Journal of Global Environment Engineering, Vol. 15, pp.1-14, 2010

APPLICATION OF A MSW GENERATION ESTIMATION MODEL: A COMPARISON OF GENERATION PROPERTY AMONG METROPOLITAN CITIES IN CHINA

Jinmei YANG[1*], Takeshi FUJIWARA[2], Yuzuru MATSUOKA[1] and Wei WANG[3]

[1]Department of Urban and Environmental Engineering, Kyoto University.
(Kyoto-Daigaku-Katsura, Nishikyo-ku, Kyoto 615-8540, Japan)
[2]Division of Sustainability of Resources, Okayama University.
(3-1-1, Tsushima-Naka, Kita-ku, Okayama 700-8530, Japan)
[3]Department of Environmental Science and Engineering, Tsinghua University.
(Qinghua-Yuan, Haidian-qu, Beijing 100084, China)
* E-mail: *yangjm03@gmail.com*

This paper applies an integrated model to estimate the generation of municipal solid waste (MSW) by composition, taking into account the consumption expenditure by category and waste management policies. Five Chinese metropolises with different economic levels are selected for model application and comparison. In each selected city, firstly, a household consumption pattern is estimated using an extension of the linear expenditure system (LES), with lifestyle of residents attributed as explanatory variables; thereafter, MSW generation by composition is quantitatively expressed in terms of expenditure for consumption category and the waste policies by using ordinary least squares (OLS). The research findings clearly indicate that the integrated model is validated in each city with good performance of model testing. Further, the range of convention efficiency from consumption to each type of waste is determined. Moreover, the average unit MSW generation per consumption expenditure is 0.213 kg/RMB. In addition, the waste measures undertaken by the local governments have different influences on MSW generation. Accordingly, the model not only has the ability to predict the generation of each type of waste, but also presents a possibility of application to other Chinese cities without sufficient waste statistics.

***Key Words:** MSW; LES model; waste generation model; waste management policy; Chinese cities*

1. INTRODUCTION

With the universal recognition and prevalence of sustainable development, environmental sustainability—defined as 'the ability of the environment to continue to function properly'[1)]—has been widely endorsed as an ideal goal for minimizing environmental degradation. Moreover, in the conduct of municipal solid waste (MSW) management, sustainable development acts under an integrated waste management philosophy with regard to the waste hierarchy of 'reduce, reuse and recycle'. This implies that waste reduction should be emphasized on the top of the hierarchy along with reusing and recycling, thus aiming at minimizing waste[2, 3)]. The starting point in adopting such an approach should be a good understanding of the upstream flow of each type of waste category and accurate prediction of waste generation by composition[4, 5)]. The latter plays a critical role in determining optimal waste management strategies and improving waste legislations as well[6)].

Early in 1992, the UNCED conference identified the unsustainable pattern of increasing consumption as the major contributor to continued environmental degradation[7)], particularly the increasing generation of MSW. Moreover, the last two decades have witnessed increasing attention given to the influence of consumption on MSW generation[8, 9)]. In this case, MSW generation—defined as the amount of waste cleaned and transported in China—refers to the portion that enters into the waste collection and transportation system, not to what citizens deal with in their homes, such as by selling old newspapers.

Furthermore, a series of specific waste management policies constituted by the central and local governments have greatly impacted MSW generation. In addition, the generation of each type of waste is manifested from the consumption of a corresponding commodity[10], thereby indicating that the consumption pattern accounts for the most waste generation in the total MSW. Therefore, prior to the prediction of waste generation, the estimation and prediction of the consumption pattern becomes necessary and important. Meanwhile, a wide variety of studies have also indicated that the lifestyle of residents and the socio-economy constitutes a latent factor in the propensity of consumer[9, 11, 12], and has an indirect impact on waste generation or recycling behaviour subsequently[9, 13].

On the other hand, in Chinese cities, due to the deficient financial support, the lack of reliable and consistent waste records makes the forecasting extremely difficult[3, 5]. Further, the records regarding waste generation by category are not open in Chinese cities. We got the limited data records from the local Municipal Sanitation Bureau (MSB) of each city. It is thus meaningful to develop a common approach that is based on the limited waste statistics of several cities and easily popularized into other cities. Moreover, different industrialization transformations in China has given rise to prominent regional disparity with coastal cities gradually integrating into the world markets, while inland regions lag far behind in terms of industrialization[14]. The striking imbalance of economic growth thrusts Chinese cities into different stages of economic development, thereby inducing a disparity in the waste generation situation. However, not enough attention has been paid to conducting a quantitative analysis of the relationship between solid waste generation and economic level[15].

Recent years have witnessed increased attention being given to the estimation and forecasts of MSW generation[10, 16, 17]. However, a majority of the literatures focused on a simple regression analysis of total MSW generation in terms of GDP or population[16, 18]. Recently, an integrated model has been developed in our group to estimate household waste generation from consumption and applied in Japan[9] and Taiwan[19], respectively. The basic rationale of the model is the same in the previous and the current researches. However, a common model revealing the disparity in the waste generation in Chinese cities will be developed in the current paper.

The integrated model comprises a consumer behaviour model and a waste generation model. Several representative metropolitan cities with distinct economic levels are selected to solve the following issues: 1) to validate the model and estimate waste generation by waste composition in Chinese cities; 2) to analyze the change in consumption pattern affected by lifestyle of residents in each selected city; 3) to develop a common model to be easily applied into other Chinese cities; 4) to compare and analyze the disparity in MSW generation related to economic development and waste management policies among the cities.

2. METHODOLOGICAL APPROACH

(1) The consumer behaviour model

The schematic diagram of entire research framework is depicted in **Fig. 1**. Model 1 is developed in order to estimate the distribution of per capita annual total consumption expenditure (TCON) among the commodity categories by using an extension of the linear expenditure system (LES) [20, 21], with lifestyle factors and socio-economic indicators attributed as explanatory variables. The basic rationale of LES model is to classify the household consumption expenditure of each commodity category into 'subsistence' demand expenditure (sustenance) and supernumerary expenditure on various accessional extravagances[20]. In LES, the expenditure for a single consumption category i are explained by

$$C_i = C_i^* + \alpha_i (C - \sum_{j=1}^{N} C_j^*) \qquad i, j = 1, \ldots, N \tag{1}$$

with $\sum_{i=1}^{N} \alpha_i = 1, \quad 0 < \alpha_i < 1, \; C = \sum_i C_i$

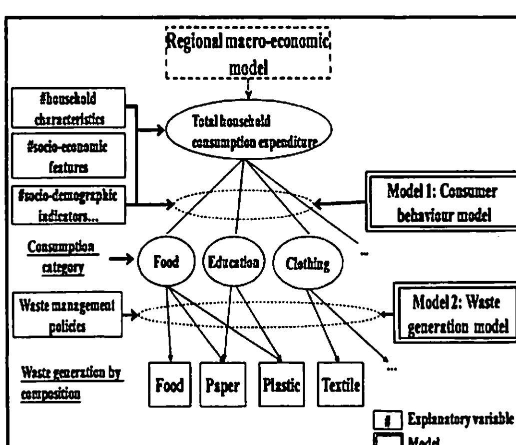

Fig.1 Schematic diagram of entire research

where the subscript i, j is a commodity category index, such as food, clothing, etc.

C: total per capita annual consumption expenditure (RMB, in base year price)

C_i: per capita annual consumption expenditure of the i-th consumption category (RMB, in base year prices)

C_i^*: subsistence expenditure of the i-th consumption category (RMB, in base year prices)

α_i: partial marginal propensity to consume in commodity category i (—)

Then, an extension of the LES model causes the subsistence expenditure to explicitly depend on a series of socio-economic and socio-demographic indicators for a time-series analysis. For simplicity, C_i^* is assumed to be a linear function of explanatory variables (γ_{ik})

$$C_i^* = b_{i0} + \sum_{k=1}^{K_i} b_{ik}\gamma_{ik} \quad (2)$$

b_{i0}: constant of per capita annual 'subsistence' demand expenditure regarded as a function of γ_{ik}

γ_{ik} (k = 1, 2,…,K_i): k-th explanatory variable of commodity category i, such as household size; however, the same variables are used for each consumption category

b_{ik} (k = 1, 2,…,K_i): parameter corresponding to γ_{ik}

Inserting the Eq. (2) in the Eq. (1) yields the final model equation, expressed in Eq. (3). Furthermore, the simultaneous equation Eq. (3) is solved using the nonlinear three-stage least square method (3SLS).

$$C_i = (b_{i0} + \sum_{k=1}^{K_i} b_{ik}\gamma_{ik}) + \alpha_i[C - \sum_{j=1}^{W}(b_{j0} + \sum_{k=1}^{K_j} b_{jk}\gamma_{jk})] \quad (3)$$

(2) The waste generation model

Model 2 in Fig. 1, named waste generation model is developed by using OLS for investigating the quantitative relationship among generation of each type of waste, corresponding consumption expenditure and waste management policies, shown as Eq. (4). In the equation, $W_{s,t}$ is the quantity of the s-th waste composition in year t (in kgs) such as food waste, paper waste, etc., computed by multiplying $W_{twaste,t}$ by the proportion of each type of waste in the total MSW. Here, $W_{twaste,t}$ is the per capita annual amount of MSW generated in year t (in kgs). Meanwhile, in order to evaluate the influence of waste measures, a dummy variable (DUM) is introduced; it is referred to as the '0/1' variable[22]. When some kind of waste legislation existed from a certain year, the variable is '1' from that year onwards; on the other hand, the variable is set to '0' prior to that year. Consequently, integrated with the predicted consumption expenditure by category computed using the LES model, and the continued influence of waste management policies, a forecasted amount for each type of waste can be obtained in the future.

$$W_{s,t} = W_{s0} + \sum_{i=1}^{W}\beta_{is}C_{i,t} + \sum_{m=1}^{M}\delta_{ms}DUM_{m,t} \quad (4)$$

W_{s0}: a constant of the waste generation of composition s

$C_{i,t}$: per capita annual consumption expenditure of the i-th commodity category in year t (RMB, in base year prices)

β_{is}: parameter corresponding to $C_{i,t}$

$DUM_{m,t}$ (m = 1, 2,…,M): m-th dummy variable (0/1 variable) in year t

δ_{ms}: parameter corresponding to $DUM_{m,t}$

Prior to the analysis of consumption pattern, the prediction of the total household expenditure can be obtained from a regional macro-economic model. The details regarding this aspect with dotted borders in Fig. 1 will be included in future works.

(3) Validation of the integrated model

The performance of the integrated model is evaluated from two aspects: (1) initially, to make the interpretation of the results straightforward with regard to economic applicability, thereby indicating that both the sizes and signs of all the estimated parameters are meaningful, for example, the explanatory variables γ_{ik}; and (2) secondly, to validate the statistical test for the sake of model reliability. In this paper, the significance and validity of the integrated model is tested using t-statistics, F-statistics, the adjusted R^2 (AdR^2) and Durbin-Watson statistic (DW)[22]. Further, mean absolute percentage error (MAPE) and root mean square error (RMSE) are taken into account as well, represented as Eq. (5). Moreover, in the waste generation model (OLS model), the heteroscedasticity is considered as well[22].

$$MAPE = \left(\frac{1}{N}\sum_{t=T_0}^{T_0+N-1}\frac{|X_t - \overline{X_t}|}{X_t}\right)\times 100\%,$$
$$RMSE = \sqrt{\frac{\sum_{t=T_0}^{T_0+N-1}(X_t - \overline{X_t})^2}{N}}\times 100\%, \quad (5)$$

where N denotes length of years; X_t, the actual value of variable X in year t; and $\overline{X_t}$, estimation value of variable X in year t.

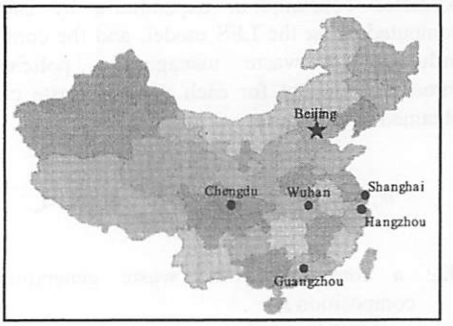

Fig.2 A sketch map of China marking the relative location of selected cities

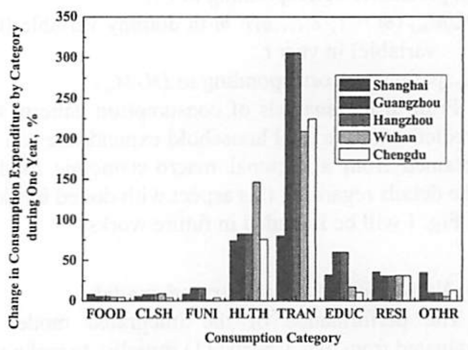

Fig.3 Average change in expenditure by consumption category in selected cities, %

Table 1 The abbreviations for the types of consumption categories

Consumption category	Abbreviation
Food	FOOD
Clothing & shoes	CLSH
Household facilities, articles & services	FUNI
Medicine & medical services	HLTH
Education, cultural & recreation services	EDUC
Transport & communication services	TRAN
Residence	RESI
Miscellaneous commodities & services	OTHR

Table 2 Geographical and economic indicators for each selected city in 2007

	Shanghai	Guangzhou	Hangzhou	Wuhan	Chengdu
Population (million persons)	13.79	7.73	6.72	8.28	11.12
Population under waste collection (old central urban area, million persons)	10.32	4.60	2.17	5.29	4.00
Areas (km^2)	6 340	7 434	16 596	8 494	12 390
Per capita GDP (RMB)^{*1}	66 367	71 808	61 258	35 500	29 888
Per capita disposal income (RMB)^{*2}	23 623	22 469	21 689	14 358	14 849

Source: respective statistical yearbooks of each city;
Note: ^{*1} calculated by permanent population; ^{*2} denotes urban households;

Table 3 Consumption expenditure by category in starting and ending years of modeling period, RMB, in 1978 prices

	Year	FOOD	CLSH	FUNI	HLTH	TRAN	EDUC	RESI	OTHR
Shanghai	1980	289.99	73.90	46.77	6.55	18.71	45.84	24.32	11.23
	2006	913.66	178.76	152.65	132.81	406.09	423.32	249.96	112.27
Guangzhou	1980	324.69	43.49	21.24	5.63	4.51	20.97	21.03	19.96
	2006	785.02	131.16	108.25	125.94	363.15	347.24	186.99	71.20
Hangzhou	1988	422.88	129.21	103.00	18.94	10.15	74.85	29.37	28.25
	2006	826.98	232.52	100.36	151.89	493.75	345.12	253.87	79.69
Wuhan	1989	371.80	76.18	66.02	5.61	5.08	54.04	30.96	21.79
	2006	668.78	194.55	83.06	144.93	185.97	211.24	194.10	40.74
Chengdu	1985	318.39	95.56	64.68	6.21	6.52	74.32	24.07	19.85
	2006	611.07	168.08	115.43	105.08	314.23	237.77	178.37	73.79

Table 4 Waste composition in 2003 in each selected city, %

	Food	*Plastic*	*Paper*	*Textile*	*Wood*	*Glass*	*Metal*	*Ash*
Shanghai	65.9	14.33	9.23	2.7	1.37	3.82	0.71	1.4
Guangzhou	57.89	18.26	8.78	4.56	2.25	1.89	0.64	5.65
Hangzhou	59.15	15.66	9.14	2.59	3.99	2.35	1.51	5.63
Wuhan	48.16	18.26	8.48	2.08	2.01	2.8	1.34	16.87
Chengdu	48.87	13.72	13.3	2.16	2.21	1.55	0.53	17.66

3. BACKGROUND OF STUDY AREAS

(1) Geographical and economic features

Broadly, integrated with the distribution of a specific geographic location, China is roughly divided into three geographical regions—the eastern, central and western regions—each of which has distinctive features with regard to MSW generation. The cities analysed in this paper are: from the eastern region, Shanghai, Guangzhou and Hangzhou; from the central region, Wuhan; and from the western region, Chengdu. A sketch map of China marking the relative location of selected cities is depicted in **Fig. 2**. Prior to further discussion, it would be helpful to briefly investigate the geographical and economic features of each city, which are listed in **Table 1**. Further, the population under waste collection is listed in the table as well for calculating the per capita waste generation. The disparity in economic levels, expressed in terms of per capita GDP, is rather evident. The level of economic development in eastern cities is higher than that in the central city Wuhan, with Chengdu being the lowest in this respect.

(2) Change in consumption pattern in study area

This section discusses the difference in consumption pattern and consumer behaviour among the selected cities. Economic database including consumption expenditure and corresponding explanatory variables, which represents urban area residents, is obtained from respective statistical yearbooks of each city. There are eight categories of consumption commodities in terms of consumption expenditure in the model (in RMB) (**Table 2**). Further, the consumption expenditures by category in starting and ending years of modeling period in each city are tabulated in **Table 3**. Moreover, the average change in consumption expenditure by category during one year in each city is depicted in **Fig. 3**.

From Fig. 3, it is easily to be found out that all cities have the similar change trends. Expenditure on HLTH and TRAN has experienced a marked increase, followed by increase of EDUC and RESI. Compared with other categories, the consumption expenditure on FOOD, CLSH and FUNI has slight rate of increase among the cities. This change in each city thus advances to a more diversified and reasonable consumption pattern placing emphasis on the product or the service that delivers without material transfer[23, 24]. Possible reasons for these changes are (1) the upgrading of the consumption pattern caused by an improvement in living standards and (2) the implementation of a set of national interventions in housing, medical and education. In addition, since the expenditures in EDUC and HLTH fall under 'productive consumption'[25], inevitable and increasing expenditure in these items within the relatively unchanged total consumption expenditure results in a subsequent decrease in the share of expenditure in other traditional consumption items.

(3) Current situation of MSW generation

Waste data that also deal with the urban area is obtained from MSB of each city. Each selected city has experienced a sharp increase in waste generation during the last decade with the development of economy. The average increase rate of total MSW generation is 4.77%, 5.76%, 5.81% 7.65% and 5.49% from 2000 to 2005 in Shanghai, Guangzhou, Hangzhou, Wuhan and Chengdu, respectively. Further, MSW composition of each city in 2003 is organized in **Table 4**. One apparent difference among the cities is the ratios of food and ash waste. It is recognized that as a result of the higher gas utilization ratio (GAS), cities in the eastern region have a higher proportion of organic compounds and lower proportion of ash waste than central and western cities[3]. A specific description is further divided into three stages. Shanghai is in the first stage with the percentage of organic matter being approximately 70%, with only 1.40% of ash waste. Then, Wuhan and Chengdu are in the third stage, with the proportion of organic waste being less than 50% and ash waste being almost 20%. Guangzhou and Hangzhou—both eastern cities that are not as developed as Shanghai—are in the second stage, with proportions of organic waste and ash waste between the first and third stages.

Table 5 Explanatory variables concerning in the LES model for each city

City	Time series	Explanatory variables			R_{ij}	VIF_{ij}
Shanghai	1980–2006	*SAV*		*Household size*, person	−0.569	1.484
Guangzhou	1980–2006	*SAV*	*NAGR*		−0.749	2.278
Hangzhou	1988–2006	*SAV*	*NAGR*		−0.171	—
Wuhan	1989–2006	*SAV*	*NAGR*	*DUM2002*	−0.621*	1.627
Chengdu	1985–2006	*SAV*	*NAGR*		−0.780	2.660

Note: *the value denotes the R_{ij} between *SAV* and *NAGR*

Table 6 Estimated results of respective LES model for each city

Shanghai	FOOD	CLSH	FUNI	HLTH	TRAN	EDUC	RESI	OTHR
Constant	1347.810*	129.775*	219.345**	37.107	—	228.256^{+}	163.359*	81.187**
(b_{i0})	(6.925)	(2.950)	(2.589)	(0.526)		(1.961)	(3.277)	(2.226)
Household size	−256.140*	−9.061	−39.670	−9.544	—	−47.460	−35.140**	−17.055
	(−4.673)	(−0.731)	(−1.662)	(−0.480)		(−1.448)	(−2.503)	(−1.66)
SAV	0.0446*	0.0072*	0.0083^{+}	0.0204*	0.0448*	0.0459*	0.0280*	0.0105*
	(4.202)	(2.978)	(1.791)	(5.300)	(11.550)	(7.219)	(10.300)	(5.298)
α value	0.312*	0.039	0.121*	0.115*	0.102*	0.169*	0.079^{+}	0.063*
	(5.773)	(0.932)	(3.238)	(3.409)	(2.993)	(4.160)	(2.020)	(4.891)
R^2	0.99	0.55	0.78	0.93	0.98	0.98	0.96	0.97
MAPE	0.029	0.126	0.129	0.954	0.168	0.107	0.169	0.137
Guangzhou	−10.425	−2.041^{+}	−5.041**	−1.054**	7.481**	—	−5.564	−2.263
(***NAGR***)	(−1.699)	(−1.756)	(−2.083)	(−2.495)	(2.714)		(−1.226)	(−1.010)
R^2	0.99	0.94	0.90	0.99	0.98	0.99	0.92	0.88
MAPE	0.022	0.086	0.101	0.073	0.223	0.107	0.187	0.118
Hangzhou	−10.704**	—	−3.465	—	−0.751	0.290	−5.281*	−4.666**
(***NAGR***)	(−2.589)		(−1.133)		(−0.223)	(0.178)	(−3.013)	(−2.745)
R^2	0.96	0.79	0.41	0.92;	0.88	0.96	0.97	0.76
MAPE	0.037	0.102	0.142	0.217	0.506	0.097	0.099	0.137
Wuhan	−7.542*	—	−3.039	−1.502	−5.182	−7.812	−12.864	−3.954^{+}
(***NAGR***)	(−3.750)		(−0.464)	(−1.485)	(−1.122)	(−0.994)	(−0.845)	(−1.680)
R^2	0.97	0.71	0.72	0.99	0.99	0.96	0.93	0.86
MAPE	0.024	0.118	0.103	0.123	0.147	0.098	0.171	0.087
Chengdu	10.149	6.879	2.641	−0.595	13.403^{+}	−1.062	—	3.639
(***NAGR***)	(0.938)	(1.611)	(0.875)	(−0.387)	(1.852)	(−0.418)		(1.433)
R^2	0.92	0.55	0.38	0.94	0.93	0.95	0.96	0.68
MAPE	0.039	0.089	0.121	0.254	0.744	0.109	0.151	0.140

Figures in parentheses are *t*-ratios for estimated coefficients, '*', '**' and '$^{+}$' denote that the parameter estimate is significant at the 1%, 5% and 10% levels, respectively; '—' denotes no clear impact.

4. COMPARISON OF INTEGRATED MODEL DEVELOPMENT AMONG CITIES

(1) The consumer behaviour model

The application area of the LES model is the urban area, while the time frame of available statistical data differs according to city. In the model, the same abbreviations for the eight types of consumption categories are adopted (**Table 2**). Before constructing the model, the consumption expenditure by category is converted into fixed prices through respective total consumer price index (CPI) of each city, in 1978 prices, and is regarded as an explained variable in the model. The essential principle for the selection of the appropriate explanatory variables (γ_{it}) is as follows. Firstly, to collect all the feasible variables regarding lifestyle of residents, socio-economic indicators and household characteristics in each city; then, to calculate the correlation coefficient (R_{ij}) between explanatory variables and variance inflation factor (VIF_{ij}) when R_{ij} is above 0.5, in order to check the multi-collinearity problem[22]; finally, to attempt to find pairs with dissimilar change trends (normalization values) that fit the models well. Limited to statistical data, inspected explanatory variables normally includes: life expectancy, percentage of employment per household, persons supported by each employee, household size, growth rate of population, saving deposits, registered urban unemployment rate, et al. Different city has different optimal integration of appropriate variables from the viewpoint of good performance of model testing. However, in order to construct a common model that can be easily applied into other Chinese cites, two explanatory variables that fit all models well are selected as shown in **Table 5**, in which '***SAV***' denotes *saving deposits*, 100 million RMB; '***NAGR***' means *growth rate of population*, ‰. '***DUM2002***' is introduced as to reflect the change in measurement standards of consumption category from 2002 in Wuhan.

All the *VIF* values are less than 4, denoting no apparent multi-collinearity problem between explanatory variables. Further, it is verified that the number of variables affecting consumer behaviour is not one but the integrations of a series of indicators. It is interesting to find out that aside from Shanghai, ***SAV*** and ***NAGR*** are currently the two common factors that significantly affect consumer behaviour in Chinese cities. ***SAV*** is introduced in the model and considered to be an indirect indicator of change in consumer consciousness. In addition, ***NAGR*** is another important influential indicator from the viewpoint of socio-demography and considered as one important indicator of welfare and medical system of a city[26]. **Table 6** summarizes the estimated results obtained from the LES model of Shanghai as an example and statistical testing for other cities. Further, the results regarding the coefficients of ***NAGR*** on 'subsistence' expenditure in each city are also tabulated in the table. The first row presents the consumption category. From **Table 6**, all the positive coefficients of ***SAV*** on 'subsistence' expenditure in Shanghai indicate that the greater the saving deposits, the higher the individual 'subsistence' expenditure. Moreover, although a majority of the partial coefficients of ***NAGR*** to consumption category, particularly those in the LES model of Guangzhou, Hangzhou and Wuhan, are negative, those in Chengdu are positive. This indicates that the increase in population will lead to the reduction of 'subsistence' expenditure in the first three cities and will augment this expenditure in Chengdu. On the other hand, in Shanghai, another variable—*household size*—is more influential as compared to ***NAGR***, indicating that it is an advanced metropolitan city as compared to other cities.

In addition, the explanatory variables of each selected city have changed rapidly over the past two decades and have undoubtedly led to significant change in all consumption categories. **Fig. 4** and **Fig. 5** plot the trend of change in explanatory variables in the LES model for each city with different time frame. For a majority of the consumption categories in each city, a sudden turning point appeared around the year 1992. Firstly, this change could be interpreted as being caused by the rapid economic growth. To be more precise, it may be attributed to the crucial and decisive operation of explanatory variables, particularly ***SAV***, which also demonstrates an unexpected turning point during the same period in each city. Further, the high correlation coefficients between ***SAV*** and the consumption expenditure of each category in each city further demonstrate the decisive significance of ***SAV*** to consumption. On the other hand, the ***NAGR*** exhibits the similar change trend among the selected cities and an apparent turning point happened around the year 1995. Then, the ***NAGR*** in each selected city is close to achieving constancy from 1995 onwards.

In **Table 6**, the crossed items of upper half table denote the estimated coefficients of 'subsistence' demand expenditure by category on the corresponding explanatory variables in Shanghai. The lower half table lists the statistical testing in other cities including the R^2 and MAPE, indicating the model performance of each single equation for each consumption category. From the table, it is evident that all R^2 values are sufficiently high to be noteworthy, with 67.5% of them being greater than 0.9 and 90% being greater than 0.6. Further, in the model of Shanghai, most of the estimators are significant at the 5% level. Moreover, the MAPE value of HLTH appears rather high with a value of 0.954, due to the low original time-series values before 1990. However, the RMSE value is calculated as 13.210 after eliminating the influence of original values. For the same reason, the RMSE value of TRAN in LES model of Chengdu is 0.261. These findings confirm that all estimators are assumed to be significant and convincing.

Fig. 6 outlines the 'subsistence' demand expenditure by category among the cities for the year 2006. It is interesting to note that the distribution of expenditure among the categories is rather similar, particularly for eastern cities; food expenditure is on the top followed by expenditure on education and transportation. However, for the central and western cities, the situation is slightly different with CLSH in the third place in Wuhan and TRAN in the second place in Chengdu. In addition, to a certain extent, the proportion of 'subsistence' expenditure in each category reflects the most basic consumption potential and induces the most basic physical components of MSW. Higher expenditure on food and education than other items in each city indicates that the waste arising from these two items is inevitable and may occupy large shares in the MSW component.

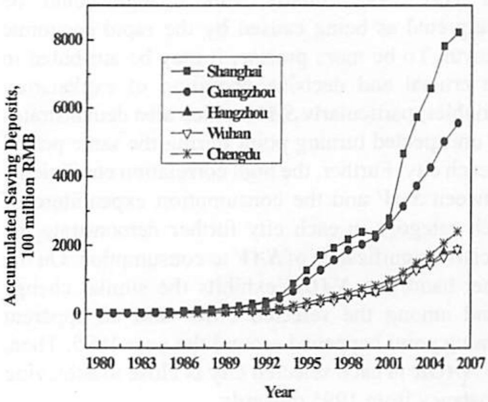

Fig.4 *SAV* in selected cities during different periods

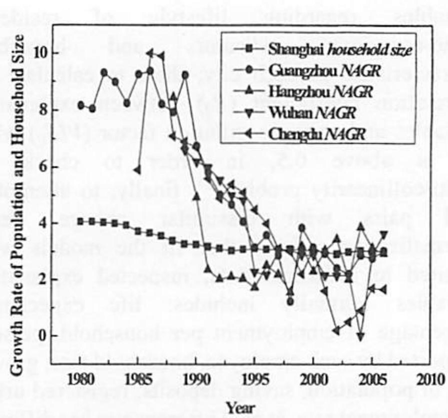

Fig.5 ***NAGR*** **and household size in selected cities during different periods**

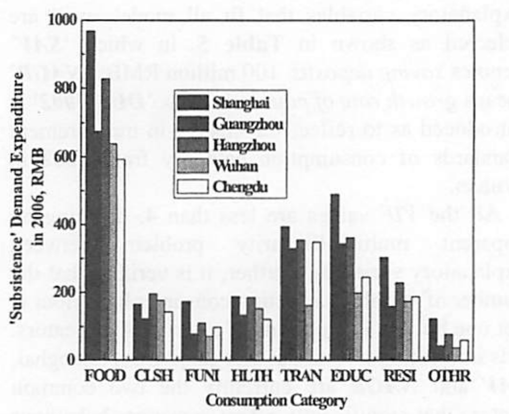

Fig. 6 'subsistence' demand expenditure by category among the cities for the year 2006

Table 7 Summary of related waste management policies constituted in each city

City	Dummy variable	Explanation of waste policies
Shanghai	DUM92	Encouraging the access of clean vegetables with removed leaf scraps in the market[1]
	DUM00	'Temporary Criterion of Management on Disposable Plastic Boxes' published in 2000 impels disposable plastic boxes separated from MSW[2]
Hangzhou[3]	DUM98	The policy of 'waste must be collected by plastic bags' had achieved remarkable results until 1998
	DUM02	From 2002 onwards, the measurement of waste composition was carried out in landfill sites instead of in transportation stations, thereby reducing the ratios of recyclable items, particularly the paper waste due to the appearance of scavengers at the same time
Wuhan[4]	DUM04	Relaxing the restrictions on waste disposal

Note: [1]City Appearance and Environmental Sanitation Regulations (State Council Decree No. 101) and: http://www.shtong.gov.cn/node2/node2245/node75681/node75692/node75729/userobject1ai92599.html in Shanghai

[2] Source from <2005 Shanghai Waste Management>; [3] from the inquiry of staff in local MSB

4 Wuhan authorities order No. 159 (http://news.sina.com.cn/c/2004-07-07/12093016294s.shtml)

(2) Relative MSW policies adopted in selected cities

Table 7 lists all the relative waste management policies constituted in each city. As mentioned above, the DUM is introduced as a reflection of waste measures. For example, 'DUM92' implies that a kind of waste legislation was constituted in 1992. Therefore, the DUM variable is '1' from 1992 onwards and '0' prior to 1992. It is believed that all the policies have played rather important roles in eliminating/facilitating waste generation. In 2004, the Wuhan government amended the criteria of 'Administration of Household Waste Management' and relaxed the standard of waste disposal. It is believed that companies can dispose MSW to the designated areas and no longer require the approval of the relevant departments. Moreover, the government also relaxed the restrictions on participating waste transportation services. These policies induced a sharp increase in the total waste generation from 2004 in Wuhan.

(3) Waste generation by waste category

a) The assumptions in the model

Prior to modelling, several assumptions are made in each city:

1) The abbreviations for the types of consumption categories are the same as those provided in **Table 2**. Further, consumption expenditure is converted into the fixed prices through the respective CPI of each city—1978 as well. Moreover, the adjusted food expenditure without the food processing fees is cited in the model of Chengdu.

2) Recently, the average ratios of food, plastic, paper, textile, glass and metal waste account for 90% in eastern cities and over 80% in other cities, dominating the fluctuation of the total amount of MSW. Respective generation of these items which are called estimated-category is estimated by the waste generation model (OLS). On the other hand, wood waste is mainly acquired from street sweeping with a slight fraction of 1.37%~3.99% in 2003 among the selected cities; ash waste including ash, tile and brick waste is mainly derived from coal burning and street sweeping, rather than consumption[27]. The quantity of the wood and ash waste which is called non-estimated waste herein is obtained by assuming the fractions based on the historical records of each city.

3) Certain waste categories with tiny proportions are merged for estimation. Sum of glass and metal waste is evaluated together in Guangzhou and Chengdu. Further, in the model of Guangzhou, since there is no respective fraction of paper, plastic and textile waste before the year of 2000, the sum of these three items is thus estimated as a whole.

b) The development of the model

Individual annual waste generation of each estimated-category is estimated using OLS in each city and represented as a reasonable regression equation. A common model illustrating the relationship among waste category, corresponding consumption expenditure and waste management policies is developed, as presented in **Table 8.** In the table, the first row stands for exogenous variables (EV), including abbreviations of corresponding consumption expenditure by commodity category and waste management policies (DUM). The first column from the left indicates each waste category (WC). Therefore, the crossed items marking with circles signify that the quantitative relationship exists between waste category and consumption expenditure or dummy variables. Taking food waste generation as an example, the estimated model is expressed as $W_{food\,waste,\,t} = f(\text{FOOD})$ in each city. The estimation result by waste category of each city is presented in **Table 9—Table 13.** In each table, the cross items signify the partial coefficient of waste to the corresponding consumption expenditure or dummy variables. Moreover, statistical testing refers to each equation for estimating each type of waste category. Figures in parentheses are t-ratios for estimated coefficients. '*', '**' and '+' denote that the parameter estimate is significant at the 1%, 5% and 10% levels, respectively.

There are several aspects to be addressed:

1) In each quantitative model for each type of waste category, the heteroscedasticity is checked by using residuals chart as residual sum of squares (ε_i^2) against estimated value of explained value ($\hat{y}_i$). It is found out that ε_i^2 has no apparent change trend with the increase of $\hat{y}_i$, thereby denoting no apparent heteroscedasticity problem. Further, among all the parameter estimators, adjusted R^2 (AdR^2) of a majority of estimators are more than or close to 0.6 (85%); 72.22% of estimators are significant at the 1% levels and 83.33% are significant at the 5% levels; the large F normally induced by a large value of R^2 signifies a good performance of model. In addition, based on a rough rule of thumb, a majority of DW are more than 1 and close to 2, thereby denoting no serious autocorrelation in the residuals. On the other hand, the interpretation of the results is straightforward with regard to economic applicability. All model performance demonstrates that the waste generation model is stable and feasible for future forecasting.

2) All the models prove the quantitative

conversion process of any type of consumed commodity to a corresponding waste category. For example, food waste is estimated by FOOD expenditure, and paper and plastic waste are estimated by the FOOD and EDUC expenditure in all cities. Further, glass and metal waste are considered from the beverages that are a part of the FOOD consumption. In addition, textile waste is estimated by CLSH expenditure.

3) The estimation model for plastic waste in each city includes the constant term, thereby representing that not only the expenditure on EDUC and FOOD, but also other factors affect the generation of plastic waste.

4) When a waste policy regarding the specific waste category is introduced in the model, the 'DUM' is related to corresponding waste category. For example, the 'DUM92' merely affects the food waste in Shanghai. On the other hand, when a general policy is introduced, the influence on all types of waste is considered. The constitution of 'DUM04' in Wuhan not only increases the generation of total MSW, but also increases the generation of each type of waste category.

Table 8 Development of waste generation model by waste category

EV / WC	FOOD	CLSH	EDUC	DUM
Food	o			
Plastic	o		o	
Paper	o		o	
Textile		o		
Glass	o			
Metal	o			

Table 9 Result of MSW generation model by waste category in Shanghai (1990–2005)

EV / WC	Constant	FOOD	EDUC	CLSH	DUM92	DUM00	Statistical testing
Food		0.386* (10.603)			–46.339 (–1.747)		DW=0.62; F=36.348; $AdR^2 = 0.78$;
Paper		0.00890* (3.009)	0.0962* (10.799)				DW=0.970; F=254.716; $AdR^2 = 0.94$;
Plastic	–55.445* (–4.086)	0.0884* (3.186)	0.198* (5.266)			–13.823** (–2.606)	DW=1.212; F=152.190; $AdR^2 = 0.97$;
Textile				0.0654* (10.103)			DW=0.30; F=8.222; $AdR^2 = 0.37$;
Glass		0.0185* (20.643)					DW=0.581; F=28.424; $AdR^2 = 0.67$;
Metal		0.00331* (15.575)					DW=1.633; F=11.926; $AdR^2 = 0.46$;

Table 10 Result of waste generation model by waste category in Guangzhou (1986–2003)

EV / WC	Constant	FOOD	EDUC	CLSH	Statistical testing
Food	–192.819* (–5.368)	0.738* (11.226)			DW = 1.427; F = 126.031; $AdR^2 = 0.88$;
Paper, plastic & textile	–110.565* (–3.209)	0.203** (2.312)	0.609* (4.978)		DW = 1.679; F = 116.237; $AdR^2 = 0.93$;
Glass & metal		0.0199* (12.279)			DW = 0.787; F = 4.500; $AdR^2 = 0.36$;

Table 11 Result of waste generation model by waste category in Hangzhou (1990–2004)

WC \ EV	Constant	FOOD	CLSH	EDUC	DUM98	DUM02	Statistical testing
Food		0.427* (47.620)					DW = 0.74; F = 203.67; AdR^2 = 0.94;
Paper				0.0788* (4.109)	47.283* (10.792)	–19.141* (–4.426)	DW = 1.359; F = 178.279; AdR^2 = 0.96;
Plastic	–32.712** (–2.997)	0.0398 (1.382)		0.276* (3.045)	19.616* (2.523)	–9.534* (–1.205)	DW = 2.409; F = 132.318; AdR^2 = 0.97;
Textile			0.0545* (10.193)			5.343* (4.424)	DW = 0.791; F = 16.55; AdR^2 = 0.72;
Glass		0.0141* (8.563)			–1.762 (–1.280)		DW = 1.121; F = 10.115; AdR^2 = 0.57;
Metal		0.00733* (15.818)					DW = 2.073; F = 21.211; AdR^2 = 0.62;

Table 12 Result of waste generation model by waste category in Wuhan (1994–2005)

WC \ EV	Constant	FOOD	CLSH	EDUC	DUM04	Statistical testing
Food		0.224* (16.017)			49.725** (2.845)	DW = 0.707; F = 25.523; AdR^2 = 0.69;
Paper		0.0105 (1.403)		0.0758** (2.701)	9.378* (3.397)	DW = 2.236; F = 30.441; AdR^2 = 0.84;
Plastic	–81.173* (–3.796)	0.194* (5.534)		0.0859 (1.535)	7.719 (1.378)	DW = 1.932; F = 68.972; AdR^2 =0.95;
Textile			0.0260* (8.067)		7.326* (7.003)	DW=0.723; F=80.548; AdR^2 = 0.88;
Glass		0.0123* (13.410)			1.925 (1.678)	DW = 1.880; F = 14.149; AdR^2 = 0.55;
Metal		0.00406* (8.767)			2.244* (3.872)	DW = 2.130; F = 30.040; AdR^2 = 0.73;

Table 13 Result of waste generation model by waste category in Chengdu (1995–2004)

WC \ EV	Constant	FOOD	CLSH	EDUC	Statistical testing
Food		0.364* (29.261)			DW = 0.927; F = 10.605; AdR^2 = 0.57;
Paper	–69.124^{+} (–1.975)	0.119 (1.554)		0.193* (3.223)	DW = 2.521; F = 11.708; AdR^2 = 0.70;
Plastic	–12.647** (–2.301)			0.283* (7.578)	DW = 2.537; F = 57.424; AdR^2 = 0.86;
Textile			0.0464* (7.238)		DW = 0.537; F = 24.000; AdR^2 = 0.75;
Glass & metal		0.0160* (9.781)			DW = 1.694; F = 2.390; AdR^2 = 0.23;

Table 14 Partial waste generation coefficient to consumption, kg/RMB

$PWC_{s/i}$ \ City	Shanghai	Guangzhou	Hangzhou	Wuhan	Chengdu	Average value
Food/FOOD	0.386	0.738	0.427	0.224	0.364	0.350
Paper/FOOD	0.00890		—	0.0105	0.119	0.0461
Paper/EDUC	0.0962		0.0788	0.0758	0.193	0.111
Plastic/FOOD	0.0884		0.0398	0.194	—	0.107
Plastic/EDUC	0.198		0.276	0.0859	0.283	0.211
Textile/CLSH	0.0654		0.0545	0.0260	0.0464	0.0481
Glass/FOOD	0.0185	0.0199	0.0141	0.0123	0.0160	0.0191
Metal/FOOD	0.00331		0.00733	0.00406		

c) Interpretation of the model results

The coefficient of each type of waste to the corresponding consumption expenditure is regarded as partial waste generation coefficient to consumption ($PWC_{s/i}$) and is applied for analysing the distinct waste generation trend among cities, as tabulated in **Table 14**. For example, $PWC_{food/FOOD}$ stands for the partial generation coefficient of food waste to FOOD consumption expenditure (in kg/RMB).

Paper, plastic and textile waste is estimated together in Guangzhou; the partial generation coefficient of these items is 0.203 kg/RMB to FOOD and 0.609 kg/RMB to EDUC expenditure (**Table 10**). Further, the main conclusions from the model can be discussed from four aspects. Firstly, the partial generation coefficients of each type of waste to the same consumed category are at the same level among the cities. Taking food waste as an example, a per yuan (RMB, in 1978 prices) increase in food expenditure results in an average increase of 0.386 kg, 0.738 kg, 0.427 kg, 0.224 kg and 0.364 kg in Shanghai, Guangzhou, Hangzhou, Wuhan and Chengdu respectively, with an average value of 0.350kg excluding Guangzhou. Further, the $PWC_{textile/CLSH}$ is 0.0654, 0.0545, 0.0260 and 0.0464 kg/RMB, respectively in Shanghai, Hangzhou, Wuhan and Chengdu; and the average value is 0.0481 kg/RMB. Moreover, among the cities, the range of $PWC_{glass\&metal/FOOD}$ is 0.0160~0.0218 kg/RMB with an average value of 0.0191 kg/RMB. All the coefficients can be applied into other Chinese cities with insufficient waste statistics for predicting generation of each type of waste category. On the other hand, it is confirmed that the same increase in FOOD expenditure yields a greater generation of glass and metal waste in eastern cities than central and western ones.

Secondly, in the models of all cities, the partial coefficient of recyclable materials in terms of EDUC expenditure is greater than that of food expenditure. For example, in waste generation model of Shanghai, a per yuan increase in EDUC and FOOD leads to an average increase of 0.0962 kg and 0.00890 kg paper waste respectively.

Thirdly, aside from Guangzhou, the increase per yuan (RMB, in 1978 prices) in education expenditure results in the increased generation of plastic rather than paper waste in all other cities because, 1) most of the newspapers related to education expenditure are sold by residents in their homes in current China; 2) EDUC expenditure includes the expenditure in culture and recreation articles, thereby inducing to the great generation of plastic waste. Except in the model of Guangzhou, the increase of per yuan in EDUC expenditure results in a range of paper waste by 0.0758~0.193 kg and plastic waste by 0.0859~0.283 kg. Therefore, an average value of $PWC_{plastic/EDUC}$ and $PWC_{paper/EDUC}$ is 0.211 kg/RMB and 0.111 kg/RMB, respectively.

Finally, the different signs of DUM for Shanghai and Wuhan further manifest the distinct influence of waste policies. The waste regulation regarding food waste in Shanghai significantly eliminates the per capita food waste generation by 46.339 kg per year (DUM92). On the other hand, the waste policy in Wuhan (DUM04) enhances the food waste by 49.725 kg each year. This result clearly indicates that the waste measures on food waste in Shanghai could serve as a valuable example for other cities. Meanwhile, waste management policies in each city have different impacts even on the same waste generation. In the case of Hangzhou, the waste measure of 'waste must be collected by plastic bags' (DUM98) significantly increases per capita paper waste generation by 47.283 kg per year, and reduces the glass waste generation by avoiding scratching the plastic bags (1.762 kg). On the contrary, the appearance of a number of scavengers from 2002 onwards substantially reduces paper generation by 19.141 kg on average, as expressed by the negative coefficient of DUM02.

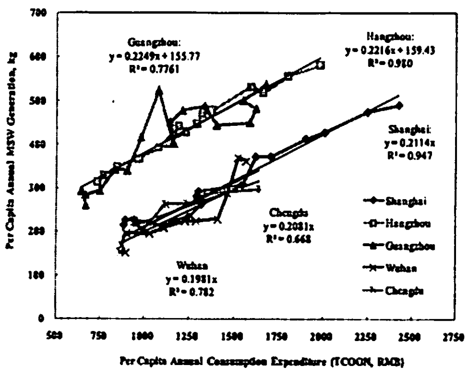

Fig. 7 Per capita annual MSW generation against consumption expenditure

(4) Comparison of total MSW generation

The simulation of the per capita total MSW amount is simultaneously conducted with the sum of each estimated-category and actual value of non-estimated category. The error evaluated by MAPE between the observed and simulated series of total MSW is 9.92%, 6.78%, 3.69%, 10.57% and 6.60% in Shanghai, Guangzhou, Hangzhou, Wuhan and Chengdu, respectively, thus suggesting acceptable results. Consequently, integrated with the predicted generation of estimated-category waste, computed using the integrated model and the assumed value of non-estimated waste, a forecasted amount of each type of waste can be obtained in the future.

Further, in order to investigate the conversion process from total consumption to total MSW generation in current Chinese cities, **Fig. 7** plots the per capita total MSW generation against TOCN in each city, in which the horizontal axis represents the TCON (in RMB), and the vertical axis MSW (in kgs).

From the figure, several points can be understood. Firstly, it seems that MSW generation increases with the economic growth in each city. This indicates that in Chinese cities, waste generation currently continues to remain in the increasing stage not only in the developing cities but also in developed ones, thereby demonstrating that economic growth is the main driving force for increasing waste generation. Secondly, from the viewpoint of linear consistency, the coefficient of MSW generation to TCON is identified as the unit waste generation per total consumption expenditure (in kg/RMB) and the value is 0.211, 0.225, 0.222, 0.208 and 0.198 in Shanghai, Guangzhou, Hangzhou, Chengdu and Wuhan, respectively. Therefore, the values are at the same level with the average of 0.213 kg/RMB (0.198~0.225). This is of great importance for those cities in which case there is a lack of adequate waste statistics, by providing a possibility for identifying total MSW generation once the current consumption expenditure is known. Thirdly, the coefficients in eastern cities are a little higher than in central and western cities and Hangzhou and Guangzhou have the highest values. Chung (2001) indicated that the lower income group tended to recover a greater portion of MSW for selling to waste depots[28], thereby improving the recycling rate and reducing the amount of waste simultaneously transported to a treatment facility. Consequently, due to the lower income level, waste generation in Chengdu is relatively diminished as compared with other cities. Finally, respective MSW generation in Wuhan and Chengdu increases along the trail of Shanghai. However, the intercepts in the models of Guangzhou and Hangzhou represent that apart from MSW, other wastes not from consumption may be mixed into MSW, such as sludge or industrial solid waste.

5. CONCLUSIONS

Accurate prediction of MSW generation is vital for the successful designing of sustainable waste management system. This paper launches a reasonable attempt at estimating MSW generation of each waste category from the perspectives of consumption expenditure and waste management policies. In this research, the comprehensive integrated model is developed and five Chinese metropolises with distinct economic levels are selected for the model application and comparison. Results clearly denote that integrated model is validated in all selected cities and is reasonable for waste forecasts by composition. Firstly, it is confirmed that *SAV* and *NAGR* are currently the two common factors affecting the consumer behaviour of a city in this research, aside from Shanghai. Secondly, the model results provide an effective range and default value of partial generation coefficient of each type of estimated-category to corresponding consumption expenditure. Further, the unit MSW generation per consumption is 0.213 kg/RMB in selected cities, thereby providing a possibility for identifying total MSW generation of other Chinese cities once the current consumption expenditure is known. Thirdly, this research conducts a comparative analysis of the different impacts of waste measures undertaken by local governments in the cities under consideration. All the waste management policies will provide feasible experiences or valuable lessons to other Chinese cities.

Accordingly, the integrated model has the ability to predict the quantity of MSW generated and the corresponding composition on a city level. The effective application of the integrated model in selected cities will be essential and effective for model development in other cities. Moreover, the degree of the model accuracy is partly determined by the reliability of the published information; long-term waste records in the future will definitely improve the current model.

ACKNOWLEDGMENT: This research was supported by 'Global Environment Research Fund by Ministry of Environment Japan' (BC-088).

REFERENCES

1) Thomas, V. M. and Graedel, T. E.: Research Issues in Sustainable Consumption: Toward an Analytical Framework for Materials and the Environment, *Environ Sci Technol*, Vol. 37, No. 23, pp. 5383-5388, 2003.
2) Barr, S.: What We Buy, What We Throw Away and How We Use Our Voice. Sustainable Household Waste Management in the Uk, *Sustainable Development*, Vol. 12, pp. 32-34, 2004.
3) The World Bank: Waste Management in China: Issues and Recommendations, in *Working Paper No. 9. Urban Development Working Papers*. East Asia Infrastructure Department: Washington, DC. pp. 156, 2005.
4) Powrie, W. and Dacombe, P.: Sustainable Waste Management-What Is It and How Do We Get There?, *Waste and Resources Management. Issue WRO*, 2007.
5) Dyson, B. and Chang, N. B.: Forecasting Municipal Solid Waste Generation in a Fast-Growing Urban Region with System Dynamics Modeling, *Waste Manage*, Vol. 25, No. 7, pp. 669-679, 2005.
6) Chang, N. B. and Lin, Y. T.: An Analysis of Recycling Impacts on Solid Waste Generation by Time Series Intervention Modeling, *Resour Conserv Recy*, Vol. 19, No. 3, pp. 165-186, 1997.
7) United Nations: Results of the World Conference on Environment and Development: Agenda 21., in *United Nations Conference on Environment and Development (UNCED)*: Rio de Janeiro, United Nations, 1992.
8) Rood, G. A., et al.: A Structure of Models for Future Projections of Environmental Pressure Due to Consumption, *Journal of Cleaner Production*, Vol. 11, No. 5, pp. 491-498, 2003.
9) Fujiwara, T., et al.: Development of Household Waste Generation Model Considering the Structure of Consumption Expenditure (in Japanese), *Selected Papers of Environmental System Research*, Vol. 35, pp. 471-480, 2007.
10) Daskalopoulos, E., et al.: Municipal Solid Waste: A Prediction Methodology for the Generation Rate and Composition in the European Union Countries and the United States of America, *Resour Conserv Recy*, Vol. 24, No. 2, pp. 155-166, 1998.
11) Gilg, A., et al.: Green Consumption or Sustainable Lifestyles? Identifying the Sustainable Consumer, *Futures*, Vol. 37, No. 6, pp. 481-504, 2005.
12) Marchand, A. and Walker, S.: Product Development and Responsible Consumption: Designing Alternatives for Sustainable Lifestyles, *Journal of Cleaner Production*, Vol. 16, No. 11, pp. 1163-1169, 2008.
13) Tucker, P., et al.: Predicting Recycling Scheme Performance: A Process Simulation Approach, *Journal of Environmental Management*, Vol. 53, No. 1, pp. 31-48, 1998.
14) Gu, Q. and Chen, K.: A Multiregional Model of China and Its Applicationn, *Economic Modelling*, Vol. 22, No. 6, pp. 1020-1063, 2005.
15) Sudhir, V., et al.: Integrated Solid Waste Management in Urban India: A Critical Operational Research Framework, *Socio-Economic Planning Sciences*, Vol. 30, No. 3, pp. 163-181, 1996.
16) Beigl, P., et al.: Modelling Municipal Solid Waste Generation: A Review, *Waste Manage*, Vol. 28, No. 1, pp. 200-214, 2008.
17) Jalili, G. Z. M. and Noori, R.: Prediction of Municipal Solid Waste Generation by Use of Artificial Neural Network: A Case Study of Mashhad, *Int J Environ Res*, Vol. 2, No. 1, pp. 13-22, 2008.
18) Xiao, Y., et al.: The Composition, Trend and Impact of Urban Solid Waste in Beijing, *Environ Monit Assess*, Vol. 135, No. 1-3, pp. 21-30, 2007.
19) Weng, Y. C., et al.: Modeling Municipal Solid Waste Discards in Taiwan Based on Consumption Expenditure and Policy Interventions: A Simultaneous Equation System Approach, *Waste Management & Research (in press)*, 2009.
20) Stone, R.: Linear Expenditure Systems and Demand Analysis: An Application to the Pattern of British Demand, *The Economic Journal*, Vol. 64, No. 255, pp. 511-527, 1954.
21) MERZ, J.: Feles: The Functionalized Extended Linear Expenditure System-Theory, Estimation Procedures and Application to Individual Household Consumption Expenditures Involving Socioeconomic and Sociodemographic Characteristics, *European Economic Review*, Vol. 23, pp. 359-394, 1983.
22) Greene, W. H.: Econometric Analysis (5th Edition), ed. N.Y. University. New York: Upper Saddle River, New Jersey 07458, pp. 608-632, 2002.
23) Kronenberg, J.: Making Consumption "Reasonable", *Journal of Cleaner Production*, Vol. 15, No. 6, pp. 557-566, 2007.
24) Mont, O.: Institutionalisation of Sustainable Consumption Patterns Based on Shared Use, *Ecological Economics*, Vol. 50, No. 1-2, pp. 135-153, 2004.
25) [Anon]: Productive Consumption and Growth in Developing Countries, *Lect Notes Econ Math*, Vol. 489, pp. 61-105, 2000.
26) Balia, S. and Jones, A. M.: Mortality, Lifestyle and Socio-Economic Status, in *Health, Econometrics and Data Group (HEDG)*. the University of York: York. pp. 46, 2005.
27) Zhuang, Y., et al.: Source Separation of Household Waste: A Case Study in China, *Waste Manage*, Vol. 28, No. 10, pp. 2022-2030, 2008.
28) Chung, S.-S. and Poon, C.-S.: A Comparison of Waste-Reduction Practices and New Environmental Paradigm of Rural and Urban Chinese Citizens, *Journal of Environmental Management*, Vol. 62, pp. 3-19, 2001.

(Received July 10, 2009)
(Accepted December 21, 2009)