Modeling of Household Waste Generation and Treatment by Bottom Up Approach

- Takeshi Fujiwara, Kyoto University
- Yuzuru Matsuoka, Kyoto University

The 7th AIM International Workshop 15-17, March 2002

Background

- Material cycle has much relation to global warming and atmospheric pollution.
- In the material production, transportation, and waste treatment, GHG and atmospheric pollutants are generated and emitted directly or indirectly.
- Analyzing and predicting the flow of material cycle is important to reduce the global environmental problem.
- To grasp the current situation of material cycle, bottom up approach is effective as well as top down approach.

Factors

Factors which can change material flow are :

(1) Consumer's preference: "Which goods does the household purchase?"

(2) Long time use: "When does the household discard the goods as the waste?"

(3) Waste treatment with low environmental load: "How is the waste reused, recycled or treated ?

Objective

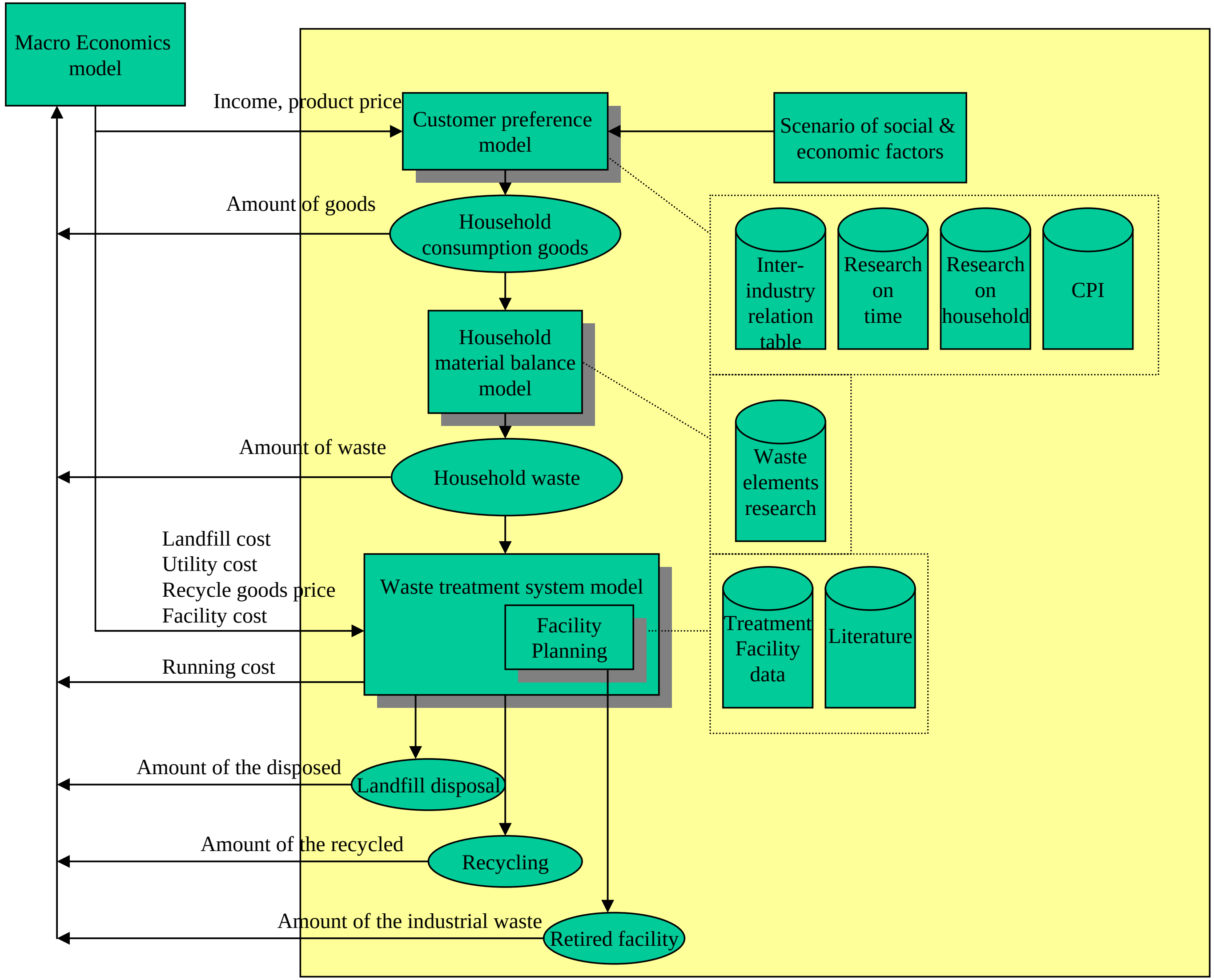
To analyze and to predict the waste flow through household, these three models are developed.

(1) Consumer preference model

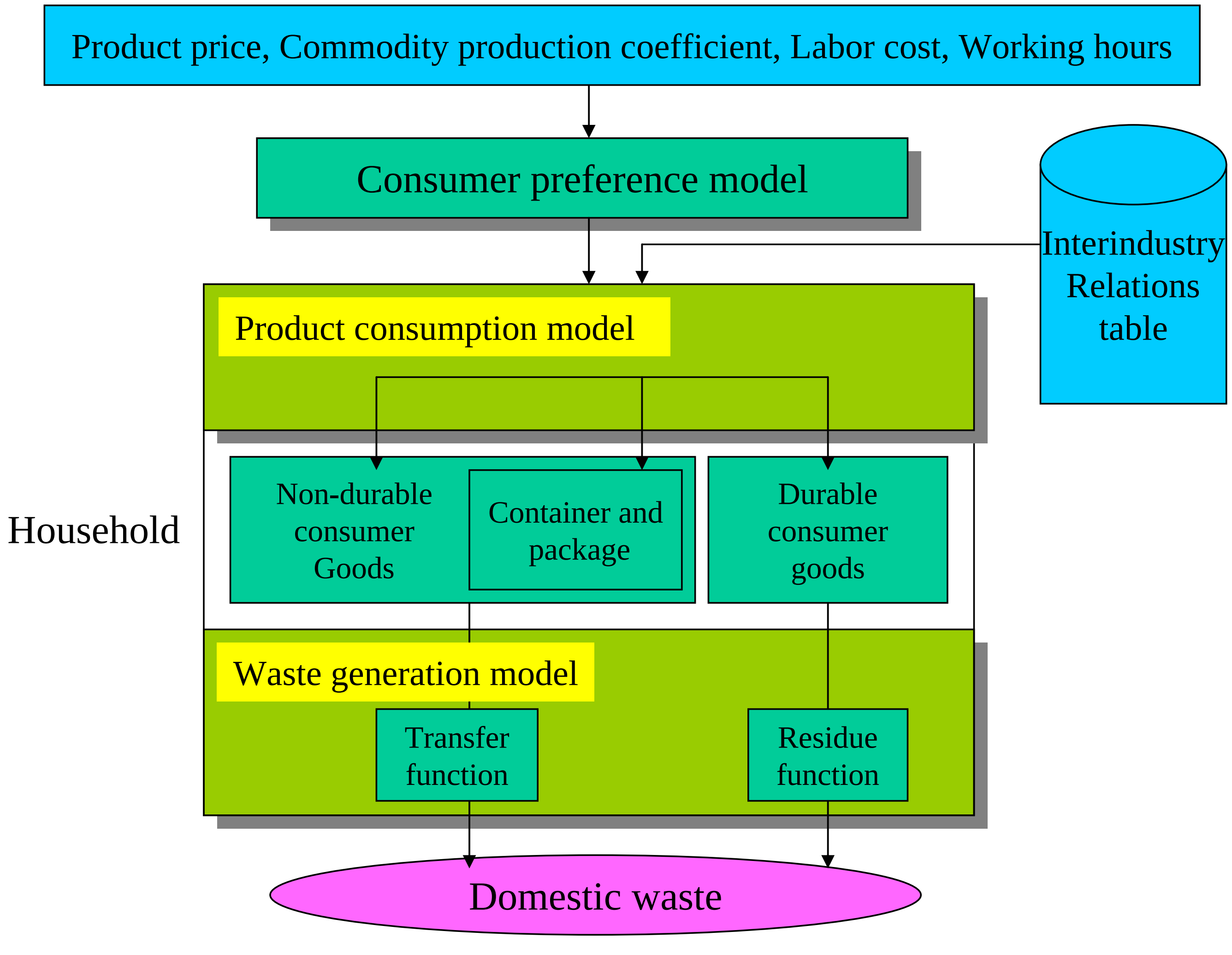
(2) Household material balance model

(3) Waste treatment model

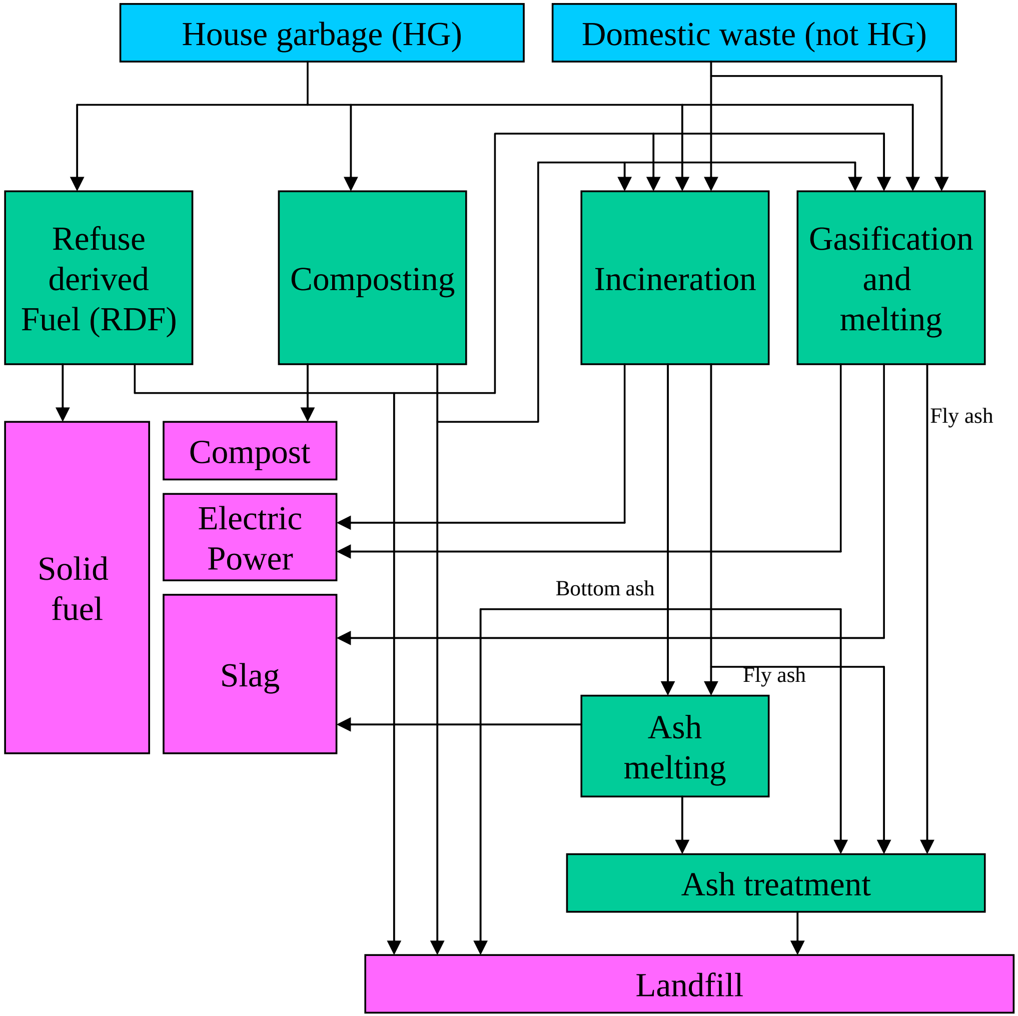
Bottom up model of household consumption and waste



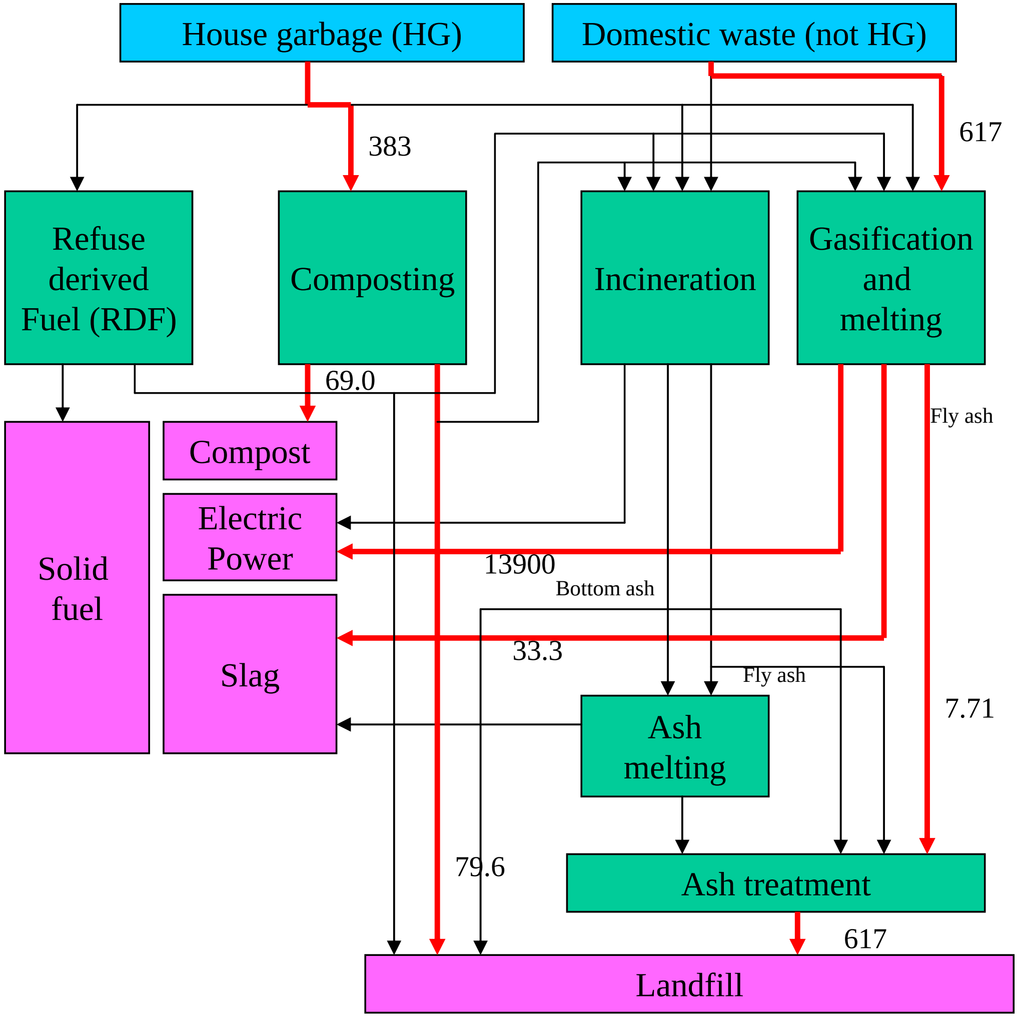
Household material balance model

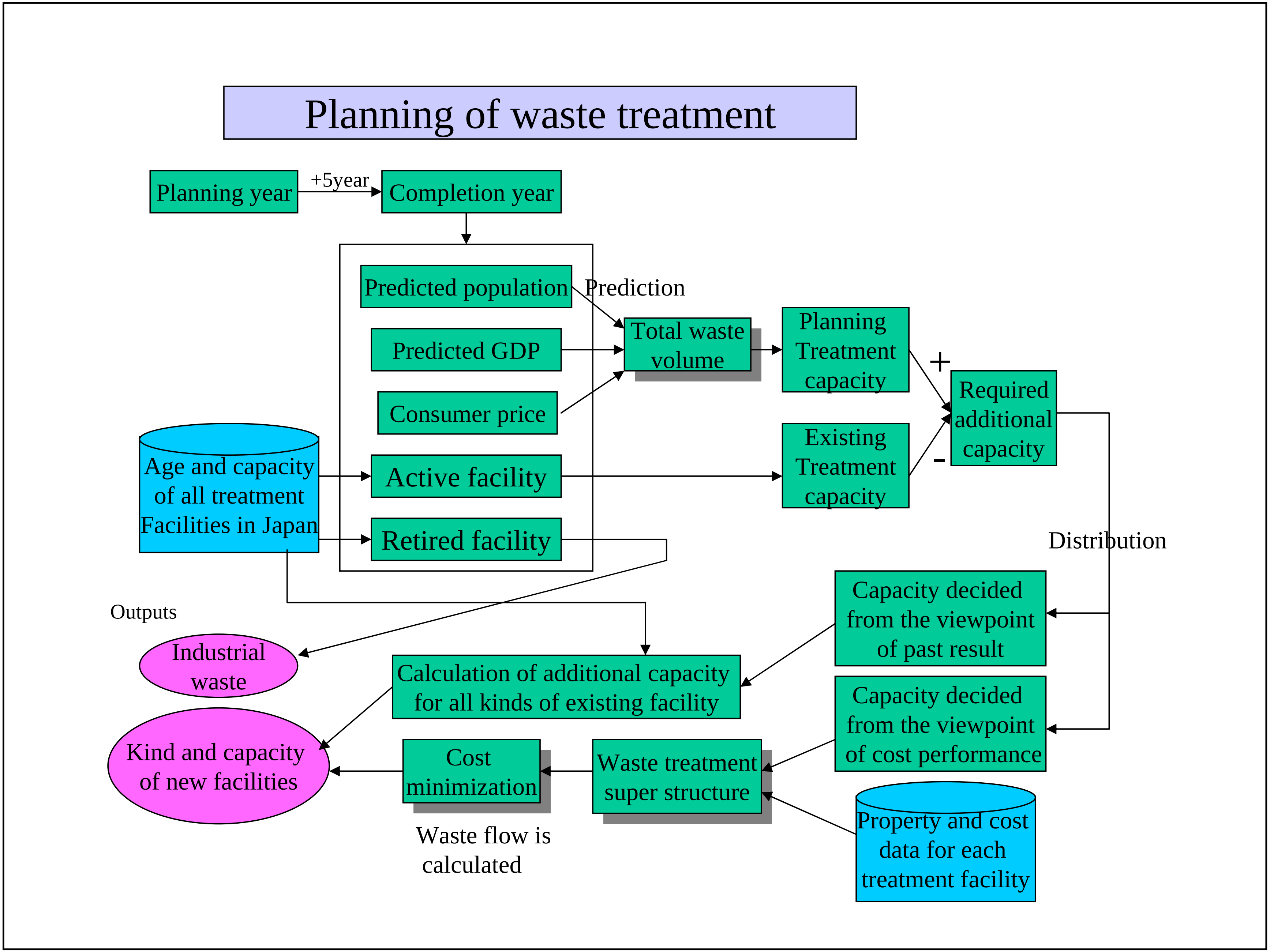


Super structure of waste treatment system



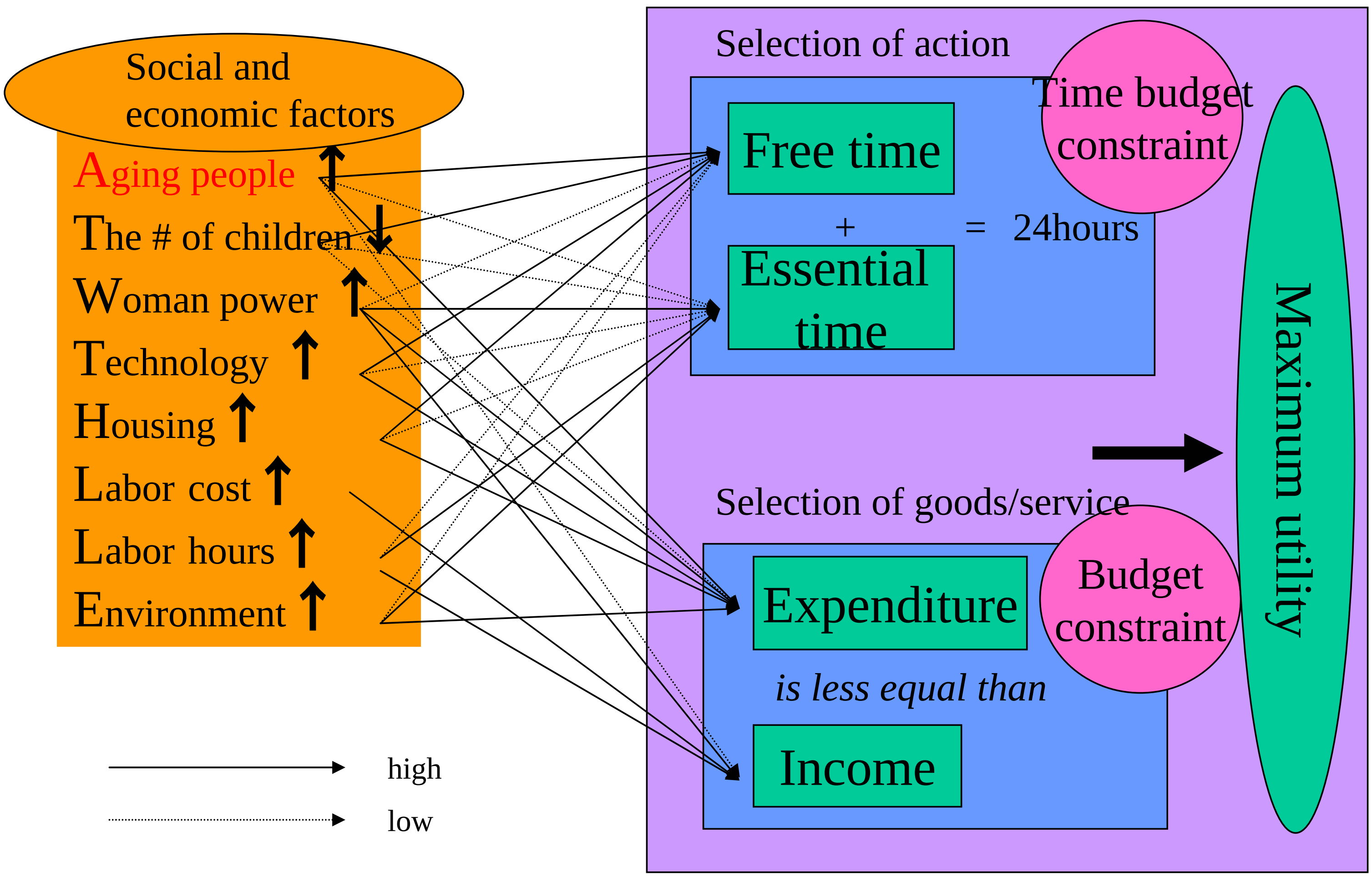
Calculated waste flow of waste treatment system



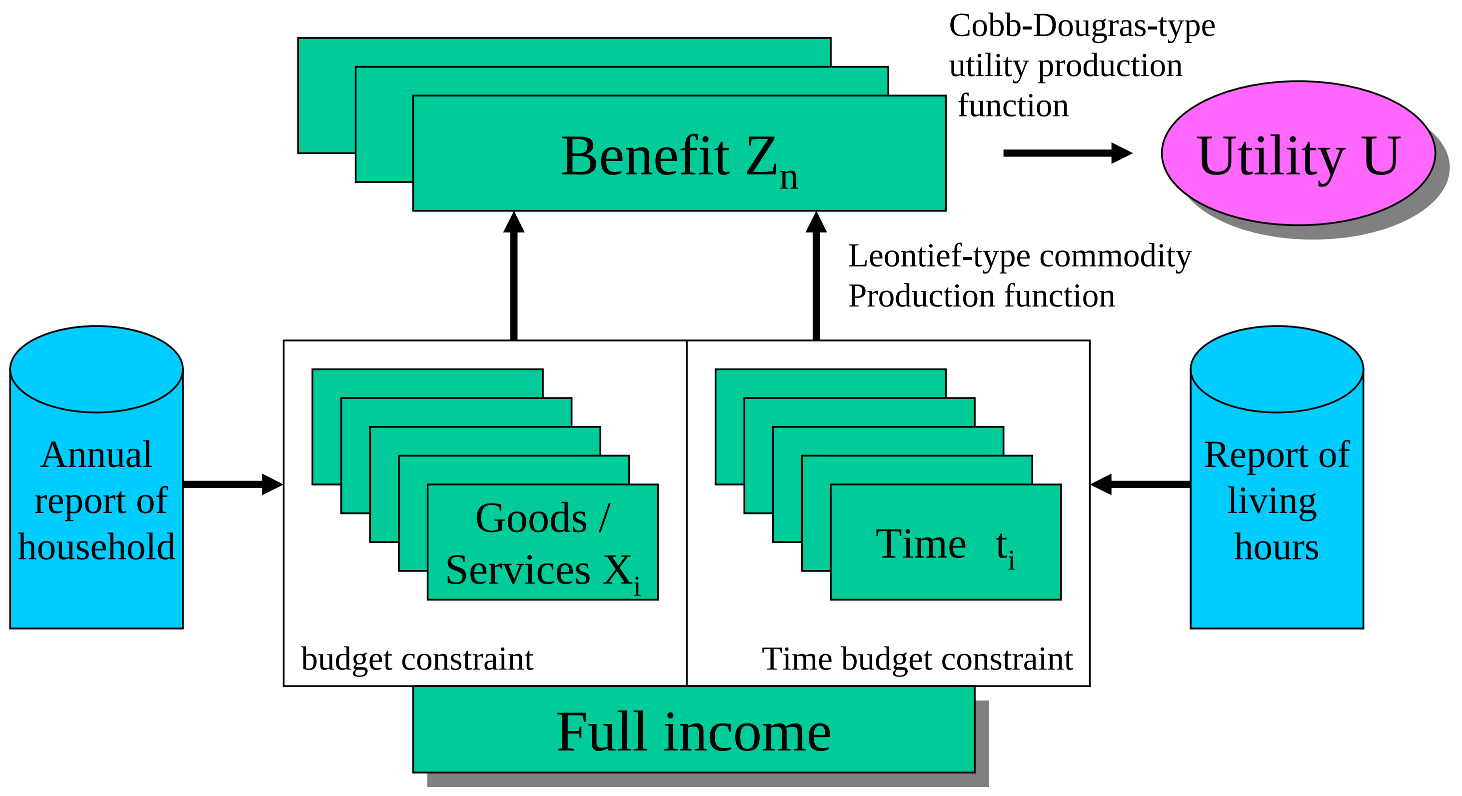


Planning of waste treatment
Planning year
+5year
Completion year
Predicted population
Prediction
Predicted GDP
Consumer price
Total waste volume
Planning Treatment capacity
+
Required additional capacity
-
Existing Treatment capacity
Age and capacity of all treatment Facilities in Japan
Active facility
Retired facility
Distribution
Outputs
Industrial waste
Capacity decided from the viewpoint of past result
Calculation of additional capacity for all kinds of existing facility
Capacity decided from the viewpoint of cost performance
Kind and capacity of new facilities
Cost minimization
Waste treatment super structure
Property and cost data for each treatment facility
Waste flow is calculated

Consumer preference model



Concept of consumer preference model



Definition of benefit production

Production function of benefit (Leontief function)

Produced benefit

Investment of money

Inestment of time

$$z_i = \min \left\{ \frac{\sum_j p_{ij} x_{ij}}{A_i}, \; \sum_k t_{ik} \right\}$$

Coefficient of benefit production

- amusement
  - TV set
  - books
  - sports goods
  - ・・・
  - hours to watch TV
  - hours to read books
  - hours to do sports
  - ・・・

Constraints for benefit production

Full income: money income when whole available time is spent for labor.
Constraint of full income is regarded as integrated budge and time budge constraints.

Full income: $$S = \underbrace{\overset{\text{Labor cost}}{\overset{\downarrow}{w}}}_{}\;\underset{\substack{\uparrow\\\text{Available total time}}}{T} + \underset{\substack{\uparrow\\\text{Income without labor}}}{K} - \underset{\substack{\uparrow\\\text{Expenditure excluding consumption}}}{V}$$

Constraint: $$S = \underset{\substack{\uparrow\\\text{Investment for goods/service}}}{\sum_i \sum_j p_{ij} x_{ij}} + \underset{\substack{\uparrow\\\text{Money income renounced while the time is spent except for labor}}}{w \sum_i \sum_k t_{ik}}$$

Definition of utility production

Utility function (Cobb-Dougras function)

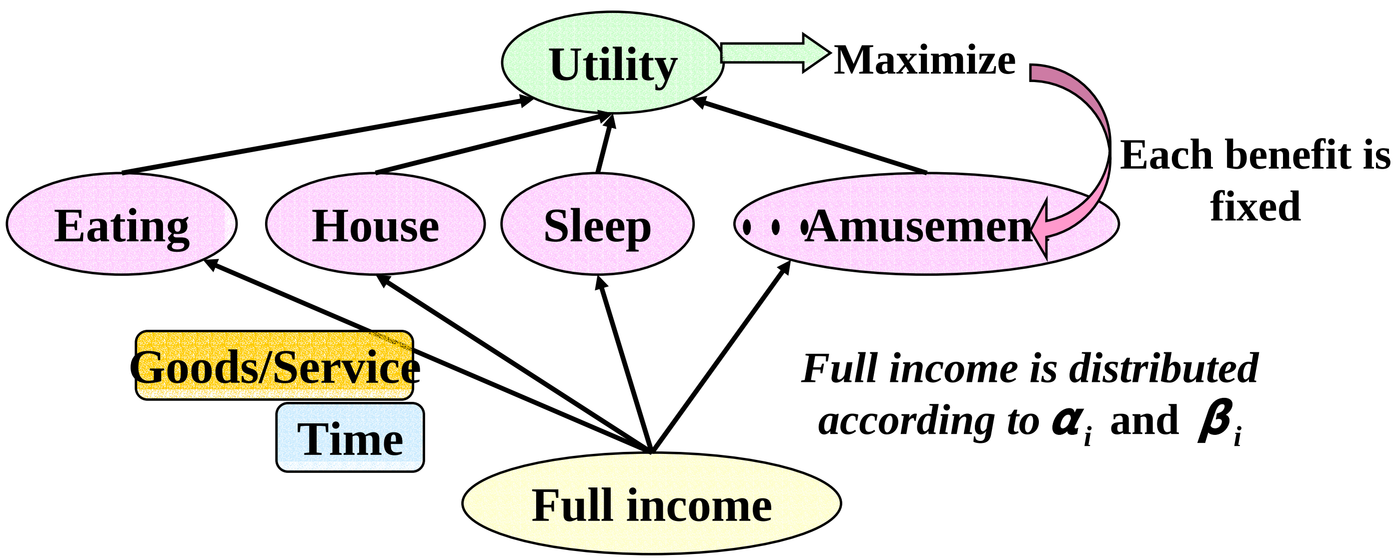
Produced utility

Base of benefit

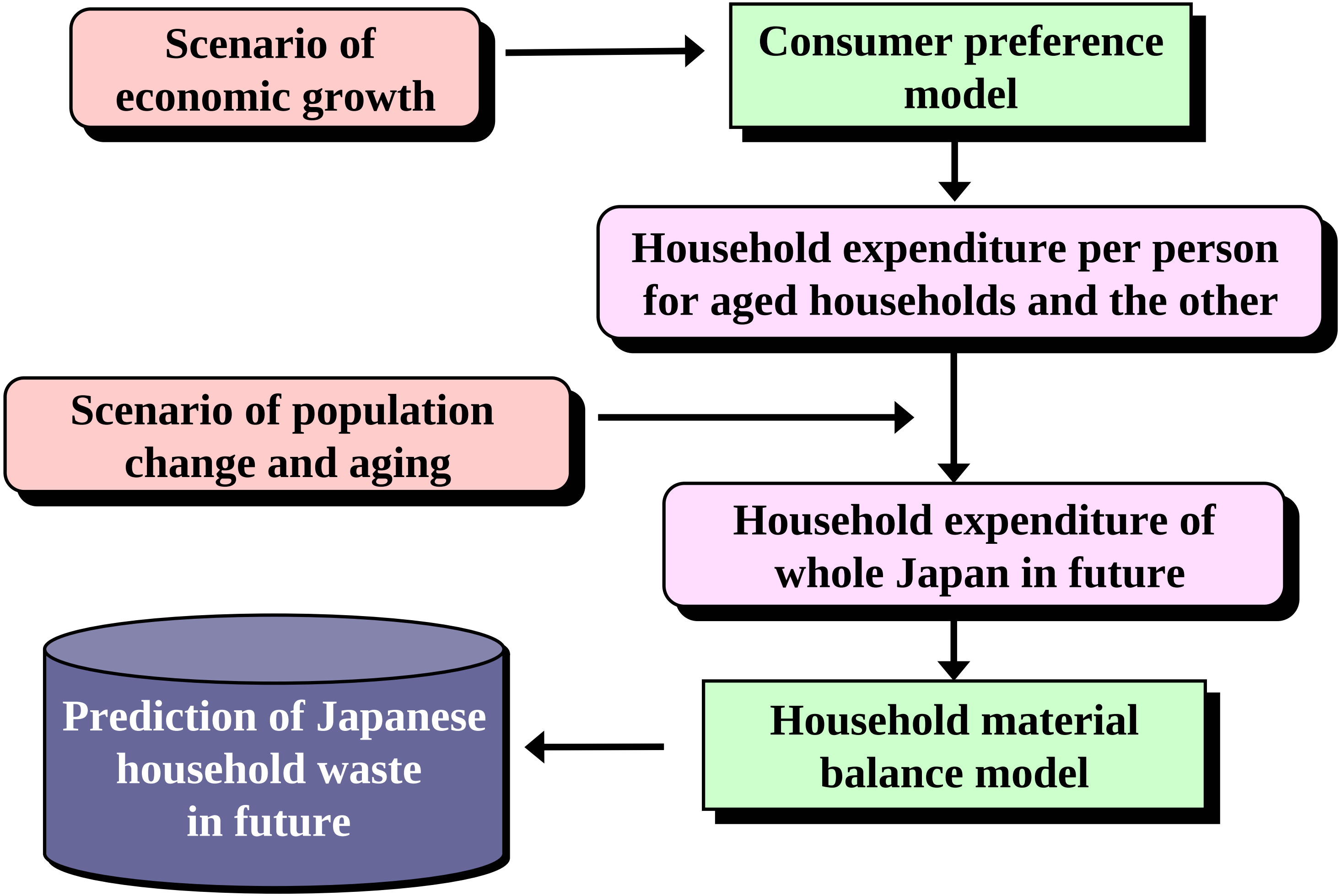
$$u = \prod_i \left(z_i - \beta_i \right)^{\alpha_i}$$

Benefit

Magnitude of preference



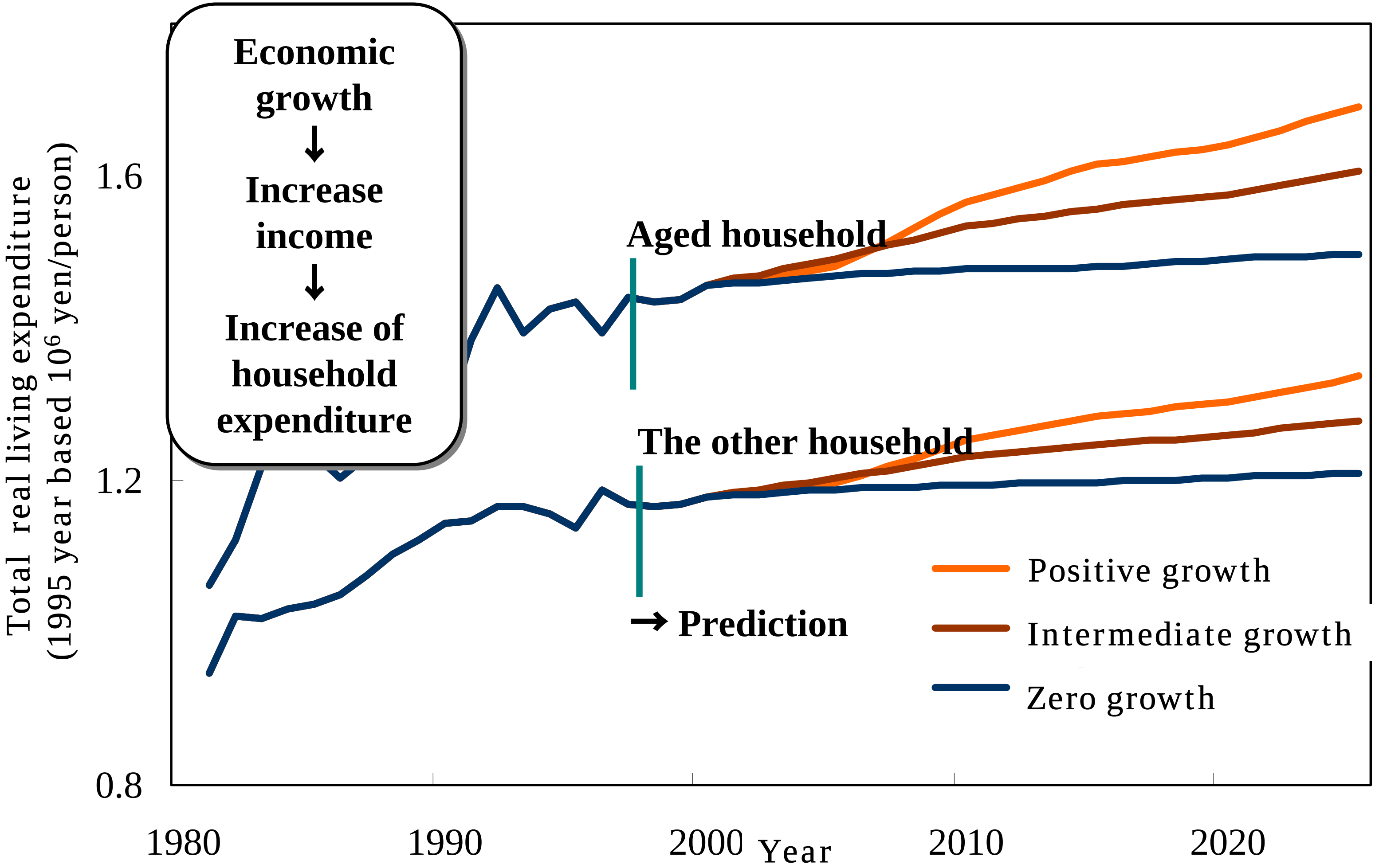
Prediction of household waste using ‘Consumer preference model’



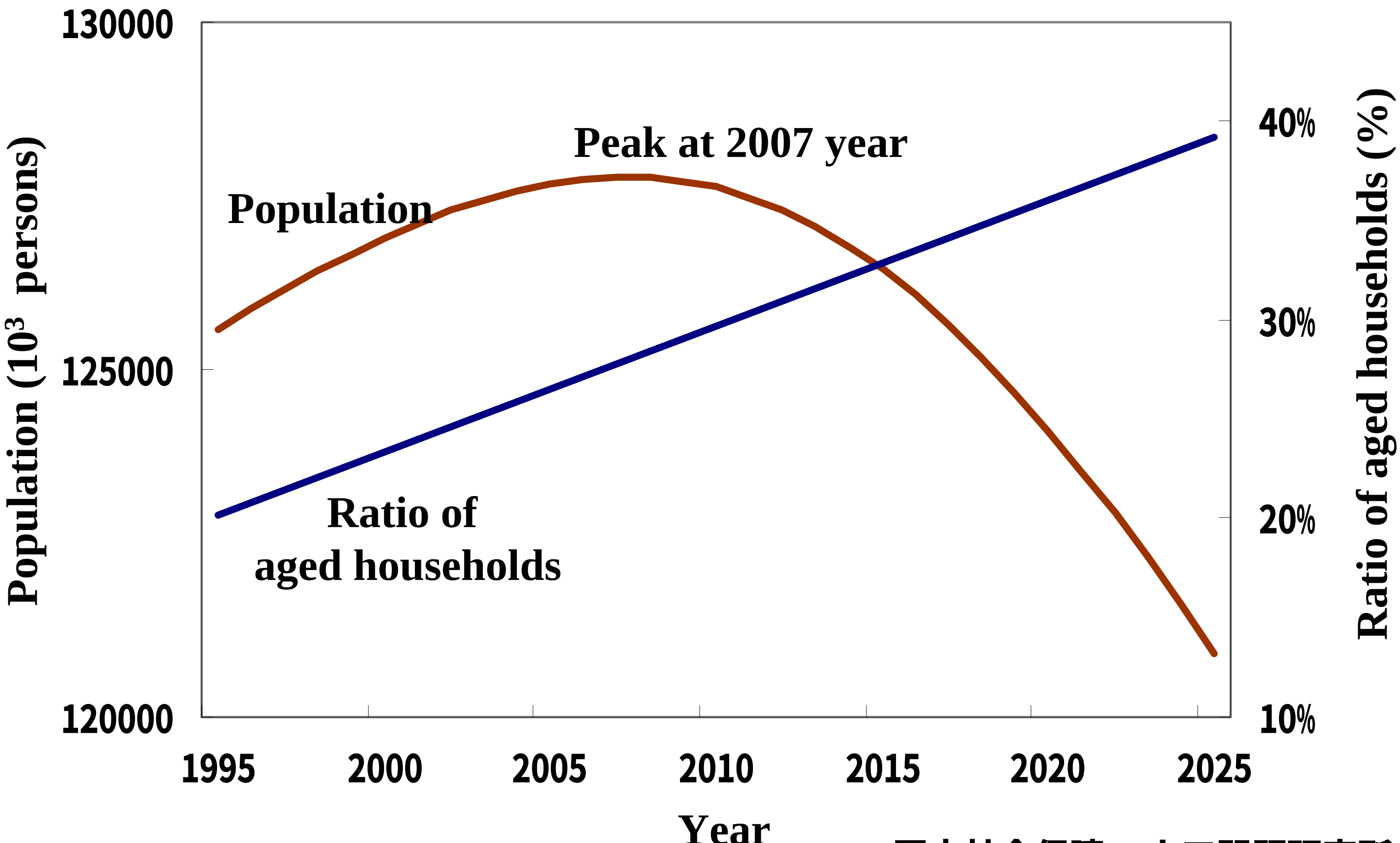
Category of benefits

Category	Benefits	Example of action
cloth	benefits by wearing clothes	clothing
eating	benefits by eating dishes	eating
house	benefits to get comfortable living	housing
education	benefits by taking educations	going to school
housework	benefits by housekeeping	cleaning、washing
health	benefits by maintaining healthy life	taking bath,washing face, going to a hospital
amusement	benefits by enjoying amusement or recreations	reading、sports、travel
sleep	benefits by sleeping	sleeping
others	the other benefits	moving、communication

Prediction of living expenditure (total cost per person)

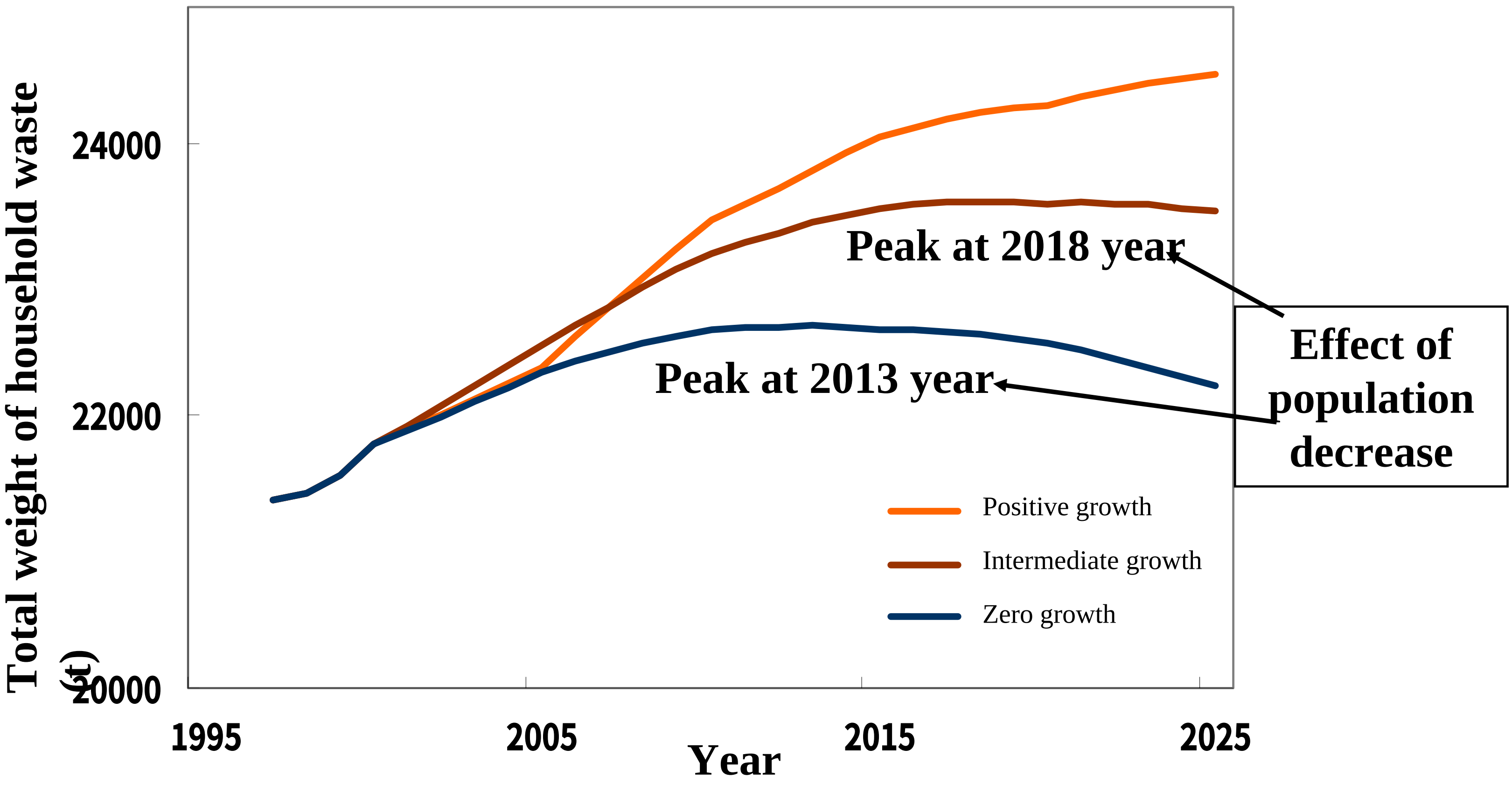


Scenario of population change and aging

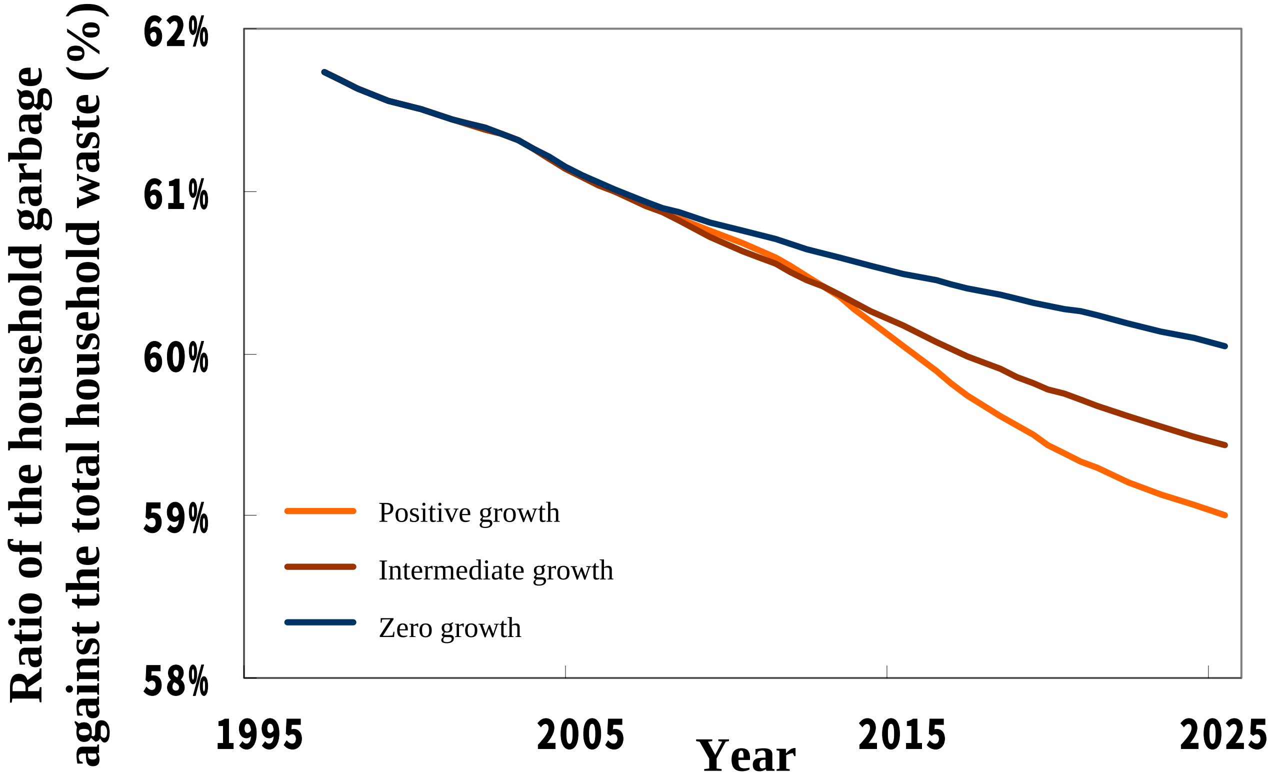


(国立社会保障・人口問題研究所)

Prediction of household waste

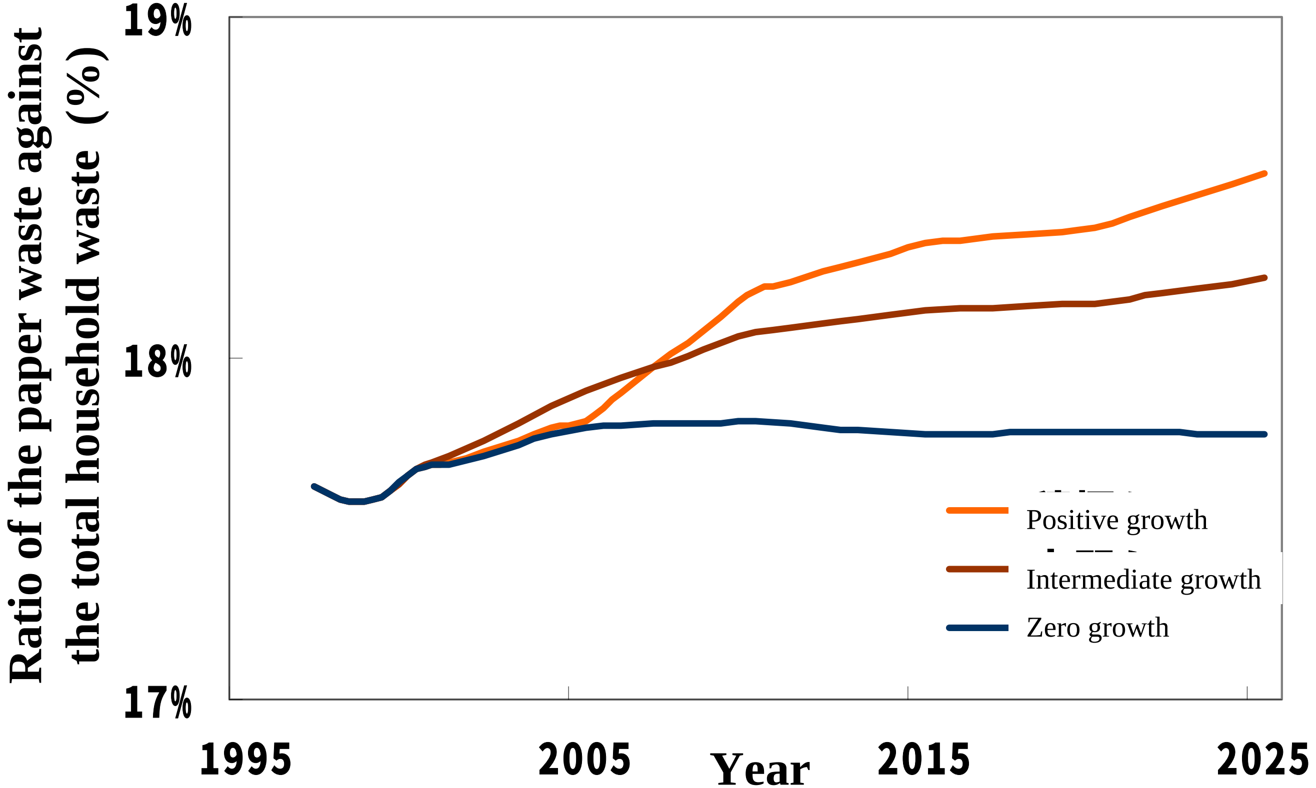


Prediction of household garbage



- In all households, the expenditure for ‘eating’ decreases.
- Household garbage, which is generated from the essential activity, the ratio of garbage decreases even if the economic growth is high.

Prediction of paper waste



- Increase of aged households.
- Expenditure for amusement in aged households increase.
- Papers have a relationship with the amusement.

Conclusion

- We developed sequential three models
- Using a scenario considering aging problem, the trend of waste in future was predicted.
- This models should be linked to the macro economic model, AIM-Material.
- In the next step, a bottom up model of industrial waste will be studied.

Appendix

(1) Commodity production function

$$Z_n = f\left(X_1, X_2, \cdots, X_M, t_1, t_2, \cdots, t_M; R\right)$$

$$\begin{cases} Z_n : \text{commodity} \\ X_i : \text{goods or service} \\ t_i : \text{hour spent for } X_i \\ R : \text{other variables} \end{cases}$$

(2)Budget constraint

$$I = \sum_{i=1}^{M} p_i X_i$$

$$\begin{cases} I : \text{Income} \\ p_i : \text{price of goods or service} \end{cases}$$

(3)Time budge constraint

$$t_{all} = \sum_{i=1}^{M} t_i + t_w$$

$$\begin{cases} t_{all} : \text{total hour} \\ t_w : \text{working hour} \end{cases}$$

(4)Full income

$$S = \sum_{i=1}^{M} p_i X_i + w \sum_{i=1}^{M} t_i + V = w t_w + w \sum_{i=1}^{M} t_i + V = w t_{all} + V$$

$$\begin{cases} S : \text{full income} \\ V : \text{other income} \\ w : \text{labor cost} \end{cases}$$

(5)Leontief – type" *Commodity production function*"

$$Z_i = \min \left\{ \frac{\sum_{j=1}^{M} p_j X_j}{A_i}, \sum_{i=1}^{M} t_i \right\}$$

A_i : Commodity production coefficient

(6)Shadow price of the commodity

$$S = \sum_{i=1}^{M} p_i X_i + \sum_{i=1}^{M} w_i t_i + V = \sum_{i=1}^{M} A_i Z_i + \sum_{i=1}^{M} w Z_i + V \equiv \sum_{i=1}^{M} \pi_i Z_i + V$$

$$\pi_i = A_i + w$$

π_i : shadow price of commodity Z_i

(7)Cobb - Douglas utility production fuction

$$U = \prod_{n=1}^{N} \left(Z_n - \beta_n\right)^{\alpha_n}, \quad Z_n \geq \beta_n \geq 0$$

$$\begin{cases} \alpha_n : \text{marginal propensity to consume} \\ \beta_n : \text{base utility} \end{cases}$$

(8)Optimization problem to be solved

$$\max U = \max \prod_{n=1}^{N} \left(Z_n - \beta_n \right)^{\alpha_n}$$

subject to

$$Z_n \geq \beta_n \geq 0$$

$$\sum_{n=1}^{N} \alpha_n = 1$$

$$S = \sum_{m=1}^{M} \pi_m Z_m$$

$$\rightarrow \quad \max \left\{ \sum_{n=1}^{N} \alpha_n \log \left(Z_n - \beta_n \right) + \lambda \left(S - \sum_{m=1}^{M} \pi_m Z_m \right) \right\}$$

(9)Utility demand function as the result of optimization

$$\pi_n Z_n = \pi_n \beta_n + \alpha_n \left(S - \sum_{m=1}^{M} \pi_m \beta_m \right)$$