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CARBON DIOXIDE EMISSION PATTERNS DUE TO CONSUMERS' EXPENDITURE IN LIFE STAGES AND LIFE STYLES

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Consumers' CO_2 emission patterns were discussed from the view point of their life stages and life styles. Here, I-O and waste function analysis were applied for statistic data on consumers' expenditure, and also multivariate analysis was applied for tentative environmental bookkeeping data reported by ordinary consumers. The results reveal that: 1)changes of the emission patterns differ with life stages for the past 3 decades, 2)both young and old single households tend to give greater contribution in 2000-2010, and 3)the tentative environmental bookkeeping grasped nearly one third of the total emission and several emission patterns were recognized for 5 clusters corresponding to the life styles.

Key Words *: carbon dioxide, consumers' expenditure, life stage, life style, input-output analysis*

1. INTRODUCTION AND OBJECTIVES

Under the agreement in Berlin Mandate adopted in April 1995, the member countries have substantially started discussion and negotiation for reducing greenhouse gas emissions toward the 21st century. In considering nation wide carbon dioxide emission pattern, here we would like to highlight increasing consumers' contribution. As it is known, consumers' expenditure has increased its proportion in final demand. This also means consumers have much contributed to carbon dioxide emission both directly and indirectly. For example, the comparison of carbon dioxide emission patterns in UK and Japan revealed the reflection of such differences in the maturity of post industrialization[1].

Concept of the analysis is shown in **Fig.1**. Carbon dioxide emission due to consumers' expenditure differs with how and which we consume. In other words, A) carefulness for consumption of goods, i.e. consumption of energy, fuel and embodied carbon dioxide through inter-industrial transaction due to final demand of households (illustrated in circle 'A'), and B) carefulness for duration of goods, i.e. stock and flow of goods (illustrated in circle 'B'). The two factors are affected by changes in households' compositions in accordance with their life stages i.e. several phases of households' life cycles. On the other hand, households' behaviors differ with their life styles even at the same life stage. Therefore, here we attempt to clarify carbon dioxide emission patterns due to consumers' expenditure in their life stages and life styles. In addition, in recent years the number of aged households and the consumption of young single households have increased remarkably. This analysis would provide useful information of

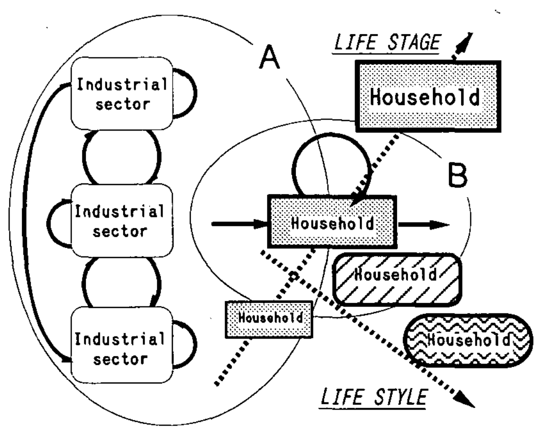

Fig.1 Concept of the analysis

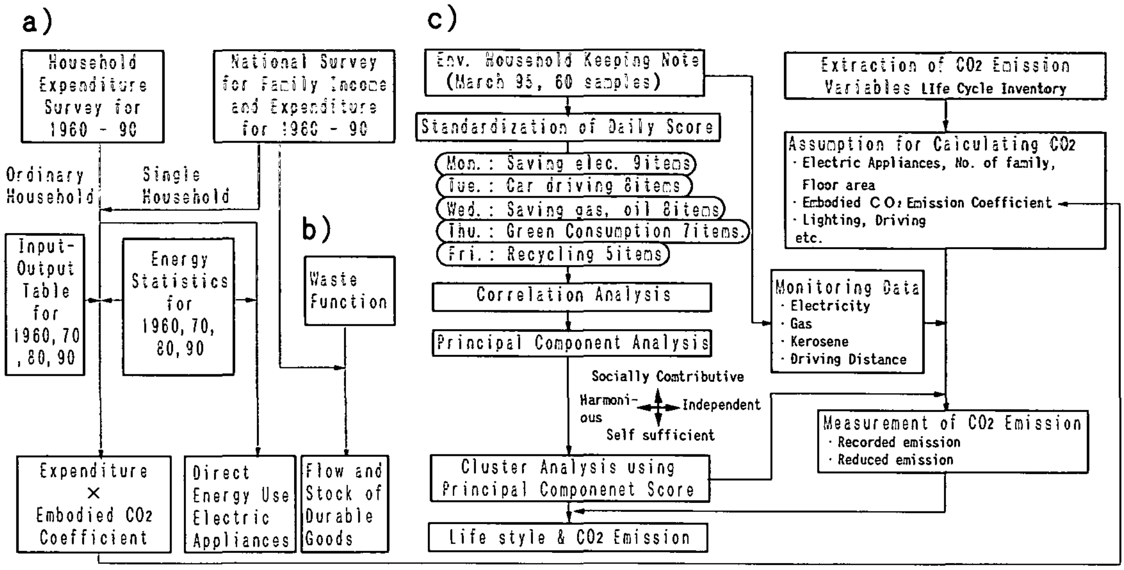

Fig. 2 Flow of the analysis

their impacts on the future carbon dioxide emission patterns. Also such Japan's experience would give some help for other sharply developing Asian countries, such as NIES, to consider their future countermeasures. Moreover, the improvement of these analytical methodology would give contribution to facility of environmental life innovation support system proposed by Morioka[2].

2. METHODOLOGY

(1) Flow of the Analysis

This analysis consists of the following three categories:

a)Direct and embodied carbon dioxide emission patterns due to consumers' expenditure through their life stages ('A' and 'life stage' in **Fig. 1**).

b)Patterns of stock and flow of durable goods and their impacts on carbon dioxide emission through consumers' life stages ('B' and 'life stage')

c)Carbon dioxide emission patterns due to consumers' life style type ('A', 'B' and 'life style')

Flows of the above analytical categories are shown in **Fig. 2. a)** and **b)** are specifically examined in terms of life stages defined as the age of household heads. Also improvement effects by learning with environmental bookkeeping are observed as well as emission patterns by life style in **c)**.

(2) Methodology

Detailed methodology in each analytical category (shown in **Fig. 2**) is as follows:

a)Direct and embodied carbon dioxide emission patterns due to consumers' expenditure through their life stages

Leontief inverse matrices were calculated by using Japanese Input-output tables, aggregated into 112 sectors, for 1960, 70, 80 and 90. Detailed theory of the inverse matrix is described in our previous research[2]. Here, inverse matrix $[I - A]^{-1}$ was applied to calculate embodied carbon dioxide of imported goods, provided that imported goods are made in the same industrial structure as the domestic products, proposed by Kondo et al.[3]. To calculate carbon dioxide emission coefficients at purchaser's price, consumption data for each ten - year age group of household head in Family Expenditure Survey (FES) was divided into producer's price, trade margin and domestic freight using trade margin and domestic freight table in each I-O table although Kondo et al. assumed the same trade and domestic freight margins distribution for annual I-O balances. National Survey for Family Income and Expenditure (NSFIE) was applied for the data of single households. As the NSFIE data is recorded only for 1 month (November), here the data of single households' annual consumption was estimated by using the NSFIE data multiplied by 12. Consequently this means estimated carbon dioxide emissions by single households have some errors. For reference, the average of monthly expenditure to the expenditure in November of ordinary family household varies from 0.98 to 1.08

(average 1.04), according to FES 1960-93. Therefore this should be taken into consideration in examining the results. Deflators estimated in Joint I-O table since 1960 was applied to convert each I-O table at current price to at 1990 constant price.

b)Patterns of stock and flow of durable goods and their impact on carbon dioxide emission through consumers' life stages

Obviously embodied carbon dioxide emission related to the consumption of electricity is determined by volume of the stock of electric appliances, not only by the flow, i.e. annually and newly purchased electric appliances because of their long duration. Therefore, first the above emission, calculated in a), was distributed using data on the share of domestic electricity consumption for each electric appliance evaluated by MITI[4] and NSFIE data. Here energy consumed is assumed to be in proportion only to the number of the stock for each age group of household. Second, annual flow and stock of durable goods and its differences with age groups of households were analyzed. Morioka applied the waste function using Erlang distribution curve shown below for analysis of urban metabolism[5]:

$$f(\tau)=(s\lambda)^s \cdot \tau^{s-1} \cdot e^{-\lambda s \tau} / (s-1)!$$

where, $f(\tau)$ is the waste function which expresses annually demolished ratio with its function feature that it monotonously increases before maximum point and then loses inclination gradually through maximum, τ is value of year, λ is the reciprocal of average duration time, s is constant which decides degree of inclination.

Here we applied the same function for durable goods, specifically electric appliances. The above function, where data of purchased durable goods by each ten - year age group of household head extracted from FES was surveyed, calculated annual number of demolished goods and number of stock. Duration time was decided as the value which minimize discrepancy between calculated value and data from NSFIE 1989 for number of stock purchased before 1979. Then we evaluated its validity with comparison to five - year stock data from NSFIE.

c)Carbon dioxide emission patterns for consumer's life styles

Data reported during 1 month by ordinary consumers for tentative environmental bookkeeping was examined (number of available samples is 60, carried out in March 1995). Environmental Bookkeeping provided total 37 check items from Monday to Friday (See **Fig. 2**) and 1 - 5 of Likert type scales for each item. Therefore, firstly, correlation analysis was applied for the standardized daily score data. Then, secondly, principal component analysis was applied to extract principal

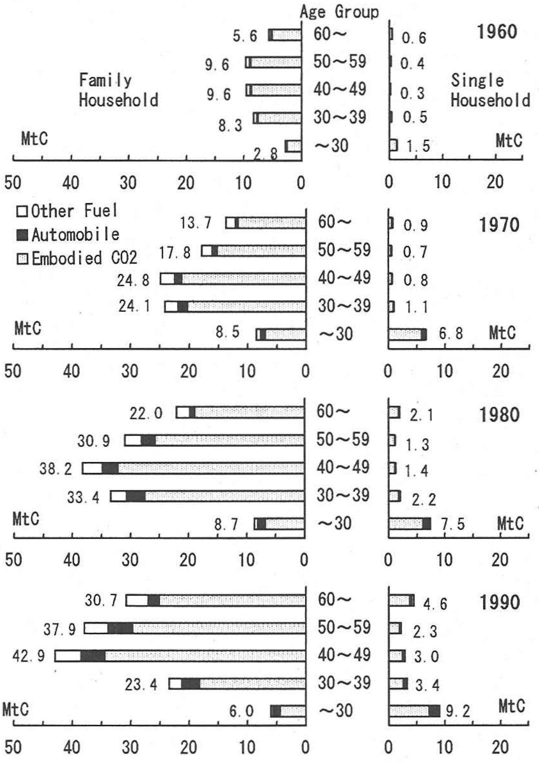

Fig. 3 Yearly trend of CO2 emission petterns for each household age group

component factors indicating consumers' life styles and consequently consumers were divided into several groups by cluster analysis using principal component scores and these groups were interpreted in terms of their life styles. Finally, measurement of carbon dioxide emission patterns were attempted by using monitoring data concerning direct energy consumption. Embodied carbon dioxide emission was calculated by using embodied coefficients by I-O analysis and the bottom up approach in the same way as the Science and Technology Agency did[6]. Also improvement effect by learning through application of the environmental bookkeeping was evaluated by assuming average reduction effects based on other reference materials[7),8),9),10)].

3. CONSUMERS' CARBON DIOXIDE EMISSION PATTERNS THROUGH THEIR LIFE STAGES

(1) Trend of consumers' carbon dioxide emission patterns

Fig.3 shows trend of carbon dioxide emission patterns due to consumers' expenditure for household

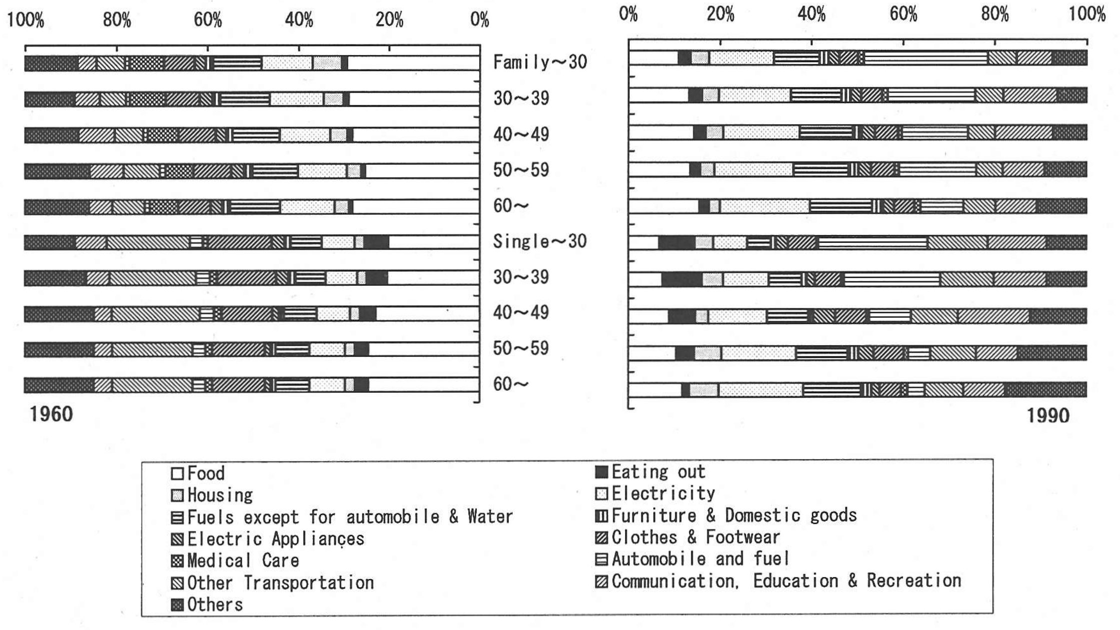

Fig. 4 Share of CO_2 emission for each household age group in 1960 and 1990

age groups. Here, the names of data series, 'Other fuel', 'Automobile' and 'Embodied CO_2' in the legend of **Fig.3** denote 'other direct fuel consumption except for automobile', 'direct fuel consumption for automobile' and 'embodied CO_2 due to consumption of goods' respectively. This shows carbon dioxide emission due to consumers' expenditure increased rather more rapidly in 1960-70 than in 1970-90. The emission for each year compared to that of 1960 is 2.5 times in 1970, 3.8 times in 1980 and 4.2 times in 1990 respectively. The amount of all direct and embodied carbon dioxide emission is 163 Mt-C in 1990, which takes embodied CO_2 of imported goods into consideration. While households of the 40s-age group consistently give great contribution to the CO_2 emission, elderly household has contributed year by year. Also the ratio of emission caused by family households to single households has been reduced from 10.6 in 1960 to 6.3 in 1990, corresponding to increasing emission by single households. Moreover increase of direct emission is rather drastic. While the embodied CO_2 emission has increased by up to 3.6 times from 1960 to 1990, direct fuel consumption has increased by up to 5.5 times for other fuels and up to 37 times for automobile.

Fig. 4 shows detailed share of the emission for 1960 and 1990. The following features are indicated: a)decreasing share of food, with contrast to increasing share of eating out especially in young single households; b) increasing ratio of automobiles, c)decreasing share of clothes and footwear; d)increasing share of communication, education and recreation. The above features are conspicuously recognized in young households in 1990.

(2) Movement of number and emission of household

Locus of the number of and emission per household is illustrated in **Fig.5**. Although normal locus of household through all the age groups is like a letter C for single household and C with left side right for family household such as in 1960, the allocations of gradually colored markers indicate yearly dispersed household components both for single and family households. Greater contribution given by elderly households is observed year by year as well as increasing emission for each cohort.

(3) Variation factors of CO_2 emission per household

Major factors of variation of the carbon dioxide emission pattern per household is recognized as number of household, expenditure, emission coefficient, local variety, life style etc.. Here we examined in terms of the above former three factors and the relationship with life stages. **Fig.6** shows each factor's contribution during each decade for each age group, by comparing CO_2 emission of a

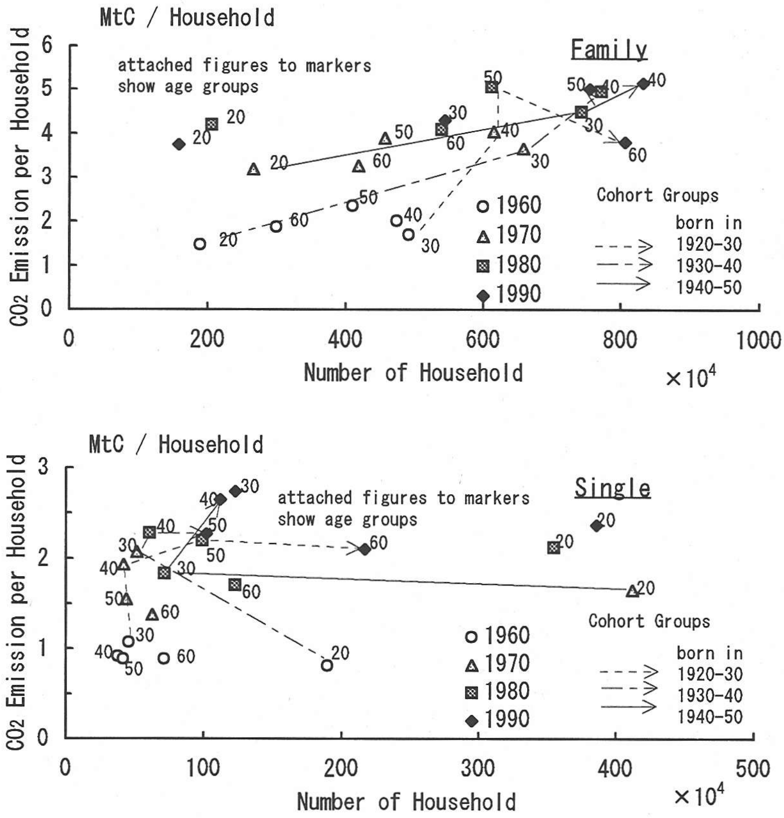

Fig.5 Trend of number and emission intensity per household in 1960 -1990

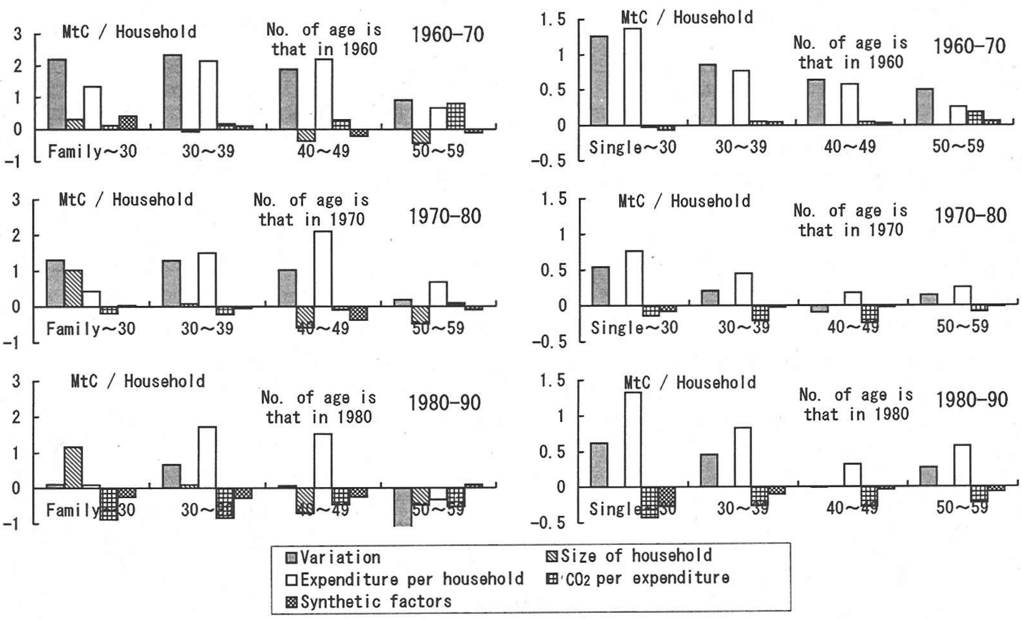

Fig.6 Variation factors of the CO_2 emission per household in 1960 - 1990

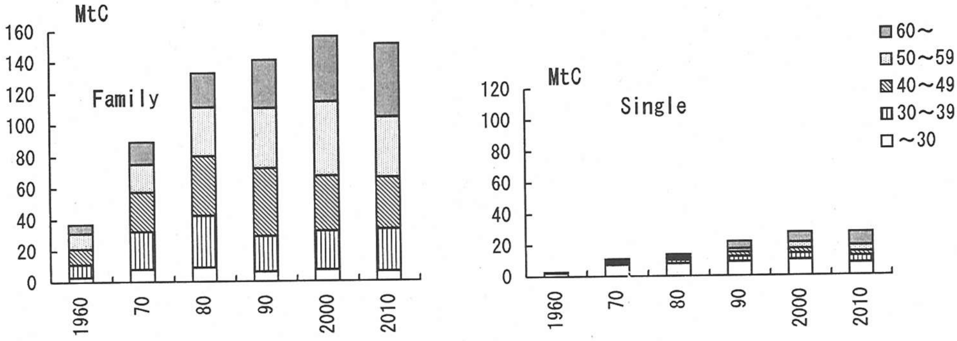

Fig.7 Estimate of CO_2 emission for the year 2000 and 2010

Table 1 Estimate of CO_2 emission for the year 2000 and 2010 (Detail)

Case	Type of Household	Family ~30	Family 30~39	Family 40~49	Family 50~59	Family 60~	Single ~30	Single 30~39	Single 40~49	Single 50~59	Single 60~
Year 2000	Number of Household (Million)	1.84	5.44	6.6	8.63	11.21	4.01	1.48	1.32	1.73	3.65
	CO_2 / Expenditure (MtC/M¥)	0.82	0.80	0.73	0.85	0.81	0.71	0.63	0.60	0.68	0.66
	Expenditure/Household (M¥)	4.92	5.67	7.23	6.37	4.60	3.64	4.22	4.13	3.31	2.96
	CO_2 (MtC)	7.4	24.8	34.7	46.6	41.8	10.4	3.9	3.3	3.9	7.2
Year 2010	Number of Household (Million)	1.53	6.14	6.82	7.01	14.44	3.02	1.74	1.54	1.98	5.98
	CO_2 / Expenditure (MtC/M¥)	0.70	0.69	0.58	0.73	0.61	0.61	0.49	0.41	0.51	0.43
	Expenditure/Household (M¥)	5.60	6.45	8.48	7.38	5.33	4.33	5.01	4.97	4.00	3.62
	CO_2 (MtC)	6.0	27.4	33.4	37.6	46.6	8.0	4.2	3.1	4.0	9.4

household age group in a year with that of the next household age group after 10 years, recognized as a cohort. For example, the variation of family household in 1960-70 equals to emission per household for 30-39 age groups in 1970 minus that for -30 age groups in 1960. In general, it is revealed that expenditure per household increased year by year and emission coefficients were sharply reduced in 1980-90 for average household[11]. The major objective of this analysis is to grasp its variation for each age group, apart from 'cohort analysis', which has been developed by Glenn et al. and is an analysis explaining social changes etc. from the view point of age, period and cohort effects.[12]

Concerning family households, the expenditure mainly contributed to middle age groups not for all age groups. After all, the increase in younger household is caused by number of household while that in middle household is caused by increase of expenditure in 1970-80 and 1980-90. This might indicate change of an attribute in 30s because of recent late marriage etc.. Also 40s has steadily increased negative contribution of the number. The opposite variation to 40s is observed in the case of elderly households. As for single households, greater contribution has been given by the expenditure for each household age group, especially in young households and it coped with the effect by improvement of emission coefficients.

(4) Future Perspective

Here we attempt to evaluate how much impacts is to be introduced by the above features of age group households. To clarify and simplify the factor component, first we express carbon dioxide emission per household as the product of the following three factors: CO_2 emission intensity per expenditure, expenditure per household, and number of household. Second, concerning the former two factors, linear regression was applied to estimate future amount of consumers' expenditure and CO_2 coefficients. In order to reflect yearly effort of energy saving after so called oil shock, data in 1960 was neglected for the regression analysis. On the other hand, household projections (middle estimate) for Japan estimated by the Ministry of Health and Welfare[13] was applied for the future number of households corresponding to all age groups. The result is shown in **Fig. 7** and **Table 1**. It was estimated that in spite of the reduction of emission coefficients CO_2 emission would increase by nearly 13 % in 2000 and 6 % in 2010 from 1990 due to increasing expenditure and number of households older than 50 for family and younger than 30 and older than 60 for single.

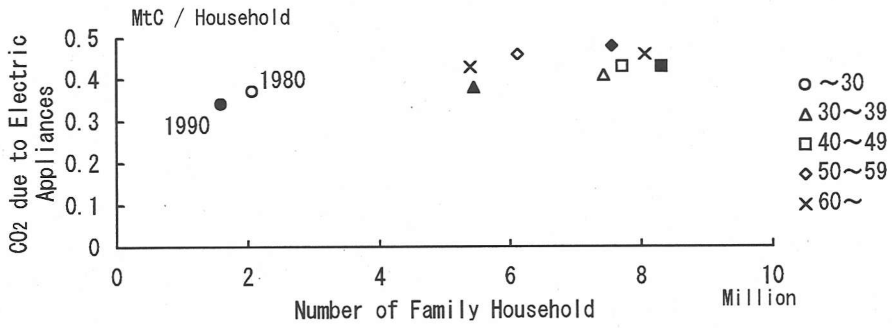

Fig.8 CO_2 related to electric appliances in 1980 and 1990

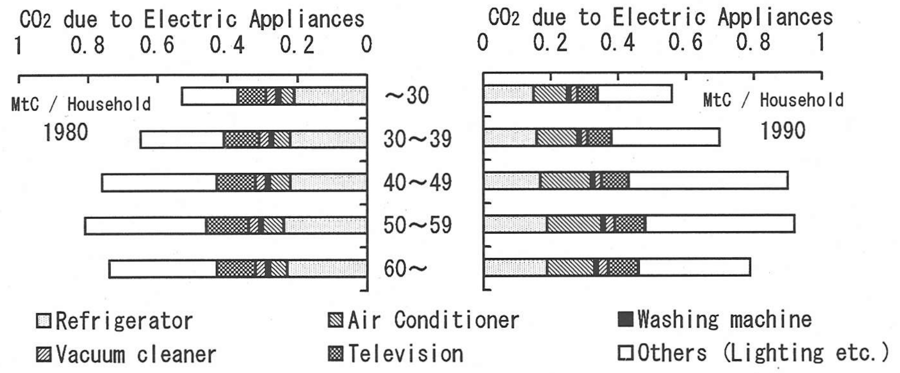

Fig.9 Share of CO_2 emission by major electric appliances in 1980 and 1990

4. PATTERNS OF STOCK AND FLOW OF DURABLE GOODS AND THEIR IMPACTS

As shown in **Fig.4**, electricity has great share of embodied carbon dioxide as well as other fuel consumption. Domestic consumption of electricity is mainly for the power of electric appliances and lighting, so stock of the appliances dominate the amount of carbon dioxide emission related to electricity as mentioned before.

First, we evaluate the share of embodied carbon dioxide emission by major electric appliances. Second, features of duration time for each household generation is to be discussed by using waste function. Because of limitation of the data by MITI[4)], the data was evaluated for 1980 and 1990.

(1) CO_2 related to energy use for durable goods

Total carbon dioxide emission in terms of number of the household and emission per household for each age group is shown in **Fig.8**. Increase of emission intensity adding to that of household number is obvious in almost all age groups. Mainly elderly households, especially the group older than 60 group, give great contribution in 1990. Then the share of carbon dioxide emission by major electric appliances for each age group is shown in **Fig.9**. Younger household has greater share by these major appliances than elderly household. Comparing 1990 with 1980, use of room air conditioners and other appliances cause to increase the emission.

(2) Stock and flow of durable goods

Using the waste function, stock and flow of major durable goods were calculated. **Fig.10** shows an example of the estimated function curve. This proves extraction of the cohort data is successful and the waste function for this analysis is also available for such domestic goods of short duration time. Also the function is available for almost durable goods of more than 10 years of stock data in NSFIE.

Fig.11 indicates overall duration times of purchased goods for each household age group corresponding to its life stage. Young households (born in 1940 ~ 1949) tend to renew goods frequently due to growth of the family. Such an tendency is typically recognized in the case of automobiles and it would cause to increase of embodied carbon dioxide. On the other hand, in the case of TVs and washing

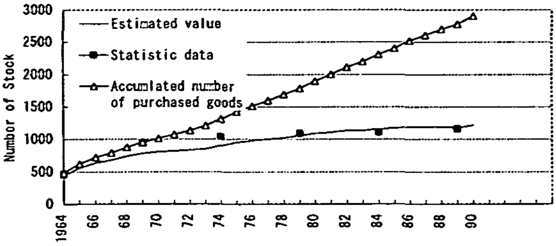

Fig.10 An example of the waste function

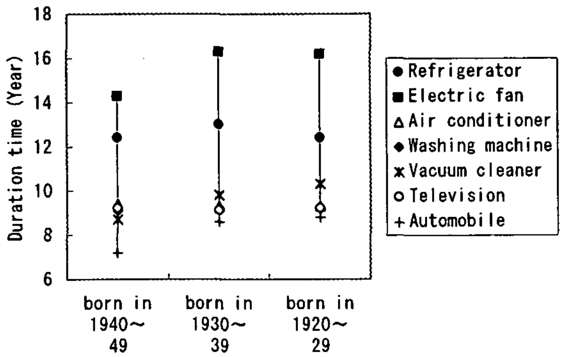

Fig.11 Duration time of purchased goods for 3 household age groups

machines, advanced household (born in 1920 ~ 1929) shows almost the same or rather shorter duration times. This would imply other factors such as progressed usefulness of the goods, change of household components etc. enhanced renewal of the goods.

5. CARBON DIOXIDE EMISSION PATTERNS FOR CONSUMERS' LIFE STYLES

While life stage of households dominates basic patterns or tendency of carbon dioxide emission, life style chosen by each household also gives variety or variation of the emission pattern. The analysis of this chapter attempted to reveal such a variation quantitatively.

(1)Principal components indicating environmental life styles

Likert type scaled data obtained from tentative environmental bookkeeping (60 samples) was firstly examined using cross and regression analysis. As a

Table 2 Weighting coefficients for each principal component

Item	Weighting Coefficient (△:+, ▼:-)				
	Perfor-mance	Car Use	Sociable	Harmoni-ous	Continu-ous
Mo1 Save lightening	△ 0.40	0.01	▼-0.39	△ 0.38	0.09
Mo2 Reduce 1h watching TV	0.16	0.07	-0.01	0.18	-0.03
Mo3 Shut refrigerator door	0.26	△ 0.24	-0.22	-0.09	-0.13
Mo4 Washing together	0.21	△ 0.29	-0.06	-0.17	-0.05
Mo5 Rice cooker	0.16	△ 0.21	0.13	0.12	0.13
Mo7 Clean vacuum filter	0.20	0.11	-0.05	0.38	-0.07
Mo8 Iron together	0.16	-0.23	0.12	△ 0.49	-0.03
Mo9 Turn off TV main SW	▼ 0.07	0.17	0.11	-0.06	0.21
Tu1 No quick accelerator	△ 0.57	▼-0.61	▼-0.36	▼-0.43	△ 0.57
Tu2 No drive around	△ 0.42	-0.05	0.13	▼-0.34	▼-0.29
Tu3 No park with idling	0.19	▼-0.30	0.13	-0.22	△ 0.30
Tu4 Keep trunk empty	0.23	▼-0.32	0.07	△ 0.27	0.09
Tu5 Check before driving	0.19	-0.19	0.06	0.03	-0.11
Tu6 Try to walk	0.23	▼-0.34	-0.09	▼-0.15	-0.08
Tu7 No drive just for fun	△ 0.46	▼-0.42	△ 0.81	-0.06	-0.09
Tu8 No car day	0.21	-0.24	0.15	-0.15	0.07
We1 Turn off ignition fire	0.19	-0.19	▼-0.31	-0.08	0.01
We2 Use bath cover	▼-0.05	-0.03	-0.02	0.15	▼-0.35
We3 Bath continuously	0.19	0.08	0.06	△ 0.33	-0.12
We4 Control air condition.	0.16	0.05	0.01	-0.14	▼-0.30
We6 Control gas cooker	△ 0.45	0.00	▼-0.50	0.20	0.18
We7 Keep barner clean	0.21	0.09	-0.18	0.06	-0.02
We8 Save taking shower	0.27	0.13	▼-0.36	-0.24	▼-0.28
Th1 Use recycled WC papers	▼ 0.06	-0.06	-0.10	-0.13	▼-0.32
Th2 No use paper cups	0.13	△ 0.34	0.10	▼-0.25	△ 0.28
Th3 No lapping	0.23	0.11	0.13	0.15	0.10
Th4 No treys	0.18	0.03	-0.17	0.10	0.04
Th5 Reuse bottles	0.13	△ 0.22	-0.08	-0.12	△ 0.30
Th6 No greenhouse crops	0.15	0.16	0.06	△ 0.27	0.16
Th7 Bring shopping bags	0.11	0.16	0.09	-0.08	-0.22
Fr1 Recyclenewspapers	▼ 0.05	-0.01	0.12	-0.22	0.21
Fr2 Recyce milk packages	0.10	△ 0.22	0.12	▼-0.26	-0.06
Fr3 Recycle tins	0.18	0.10	△ 0.33	0.04	-0.06
Fr4 Recycle bottles	▼ 0.07	0.01	△ 0.30	-0.03	-0.22
Fr5 Recycle cards	▼ 0.04	-0.03	△ 0.30	0.08	0.03
Eigenvalue	5.75	3.35	2.71	2.15	2.03
Contribution rate	0.16	0.10	0.08	0.06	0.06
Cumulative Contri. rate	0.16	0.26	0.34	0.40	0.46
Interpretation of principal components	Good perfor-mance ⊕↑ ↓⊖ Bad perfor-mance	Not care for cars ⊕↑ ↓⊖ Care for cars	Sociable ⊕↑ ↓⊖ Self Sufficient	Harmoni-ous ⊕↑ ↓⊖ Indepen-dent	Not so continu-ous ⊕↑ ↓⊖ Prefer continu-ous

result, it is found that highly scored items or activities concerning environmental soundness were tend to be linked through rather places beyond the day items set up for the same kind of energy or resources, for example: quick open and close of refrigerator door (Mon.) and banner control (Tues.); taking shopping bags (Thrs) and milk packages recycling (Fri.) etc. After that, these daily score data was standardized and principal component analysis was applied to extract several principal component factors indicating households' life styles. **Table 2** shows weighting coefficients for each item, by which, as it is known, standardized scores multiplied give principal component scores. Each principal component was interpreted by observing a pair of these weighting coefficients, so called structure vectors. Thus, five components were interpreted as follows: the 1st component indicates degree of environmental performance; the 2nd caring for use of automobiles;

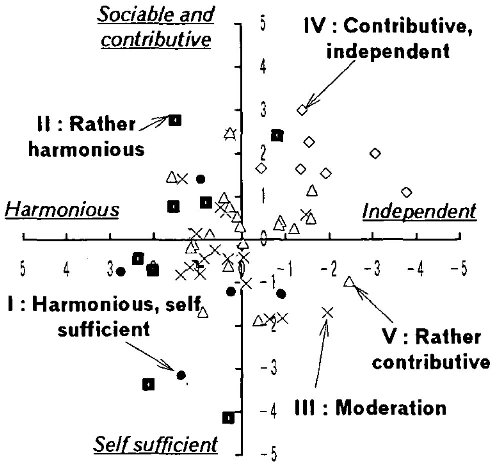

Fig.12 Allocation of the samples based on principal component scores

the 3rd preference for sociable environmentally sound action; the 4th harmonious character; and the 5th preference for ordinary continuous actions. Cumulative contribution rate for these five components was 0.46, therefore this indicates environmental performance might consist of other various factors as well as these 5 factors.

(2) Clusters corresponding to life styles and carbon dioxide emission patterns

Cluster analysis was applied for the consequent principal component scores and 5 clusters were observed. As the 3rd and 4th principal component nearly express attribute related to environmental life styles, samples corresponding to the above 5 clusters were allocated on the plain figure which consists of these two axes as shown in **Fig.12**. Here five clusters were interpreted in terms of the life styles explained by the two components. Then, the carbon dioxide emission inventories were calculated by using monitoring data of direct energy use and driving distances. Also embodied carbon dioxide emission corresponding to the scores of Likert type scales were estimated by I-O analysis and bottom up approach. This also means quantitative learning effects through reporting to environmental bookkeeping.

Fig.13 shows the emission patterns with some attributes for each cluster. the following facts were observed: a)Although emission patterns by using the environmental bookkeeping are limited, it was found that it captured nearly one third of the average carbon dioxide emission per household, which estimated in the previous paper[1]; b)Samples were divided into 5 clusters which consists of mixed several households age groups although average ages tend to show clusters' characteristics in a few cluster;c)While I and II clusters with the large amount of emission caused by driving cars is related to life stage or age group, data also shows emission patterns differ between IV and V in spite of the same age group. Several attributes such as types of dwellings and car ownership also explain the relationship between difference of life styles and emission patterns; d)As shown in emission patterns of cluster III from 1st week to 4th week, steadily reduced emission patterns indicate environmental learning effect through reporting to the environmental bookkeeping.

6. CONCLUSIONS

Carbon dioxide emission patterns due to consumers' expenditure were examined in terms of their life stages and life styles. I-O analysis, waste function and multivariate analysis was applied for statistic data and field data respectively. As a result, the followings were clarified:

(1)Rapid increase of the carbon dioxide emission by both younger and elderly single households was observed in recent years as well as that by elderly family households.

(2)Both increasing number of household and comparatively higher emission intensities give contribution year by year.

(3)Expenditure mainly caused increase of the emission in the case of middle aged family households and single households while family size caused in the case of younger family households.

(4)Future trend indicates that CO_2 emission will increase by nearly 13 % in 2000 and 6 % in 2010 from 1990 due to increasing expenditure and number of households older than 50s for family households, and younger than 30s and older than 60s for single households in spite of assuming reduction of the emission coefficients.

(5)Increasing emission due to electric appliances was found to be caused by both higher emission intensity and increasing number of household related in 1990 comparing to 1980. Plural possessing of air conditioner gives great contribution to the energy consumption.

(6)At least 2 principal components were extracted from environmental bookkeeping data and consequently some of 5 clusters showed emission patterns related to the life styles beyond life stages.

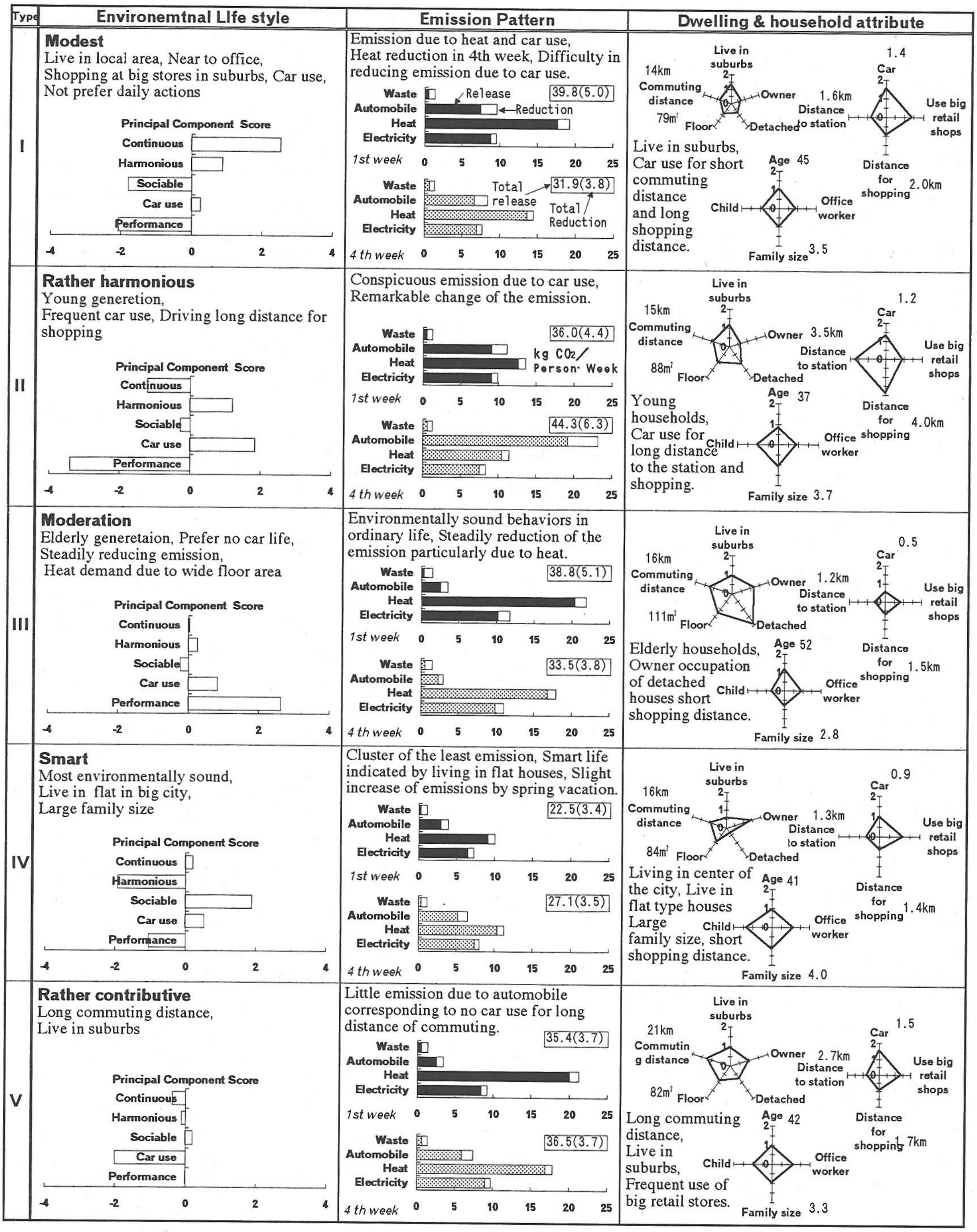

Fig.13 CO_2 emission patterns for 5 clusters with various household attributes

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ライフステージとライフスタイルからみた家計消費に伴う二酸化炭素排出構造の分析

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1960,70,80,90 年産業連関表，家計消費報告，全国消費実態調査および環境家計簿データを用いてライフスタイルとライフスタイルが規定する家計起因二酸化炭素排出構造の分析を行った．まず，直接間接の二酸化炭素排出量を２人以上の普通世帯と単身世帯別，世帯主年齢による５階層別に集計し，耐久財保有を含む各世帯属性別の寄与と年齢階級別のコーホートの経年的な排出構造の分析を行い，高齢普通世帯と若齢，高齢世帯の寄与とそれによる将来的な環境インパクトを計量した．更に 60 サンプルの環境家計簿の実行度データをもとに多変量解析を用いてライフスタイルに関連する主成分を抽出し，それによる５つのクラスター毎にライフスタイルによる排出構造の変化と環境家計簿による効果を定量的に評価した．

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