asian region—with a large population—is extremely important as rapid economic growth has led to changes in household consumption behavior; a method for estimating environmental load generation that explicitly captures the regional consumption structure has barely been developed thus far.

2. Analysis on Waste Generation Associated with Household Consumption

In Japan, the availability of a variety of social and economic statistics as well as data on household waste generation has been the foundation of a number of research activities. For example, for total household waste generation, the Ministry of the Environment[3] publishes an annual report, in addition to the investigations unique to municipal governments, that provide not only the total amount but chronological [4), 5), 6)] or sporadic[7] data (which could continue to be investigated in the future) on the detailed composition of household waste. Japan's small land area has long led to problems related to generation control, appropriate treatment, and disposal of waste, including household waste. In contrast to the traditional estimate of household waste generation by regression analysis using economic statistics, the estimation method used to explicate consumption behavior has recently been proposed, as mentioned above; the source of household waste is included in order to enable estimation of household waste generation associated with drastic changes in consumption activities that cannot be analyzed by simple regression analysis. Kanamori and Matsuoka[8] analyzed the consumption behavior in Japan on the basis of Becker's household production theory and developed a model for estimating environmental load generated from the behavior. Similar to Kanamori and Matsuoka[8], Takase et al.[9] focused explicitly on consumption and estimated environmental load generation using the waste input-output table. Such research requires detailed data and it is difficult to simply apply the model to Asian countries with a stringent limitation on data. In addition to studies on the amount of waste generation itself, generation control by economic means[10), 11)] has also recently been studied. Thus, it is evident that active research has been conducted in Japan in relation to the estimation of household waste amount as well as generation control. Moreover, research in developing Asian countries focuses on specific cities or regions owing to a lack or extremely limited availability of data on household waste generation or insufficient awareness of local waste problems as a nationwide key issue. Under these circumstances, Yoshizawa et al.[12] and the Research Institute of Solid Waste Management Engineering[13] conducted a global study to clarify the relationship between GDP per capita and general waste generation per capita and predicted global waste generation until 2050. These rare studies attracted the attention of a number of other researchers at the time of their publication in 2004. Generally, waste problems are not global but regional, and their analyses barely focus on multiple countries.

As mentioned above, it is expected that household waste generation increases and its composition changes as a result of changes in consumption behavior associated with future population increase or economic growth in the Asian region. It is also extremely important to identify changes in waste composition from the perspective of not only total waste generation but also of its treatment and disposal. To this end, analyses must explicitly focus on changes in consumption behavior that indicate what households purchase and how they consume, in addition to identifying the total consumption amount through traditional social and economic statistics. In this study, we develop a tool that estimates environmental load generation from

simplified consumption behavior on the basis of the method proposed by Kanamori et al.[8], which is applicable to Asian countries where such data is limited. Further, the tool is applied to study the environmental load generation in six Asian countries (i.e., Japan (JPN), China (CHN), India (IND), Indonesia (IDN), Korea (KOR), and Malaysia (MYS)) in order to estimate the household consumption structure and household waste generation until 2020.

3. Household Consumption Activity Estimation Tool

This tool has been developed on the basis of the model given by Kanamori and Matsuoka[8]. Kanamori and Matsuoka[8] established a model on the basis of Becker's household production theory considering consumption expenditure and time use to study household behavior, clarified household consumption behavior for each household classification, and estimated environmental load generation from estimated consumption expenditure. In Asian regions where there is no time use data, this study identifies the household demand function from consumption expenditure data and estimates household waste generation from consumption expenditure estimated on the basis of the household demand function. The following paragraphs explain the development of each operation.

The household demand function is represented by the linear expenditure systems shown in Equations (1)–(3):

$$p_i x_i = p_i b_i + a_i \cdot \left(\sum_i p_i x_i - \sum_i p_i b_i \right); \quad (1)$$

$$\sum_i a_i = 1; \quad (2)$$

$$a_i \quad , \quad b_i \geq 0; \quad (3)$$

p_i : Consumption of goods and services i

x_i : Price of goods and services i

a_i : Preference coefficient of goods and services i

b_i : Lowest level consumption of goods and services i

The household demand function contains two parameters that determine consumption behavior. The preference coefficient a_i is a parameter representing the strength of preference for household activities, while lowest level consumption b_i may be interpreted as the minimum required consumption for living.

Next, the household waste generation is estimated from consumption expenditure using Equation (4):

$$W_{wt,t} = \sum_i E_{i,t} \cdot M_{i,wt} . \quad (4)$$

$$E_{i,t} = p_{i,t} x_{i,t} . \quad (5)$$

$W_{wt,t}$: Amount of household waste type *wt* generated in year *t*

$E_{i,t}$: Consumption expenditure of goods and services *i*

$M_{i,wt}$: Amount of household waste type *wt* generated per unit consumption expenditure of goods and services *i* (transformation matrix of household waste)

4. Estimation Flow and Data

Household waste generation associated with household consumption is defined as household waste generated as a result of consumption behavior within households. For example, the amount of waste generated from service providers (e.g., the amount of kitchen waste generated from the restaurant industry) when any service is used is not included. Household waste generation is estimated from consumption expenditure, as shown in Equation (4) above, which means that any household waste not generated from purchased goods in the household market is not estimated either. More specifically, any household waste generated from posted flyers, crops self-consumed by farmers or containers/packages brought into households as a result of purchasing goods cannot be estimated. Containers/ packages are brought into households when purchasing goods in the market; the percentage of their usage must be clarified on the basis of the relationship between goods and their containers/packages, for example, between beverages and their cans, plastic bottles, cartons, and various other containers/packages. However, this aspect is not included in this study owing to a lack of sufficient data for analysis in the Asian region.

Figure 1 presents the estimation flow. The flow of the estimation can be described in the following manner: First, we identify the parameter of the demand function (Equation (1)) from the household consumption expenditure by income class and household activity between 2005 and 2011. Then, we estimate the household consumption expenditure by income class until 2020. Using the result as well as the identified parameter of the demand parameter, we estimate the household consumption expenditure by household activity until 2020. Finally, we estimate household waste generation using Equation (4) on the basis of the estimated household consumption expenditure by household activity.

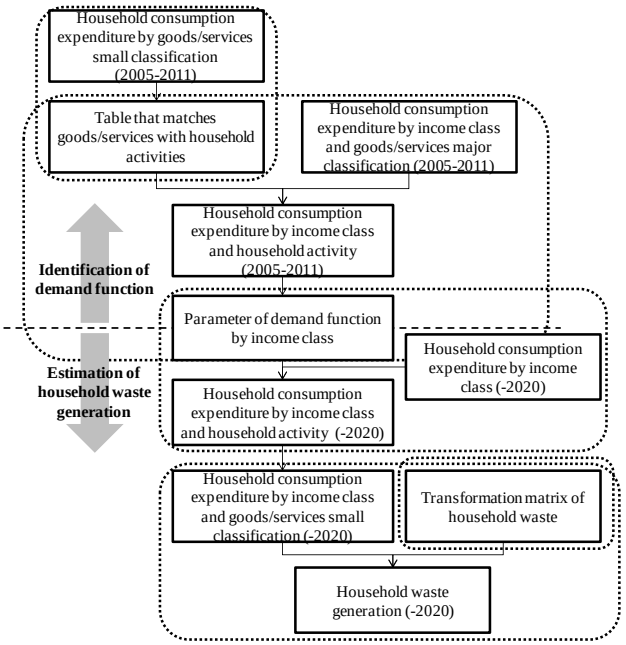

Figure 1 Eatimation flow

(1) Table that matches goods/services with household activities

Unlike simple classifications of consumption, household activities were classified according to purposes of households. This study identified the household activities shown in Table 1. A significant difference from general consumption classification is how the data on traffic, energy, and water are handled. With respect to traffic data, while some studies analyze traffic-related behavior (e.g., purchase of passenger vehicles and use of public transportation) only, in this study, we interpret it as the behavior related to any household activity. For example, the use of public transportation for purchasing groceries is regarded as an activity for food. Similarly, energy or water used for cooking should be considered as consumption for food while that used for bathing should be regarded as consumption for health and hygiene.

The consumption expenditure data used for the estimation are not classified according to household activities but according to goods and services. Table 2 matches the goods and services classification with the household activities classification of the household consumption expenditure data from Euromonitor International[14]. The present study did not include house rent in household consumption expenditure. Although the data from Euromonitor International[14] account for imputed rent, rent payment should not be equivalent to the intention of consuming goods and services apart from house rent because the cost of a house is high and payment is generally required to be made over a long period of time.

The corresponding percentage was obtained for goods and service classification that corresponds to multiple household activities in Table 2. Table 3 presents the corresponding percentages other than that of water and energy consumption:

Table 1 Household Activity

Household activity	Examples
Food (HA1)	Preparation of meals, eating-out, and purchase of cooking ingredients
Clothing (HA2)	Purchase of cloth and cleaning
Housing (HA3)	Purchase of A/C and lighting, housing repairs and maintainance
Care (HA4)	Child care and nursing care
Health care (HA5)	Hospital visit and purchase of medicine
Peraonal care (HA6)	Bath, face-wash, and purchase of makeup
Communication (HA7)	Telephone call and e-mail
Education (HA8)	School expenses
Recreation (HA9)	Trip, thieater visit and playing sports
Other (HA10)	Others

Table 3 Corresponding persetages

Goods/services	Corresponding persentages			Reference NO.
Household appliances	HA1	HA2	HA3	15)
	0.41	0.14	0.45	
Glassware, Tableware and Household Utensils	HA1	HA2	HA3	15)
	0.51	0.13	0.36	
Transport	HA1	HA2	HA9	15)
	0.4	0.2	0.4	16)

Table 2 Goods/Sertvice and household activity

Goods/Services	Household activity	G/D/S*	Goods/Services	Household activity	G/D/S*
Food and Non-Alcoholic Beverages	**HA1**		**Household Goods and Services**	**HA1・HA2・HA3**	
Food	HA1		Furniture and Furnishings, Carpets and Other Floor Coverings	HA3	D
Bread and Cereals	HA1	G	Household Textiles	HA3	D
Meat	HA1	G	Household Appliances	HA1・HA2・HA3	D
Fish and Seafood	HA1	G	Glassware, Tableware and Household Utensils	HA1・HA2・HA3	SD
Milk, Cheese and Eggs	HA1	G	Hardware and DIY Goods	HA3	D
Oils and Fats	HA1	G	Household and Domestic Services	HA3	S
Fruit	HA1	G	**Health Goods and Medical Services**	**HA5**	
Vegetables	HA1	G	Pharmaceutical Products, Medical Appliances and Equipment	HA5	G
Sugar and Confectionery	HA1	G	Outpatient Services	HA5	S
Other Food	HA1	G	Hospital Services	HA5	S
Non-Alcoholic Beverages	HA1		**Transport**	**HA1・HA2・HA9**	
Coffee, Tea and Cocoa	HA1	G	Purchase of Cars, Motorcycles and Other Vehicles	HA1・HA2・HA9	D
Mineral Waters, Soft Drinks, Fruit and Vegetable Juices	HA1	G	Operation of Personal Transport Equipment	HA1・HA2・HA9	S
Alcoholic Beverages and Tobacco	**HA1**		Transport Services	HA1・HA2・HA9	
Alcoholic Drinks	HA1		Rail Travel	HA1・HA2・HA9	S
Spirits	HA1	G	Buses, Coaches and Taxis	HA1・HA2・HA9	S
Wine	HA1	G	Air Travel	HA1・HA2・HA9	S
Beer	HA1	G	Other Travel	HA1・HA2・HA9	S
Tobacco	HA1	G	**Communications**	**HA7**	
Clothing and Footwear	**HA2**		Postal Services	HA7	S
Clothing	HA2		Telecommunications Equipment	HA7	S
Clothing Materials	HA2	SD	Telecommunications Services	HA7	S
Garments	HA2	SD	**Leisure and Recreation**	**HA9**	
Other Articles of Clothing and Clothing Accessories	HA2	SD	Audio-Visual, Photographic and Information Processing Equipment	HA9	D
Cleaning, Repair and Hire of Clothing	HA2	S	Other Major Durables For Recreation and Culture	HA9	D
Footwear	HA2	SD	Other Recreational Items and Equipment, Gardens and Pets	HA9	SD
Housing	**HA1・HA2・HA3・HA6・HA9**		Recreational and Cultural Services	HA9	S
			Newspapers, Magazines, Books and Stationery	HA9	SD
Actual Rentals For Housing			Package Holidays	HA9	S
Imputed Rentals For Housing			**Education**	**HA8**	S/SD
Maintenance and Repair of Dwellings	HA3	D	**Hotels and Catering**	**HA1・HA9**	
Water and Miscellaneous Domestic Services	HA1・HA・HA6	G	Catering	HA1	S
Electricity, Gas and Other Fuels	HA1・HA2・HA3・HA6・HA9		Accommodation	HA9	S
			Miscellaneous Goods and Services	**HA4・HA6・HA10**	
Electricity	HA1・HA2・HA3・HA9	G	Personal Care	HA6	S/SD
Gas	HA1・HA3・HA6	G	Jewellery, Silverware, Watches and Clocks, Travel Goods	HA6	SD
Liquid Fuels	HA1・HA3・HA6	G	Social Protection	HA4	S
Solid Fuels	HA1・HA3・HA6	G	Insurance	HA10	S
Heat Energy	HA3	G	Financial Services	HA10	S
			Other Goods and Services	HA10	S

*Non-durable goods (G), semidurable goods (SD), durable goods(D), and service(S).

The corresponding percentages for household appliances and glassware, Tableware amd household utensils were obtained using the Statistics Bureau of the Ministry of Internal Affairs and Communications[15] between 2003 and 2010. The average values for the period were used owing to a lack of an upward or downward trend over time despite slight annual fluctuations. Transportation was believed to be mainly used for shopping, travelling, or other outdoor entertainment, and the main activities during shopping were assumed to be related to purchase of food and clothing. Based on these assumptions, the percentages of expenditure on three items (i.e., food, clothing, and entertainment) were calculated using the data provided by the Statistics Bureau of the Ministry of Internal Affairs and Communications[15] and Tokyo Metropolitan Region Transportation Planning Council[16]. Note the following two limitations of the estimation: 1) circumstances in Japan differ from those in other countries, and 2) although the estimate in this study has been simplified, the actual estimate corresponds to a larger number of household activities. Nevertheless, the corresponding percentages available in Japan were applied to all regions owing to the unavailability of corresponding percentages specific to each country as a result of a limitation on available data.

The percentages of consumption expenditure related to water/sewerage and energy consumption that correspond to household activities were obtained from the results of Kanamori and Hijioka[17] and Kanamori and Matsuoka[18], respectively. Kanamori and Hijioka[17] estimated household water usage according to applications in five Asian countries (i.e., Japan, China, India, Korea, and Vietnam) by an accumulation calculation. Kanamori and Matsuoka[18] estimated detailed energy consumption using social and economic statistics and energy consumption information of limited availability based on the demand-supply balance of energy services in 35 regions worldwide in 2005. Water usage and energy consumption obtained from their research were matched with each household activity in order to calculate corresponding percentages. For water usage, sewerage also needs to be considered since water and sewerage bills must be allocated to household activities. However, only the result pertaining to water usage was used owing to a lack of appropriate data.

(2) Identification of parameters in demand function

In this study, we classified households according to income classes for estimating the characteristics of consumption structures arising from different types of households in regions that were studied. This study uses data according to decile classifications of annual income (HT1: Households of the lowest income class, HT2, …, HT9, HT10: Households of the highest income class). However, the goods and services classification of consumption expenditure data by income class represents the large classification of goods and services shown in Table 2 (in bold face in the Table), and the data were classified by household activity using the percentages obtained from the consumption expenditure data of all households.

$$E_{i,t}^{ht} = E_{LC,t}^{ht} \cdot E_{i,t} / \sum_{i \in LC} E_{i,t} \cdot \quad (5)$$

$E_{i,t}^{ht}$: Household consumption expenditure of goods and services *i* at the household type *ht* in year *t*

$E_{LC,t}^{ht}$: Household consumption expenditure of large classification of goods and services *LC* at the household type *ht* in year *t*

$E_{i,t}$: Household consumption expenditure of goods and services classification *i* for all households in year *t*

The divided data are classified into data by household activity using the table that matches goods/services with household activities mentioned in 4. (1) (Equation (6)):

$$E_{ha,t}^{ht} = \sum_{i} E_{i,t}^{ht} \cdot T_{ha,i,t} \cdot \quad (6)$$

$T_{ha,i,t}$: Table that matches goods and services classification *i* with household activities classification *ha* in year *t*

For the two parameters related to the demand function as well as the preference coefficient and lowest level consumption expenditure, Equations (1)–(3) were applied according to household activities to identify the preference coefficient by household activity a_{ha} and the lowest level consumption expenditure $p_{ha}b_{ha}$. More specifically, using the consumption expenditure data by income class and by household activity between 2005 and 2011, as mentioned in 4. (2), the preference coefficient a_{ha} and the lowest level consumption expenditure $p_{ha}b_{ha}$ were assumed to be the parameters that do not change over years; such parameters were determined so that the sum of squares of the difference between the estimated and observed values of the consumption expenditure by household activity $p_{ha}x_{ha}$ would be minimized. Note that the consumption expenditure data between 2005 and 2011 were used because the consumption expenditure data by income class became available only after 2005.

(3) Estimation of household consumption expenditure by income class and region

Household consumption expenditure until 2020 was estimated through regression analysis with the GDP per capita and average number of people in a household, shown in Equation (7), as the explanatory variables:

$$\log\left(E_t^{ht}\right) = c1 \cdot \log\left(GDPP_t\right) + c2 \cdot HS_t + C + ERR \cdot \quad (7)$$

E_t^{ht} : Household consumption expenditure in household type *ht* in year *t*

$GDPP_t$: GDP per capita in year *t*

HS_t : Average number of people in a household in year *t*

*c*1, *c*2: Regression coefficients

C: Constant term

ERR: Error term

The variables were regressed using the data for the period be-

tween 2005 and 2011 provided by Euromonitor International[14]; and the household consumption expenditure by household type until 2020 was estimated using the GDP per capita and average number of people in a household until 2020 estimated by Euromonitor International[14].

The consumption expenditure by household activity was estimated using future consumption expenditure estimated from Equation (1) and the parameters estimated in 4. (2):

(4) The transformation matrix of household waste

The transformation matrix of household waste is multiplied by consumption expenditure to estimate household waste generation by type. This relation is shown in Equation (4).

The transformation matrix of household waste is believed to be the product of the ratio of the price per unit weight to the amount of household waste type *wt* generated by consuming unit goods *i*, as shown in Equation (8):

$$M_{i,wt} = WM_{i,wt} / p_{i,t} \cdot \qquad (8)$$

$WM_{i,wt}$: Ratio of the consumption of goods and services *i* to the amount of household waste type *wt* generated

The transformation matrix of household waste could vary by region or household class. For example, households in the higher income class are likely to tend to purchase luxury items (i.e., products that have higher prices). Prices also vary by country as well as the structure of goods in the consumption expenditure classification. In order to obtain the transformation matrices of household waste by country, this study focuses only on the differences in prices among countries. The differences in the structure of goods in the consumption expenditure classification of different countries were estimated to be the same as that of Japan because of the relatively minute consumption expenditure classification used in this study.

We estimate the purchase volume by item in Japan in 2009. The data provided by the Statistics Bureau of the Ministry of Internal Affairs and Communications[15),19)] was used for the price data by item. The items were classified into four types: non-durable goods, semidurable goods, durable goods, and services. Non-durable goods are consumed and turn to household waste in the year of purchase, represented by food. Semidurable goods have a relatively short service life and are consumed and changed to household waste within a few years after purchasing. They mainly include the items relatively necessary for living; newly purchased items are assumed to be replacements for older items that reach the end of their service lives and the purchase volume to be equal to household waste generation. In other words, the purchase volume of both consumer and semidurable goods should be equal to household waste generation. This study does not estimate the amount of household waste generated from durable goods. The durable goods purchased in the past and that have expired end up in household waste. Taking into account that although new products as durable goods continue being released even in developed countries, it is unlikely that household waste generation and purchase volume stay constant where such goods have already been fully disseminated. However, this study did not estimate household waste generation owing to unavailability of data that represent current stocks.

With regard to consumer goods, not all food purchased will be disposed of and only kitchen waste or leftovers will account for environmental load; therefore, the percentages of kitchen waste and leftovers were obtained in a manner similar to that in Kanamori and Matsuoka[8]. Assuming that kitchen waste should be common to all regions, the amount of kitchen waste generated including leftovers was set at 15%[4] for Japan and Korea and 3% for China, India, Indonesia, and Malaysia—a fifth[20] of the level of developed countries.

The data on household waste generation by item and by household waste type in Japan were organized by consumption classification, which was used for obtaining the transformation matrix of household waste in Japan.

The transformation matrices of household waste by country are obtained considering differences in prices. The differences in prices shown in Table 4 were considered in comparison to the transformation matrix of household waste in Japan, and were obtained as the average of the surveyed year by referring to the Japan Center for International Finance[21]. For example, in China, where food is 0.167 times as expensive as that in Japan, the transformation matrix of household waste for food was set to 6 (= 1/0.167) times.

Table 4 The differences in prices

	JPN	KOR	CHN	IND	IDN	MYS
Food	1	0.57	0.167	0.167	0.4	0.4
Others	1	0.5	0.25	0.333	0.833	0.625

(5) Estimation of household waste generation

The amount of environmental load generated until 2020 was estimated using the future consumption expenditure estimated in 4. (3) and the transformation matrix of household waste obtained in 4. (4).

5. Results of the Estimation and Discussion

(1) Results of parameter identification

Figures 2–7 show the results of parameter identification related to household activities. The text of this paper discusses part of the results of 600 parameters estimated for each Figure. With respect to

the household activities necessary for living such as food (HA1), the higher the income class, the smaller the expected preference coefficient a_{ha} . In contrast, as for household activities like recreation (HA9), which are not necessary for living but increase convenience or comfort and enrich lives, the coefficient for higher income classes is expected to be higher. The lowest level consumption expenditure $p_{ha}b_{ha}$ seems to be greater for higher income classes that are likely to require a higher standard of living at a minimum.

The results obtained for developing countries like China and India were as expected. In other words, higher income classes had greater lowest level consumption expenditure by household activity. Considering the preference coefficient of high-income classes in comparison with low-income classes, the coefficient for the activities

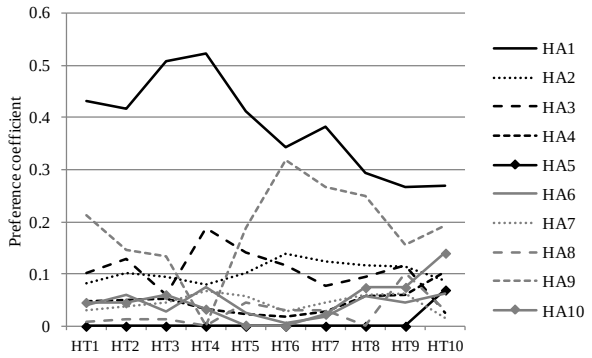

Figure 2 Preference coefficient in JPN

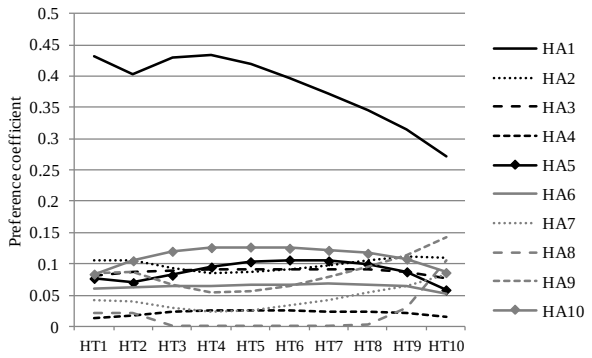

Figure 3 Preference coefficient in CHN

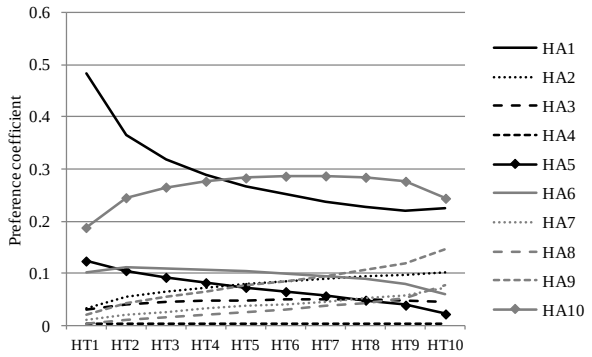

Figure 4 Preference coefficient in IND

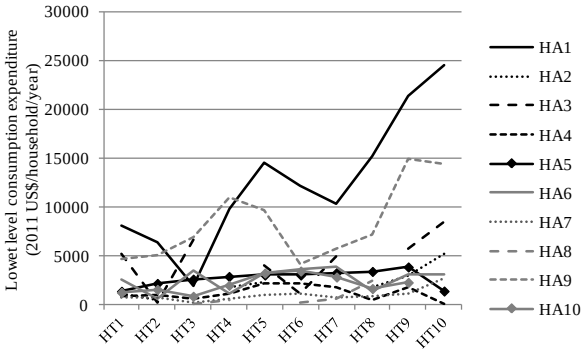

Figure 5 Lowest level consumption espenditure in JPN

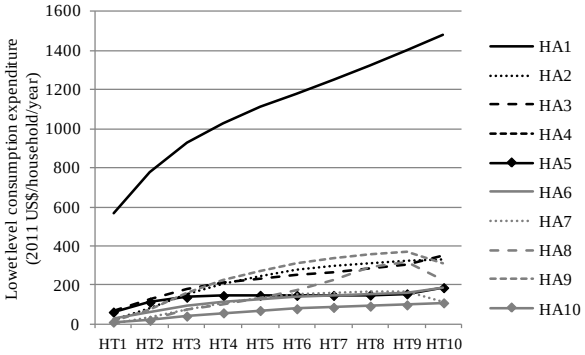

Figure 6 Lowest level consumption espenditure in CHN

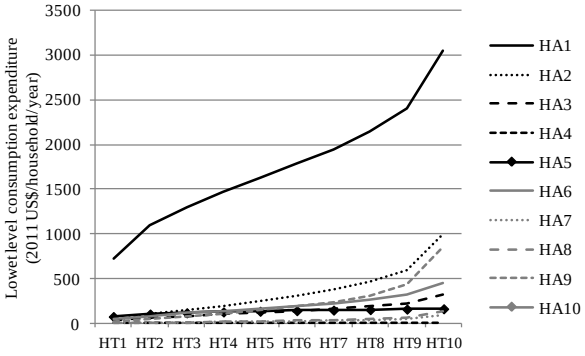

Figure 7 Lowest level consumption espenditure in IND

necessary for living, like HA1, tended to be lower, while that for HA9 tended to be higher. Some activities in India have higher lowest level consumption expenditure per household than in China, which could be well explained by the remarkable difference between the average number of people in 2005—3.5 per household in China and 5.3 per household in India[14].

Consider food (HA1) in China and India. HA1 are essential for living, but at the same time have a dimension of entertainment. For example, there has recently been increasing interest in purchasing safe, secure, and expensive groceries to care about health, and fancy restaurants or elaborate meals have drawn customer attention because eating is regarded as an entertaining activity. Examining the relation between the level of national development and the positioning of

household activities, acquiring food, houses, and clothing required for surviving is prioritized when the level of national development level is extremely low, while wealth begins to be focused on by spending more money on televisions or activities related to recreation once the nation begins developing. When it is further developed, basic activities are reviewed to purchase more expensive meals and clothes or acquire more comfortable living spaces. Bearing in mind these characteristics, the results in China and India were examined. In the former, the more developed country, an increasing number of households have begun to consider eating to be an entertaining activity and the preference coefficient decreases at a small recession ratio as the income class becomes higher; in the latter country, which is less developed than China, eating is more likely to be regarded as an activity necessary for living rather than an entertaining activity and the recession ratio of the preference coefficient would become greater as the income class becomes higher.

The results in Japan indicate that as for the lowest level consumption expenditure, the household budget of the highest income class (HT10) tends to be generally higher than that of the lowest income class (HT1), or the households of higher income classes tend to have a higher preference coefficient for recreation (HA9) than those of lower income classes although they are not as clear as the tendency arising out of different income classes examined in China or India. In developed countries like Japan, even low-income classes have attained a satisfactory standard of living compared to other parts of the world; moreover, the consumption activities of these classes do not rely on the concept that more entertainment-related or convenient goods and services are to be consumed once income increases. This tendency is seen in Korea. Analyses on developed countries require appropriate household classification or a review of the demand function, which should be studied in future research.

Table 5 Japan's household waste generation in 2005

(Unit: 10^3t)	Statistical value (S) Volume*3)	Rate*2)	Estimated value (E)	E/S
Household waste*1)	25580			
Paper	9669	37.8 %		
Containers and packaging	2225	8.7 %		
Other paper	7444	29.1 %	1797	24%
Plastic and lether	4528	17.7 %		
Containers and packaging	3223	12.6 %		
Other plastics and lethers	1305	5.1 %	701	54%
Wood waste	1407	5.5 %	699.5	50%
Textile	1688	6.6 %	1635	97%
Kitchen garbage	8007	31.3 %	7270	91%
Metal	128	0.5 %	167.3	131%
Glass	77	0.3 %	78	102%
Others	77	0.3 %	26	34%

*1) Ministry of Environment[3)]

*2) Maeda et al[6)]

*3) This value is estimated using total household waste generation and household waste rate

Table 6 Household waste generation in 2005

		JPN	KOR	CHN	IND	IDN	MYS
Domestinc waste generation							
Euromonitor International[14)]	10^3t	51607	18252	148565*1)			
Research institute of solid waste management engineering[13) *2)]	10^3t			142987	115706		
China statistical yearbook[22) *3)]	10^3t			155768			
Household waste generation (=70% of domestic waste generation)	10^3t	36125	12776	100091	80994		
Estimated value of household waste generation	10^3t	12753	3082	31921	23085	3674	688
Estimated value / household waste generation		35.3%	24.1%	31.9%	28.5%		

*1) The value is in 2003

*2) The data is calculated using Figure 2 of Research institute of solid waste management engineering[13)] by author.

*3) The data only includes waste generation from urban area in China.

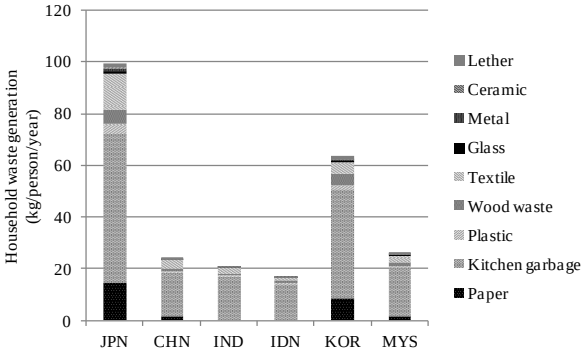

Figure 8 Household waste generation by waste type in 2005

(2) Amount of household waste generated from household activities in 2005

Tables 5 and 6 and Figure 8 show household waste generation as a result of household activities in 2005:

First, we consider the validity of the estimated values by household waste type in Japan, as shown in Table 5. The estimated results must be compared with statistics that provide data not on the amount generated but on the amount discharged. Further, there are no statistics available on the amount of household waste discharged by household waste type throughout Japan. Therefore, as indicated in a footnote to Table 5, the current study established the statistics on household waste generation using the household waste discharge rate by waste type that was obtained from household waste discharge and Maeda et al.[6)] The results must be examined under the assumption that the household waste discharge rate by waste type for a specific municipal government allows for the identification of a rough tendency with some possible errors by comparing it with the nationwide household waste discharge rate by waste type.

In this study, the results of the estimated household waste generation that does not include containers and packages were compared. Textile, kitchen, and glass wastes were relatively well estimated, while the estimate results of paper, plastic, wood, or straw waste were not satisfactory. Paper and plastic classifications include resource recovery items that might have been affected by different resource recovery rates in different regions. The insufficient results of wood and straw wastes seem to have been caused mainly by failure to consider the household waste generated by mowing the lawn or other gardening activities at the time of conducting the estimation. In any case, no further consideration can be made thus far and determining the accuracy of statistics is an aspect for future study.

Next, we examine the estimated results of household waste generation in different countries in 2005. The examination attempted

Table 7 Estimated result of consumption expenditure

10^3US$ / household		HT1			HT3			HT5			HT8			HT10		
		E	S	Compared to 2005	E	S	Compared to 2005	E	S	Compared to 2005	E	S	Compared to 2005	E	S	Compared to 2005
JPN	2005	24.3	25.3	1.0	42.8	43.6	1.0	54.2	55.3	1.0	71.2	71.3	1.0	101.2	97.2	1.00
	2010	21.8	21.8	0.9	41.9	41.7	1.0	51.1	51.2	0.9	68.6	68.0	1.0	101.3	102.2	1.00
	2015	19.6		0.8	41.6		1.0	47.9		0.9	66.2		0.9	102.6		1.01
	2020	17.3		0.7	43.1		1.0	44.2		0.8	64.1		0.9	109.2		1.08
CHN	2005	1.6	1.4	1.0	2.7	2.5	1.0	3.3	3.1	1.0	4.2	4.2	1.0	5.7	6.3	1.00
	2010	1.4	1.1	0.8	2.9	2.6	1.1	4.1	3.8	1.2	6.3	6.3	1.5	12.3	14.0	2.17
	2015	1.3		0.8	3.3		1.2	4.9		1.5	8.7		2.1	21.5		3.79
	2020	1.2		0.8	3.6		1.4	5.9		1.8	11.5		2.7	34.6		6.10
IND	2005	1.1	1.1	1.0	2.2	2.2	1.0	2.9	2.9	1.0	4.4	4.4	1.0	7.8	7.8	1.00
	2010	1.3	1.2	1.2	2.6	2.6	1.2	3.6	3.6	1.2	5.5	5.4	1.3	10.2	10.0	1.30
	2015	1.5		1.4	3.2		1.5	4.4		1.5	6.9		1.6	13.2		1.68
	2020	1.7		1.6	3.8		1.8	5.4		1.8	8.6		2.0	16.9		2.15
IDN	2005	1.6	1.5	1.0	3.1	3.0	1.0	4.1	4.0	1.0	5.9	5.9	1.0	9.8	10.0	1.00
	2010	1.9	1.8	1.2	3.7	3.7	1.2	5.0	5.0	1.2	7.3	7.4	1.2	12.5	12.9	1.28
	2015	2.2		1.4	4.7		1.5	6.4		1.6	9.8		1.7	17.7		1.80
	2020	3.2		2.0	6.4		2.1	8.6		2.1	12.6		2.1	21.5		2.19
KOR	2005	12.2	12.0	1.0	18.8	18.6	1.0	23.5	23.3	1.0	32.4	32.3	1.0	52.9	52.9	1.00
	2010	12.0	11.8	1.0	18.8	18.7	1.0	24.0	23.9	1.0	33.8	33.7	1.0	56.9	56.9	1.08
	2015	11.6		1.0	19.0		1.0	24.7		1.1	35.8		1.1	62.7		1.19
	2020	11.3		0.9	19.3		1.0	25.7		1.1	38.2		1.2	70.2		1.33
MYS	2005	3.6	3.6	1.0	8.2	8.2	1.0	11.8	11.7	1.0	19.1	19.1	1.0	40.1	40.1	1.00
	2010	4.2	4.2	1.2	9.8	9.7	1.2	14.2	14.1	1.2	23.7	23.5	1.2	52.8	52.1	1.32
	2015	5.0		1.4	11.8		1.4	17.4		1.5	29.7		1.5	69.2		1.72
	2020	6.1		1.7	14.6		1.8	21.7		1.8	37.5		2.0	90.7		2.26

E: Estimated value S: Statistical value

to compare the statistics of general waste discharge since the statistics pertaining only to household waste were not available. General waste includes industrial waste apart from household waste. In Japan, household waste accounts for approximately 70% of general waste[3], and the reported values of household waste in Table 6 were calculated by multiplying the amount of general waste discharged by 70%. As mentioned in section 4. above, household waste in this study includes what is generated after household activities lead to consumption of the goods purchased from the market and does not include any durable goods. Therefore, only approximately 35% of household waste discharged was estimated even in Japan.

In Korea, household waste generation was estimated to be 3,082,000 tons, approximately a quarter of the amount in Japan; moreover, the amount generated per capita was estimated to be approximately around 60% of that in Japan. Considering the current level of development in Korea, it is possible that the values have been underestimated. In China and India, which have large populations, nationwide household waste generation was double to 2.5 times as large as that in Japan while household waste generation per capita was estimated to be as small as around one-fifth of that in Japan. Further, the estimation also revealed that the household waste generated per capita in Malaysia and Indonesia was small.

(3) Estimated result of future consumption expenditure

Table 7 depict the estimated result of consumption expenditure for Japan in the future:

In general, the estimations reproduce past data well. The tendency common to all surveyed countries is that there is a remarkable increase in the amount of consumption expenditure in high-income classes, while the rate of increase in low-income classes is lower than that in high-income classes; the amount of consumption expenditure also tends to decrease. The above Table indicate that although an increase in the amount of consumption expenditure has generally slowed down in Japan, Korea, and other developed countries, this amount increases remarkably in the high-income classes of developing countries. While the amount of consumption expenditure increases at a similar rate in all income classes of Indonesia, this increase is more significant for higher income classes than lower ones in China, India, and Malaysia; in particular, China had a rather pronounced tendency in this regard.

(4) Estimation of amount of household waste generated in the future

Figures 9 and 10 and Table 8 present the estimation of the amount of household waste generated in the future. The estimated amount of household waste generated in Japan remained unchanged owing to a decrease in population or a slowed increase in consumption expenditure. In contrast, household waste generation was estimated to increase in all Asian countries other than Japan. In Korea, where consumption expenditure was estimated to slow down in a manner that was less significant than Japan, the amount of household waste generated in 2020 was estimated to increase by 1.36 times over the 2005 level; this estimate was around three times in China, Indonesia, and Malaysia and around twice in India. China presented an extremely high rate of increase in the amount of household waste generated per capita, with the amount estimated for 2020 being 2.67 times as much as the actual level in 2005.

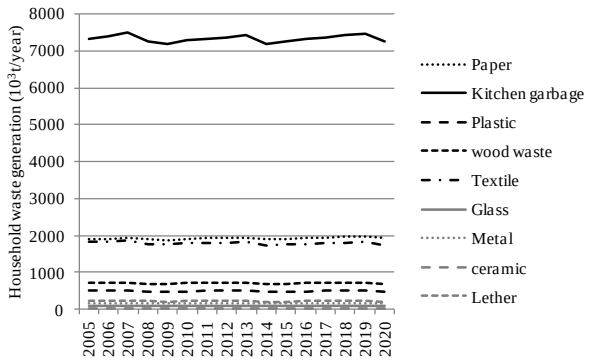

Figure 9 Household waste generation in Japan

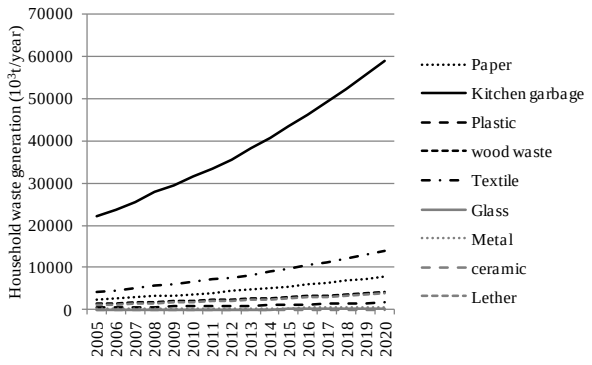

Figure 10 Household waste generation in China

Table 8 Estimated result of household waste generation

Total (Unit: 10^3 t)		2005	2010	2015	2020
JPN	Waste generation	12753	12719	12614	12602
	Growth rate		100%	99%	99%
CHN	Waste generation	31921	46635	65641	90683
	Growth rate		146%	206%	284%
IND	Waste generation	23085	28662	35438	43702
	Growth rate		124%	154%	189%
IDN	Waste generation	3674	5110	7409	10392
	Growth rate		139%	202%	283%
KOR	Waste generation	3082	3538	3904	4207
	Growth rate		115%	127%	136%
MYS	Waste generation	688	991	1407	1984
	Growth rate		144%	205%	288%
Per capita (Unit: kg/perso/year)		2005	2010	2015	2020
JPN	Waste generation	99.8	99.9	100.2	102.1
	Growth rate		100%	100%	102%
CHN	Waste generation	24.6	34.9	48.1	65.5
	Growth rate		142%	196%	267%
IND	Waste generation	20.9	24.0	27.7	32.0
	Growth rate		115%	132%	153%
IDN	Waste generation	16.8	22.0	30.3	40.9
	Growth rate		131%	181%	244%
KOR	Waste generation	64.0	72.4	79.2	85.3
	Growth rate		113%	124%	133%
MYS	Waste generation	26.3	35.1	46.6	61.8
	Growth rate		133%	177%	235%

6. Conclusion

This study developed a tool for estimating household waste generation that explicitly focuses on household consumption activities; the developed tool was applied to six Asian countries to estimate household waste generation until 2020. The following are the three main results:

- It was revealed that consumption patterns varied significantly between developed and developing countries and by income class. Although the reference amount of consumption and preference coefficient showed the expected tendency in developing countries, consumption activities that could not be expressed with the simple demand function were identified in developed countries where even low-income classes have attained a satisfactory standard of living compared to the other parts of the world.
- Among the countries studies, Japan accounted for the largest portion of household waste generation per capita in 2005; the amount in Korea was estimated to be approximately 60% and other developing countries to be approximately 20% of the level of Japan.
- In 2020, household waste generation is expected to increase in developing countries in particular owing to an increase in household consumption expenditure. It was revealed that household waste generation per capita in China would rapidly increase by 2.67 times over the 2005 level, which would account for almost 65% of household waste generation per capita in Japan.

The following two issues must be addressed in future studies:

- Household waste generation must be estimated as a result of bringing items not associated with the flow of money into households, which is not covered by this study.

  The amount of containers and packages included in household waste cannot be ignored even in Japan or other countries where containers and packages are recycled to a certain extent. In developing countries, where all containers and packages are disposed of as household waste without being actually recycled, it is of great significance to estimate such waste generation. In addition, the possibilities of self-consumption of food or farming-related waste getting mixed in household waste in rural areas must be taken into account in order to conduct an exhaustive estimation of household waste generation.
- It is important to conduct an exhaustive estimation of environmental load generation associated with household consumption activities by developing a tool that could calculate energy or water consumption along with household waste.

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