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Analysis of the Energy Efficiency and the Amount of Carbon Dioxide Emission based on the Person Trip Survey Data in case of Commuting and Schooling Trips

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Synopsis

COP3 (The Kyoto Protocol to the United Nations Framework Convention on Climate Change) was held in 1997, in Kyoto, Japan. The Japanese government pledged that Japan would reduce 6% of the quantity of greenhouse effect gas discharge in 2008-2012 compared with that in 1990. Then, the central government has begun to make many action plans toward prevention of global warming.

In this paper, the authors put point of view on the transport, which is increasing energy consumption rapidly. And we did an analysis about the amount of energy consumption and carbon dioxide emission by commuting and schooling trips based on the person trip survey data for various sizes of metropolitan or urban areas in Japan. As a result, the amount of carbon dioxide emission has not been dependent on the size of metropolitan or urban area.

KEY WORDS: global environment, carbon dioxide, energy efficiency, person trip survey, commuting

1. Introduction

Nowadays, it tends to be increasing the amount of energy consumption to pursue the improvement and convenience in life style, especially, in the field of transportation. Reasons of above cause to increase the vehicle traffic, traffic congestion in trunk road of the area designated for urbanization and to tend to be larger in the amount of private cars to point leisure. As these results, transportation systems consume larger quantity of energy and discharge carbon dioxide.

Under the condition, the Japanese government made a pledge in COP3 in Kyoto, in December 1997 to reduce the carbon dioxide emission, which target of discharge is 94% in 2008-2012 compared with that in 1990. To achieve this target, the Japanese people must restrain 15% of the present amount of carbon dioxide emission.

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In this paper, the present condition of carbon dioxide emission was grasped, particularly in the field of commuting and schooling transports. And an analysis was carried out based on the urban area size to discover the relation of carbon dioxide emission and the situation of making use of main travel mode and its trip length in commuting.

2. Outlines of the Urban Area and Person Trips

In this study, the data of person trip survey showing a state of the present traffic volume and condition for each urban area were used, to estimate the amount of carbon dioxide emission from the averaged energy consumption and efficiency of each traffic mode. The essential features of the urban areas analyzed in this study are shown in Table-1.

Table-1: Summary of the urban areas analyzed in this study

Urban Area Name	Central City	Data of Analysis Area				
		Night-time Population (1000 person)	Area (km^2)	Commuting Trips (1000 trips)	Average Trip Length of Commuting (km)	Private Car Use Rate in Commuting
Kagoshima Urban Area	Kagoshima city	622	449.6	192	7.13	58.4%
Kanazawa Urban Area	Kanazawa city	637	707.7	258	6.45	72.1%
Fukui Urban Area	Fukui city Takefu city Sabae city	674	3,090.3	253	4.90	73.3%
Higashi-Mikawa Urban Area	Toyohashi city	711	783.3	265	7.75	70.6%
Kagawa-chuo Urban Area	Takamatsu city	841	1,351.5	335	6.31	61.9%
Shizuoka-chubu Urban Area	Shizuoka city Shimizu city	992	1,893.6	362	5.70	51.9%
Okayama-minami Urban Area	Okayama city	1,346	1,758.0	509	7.14	67.8%
Sendai Urban Area	Sendai city	1,493	2,181.2	521	8.94	55.3%
Hiroshima Urban Area	Hiroshima city	1,680	2,187.8	563	7.57	43.6%
Do-o Urban Area	Sapporo city	2,323	3,350.5	822	9.22	52.8%
Chukyo Urban Area	Nagoya city Gifu city	8,297	5,201.0	3,042	7.96	60.1%
Keihanshin Metropolitan Area	Osaka city Kyoto city Kobe city	17,970	9,217.7	6,426	12.44	32.5%
Tokyo Metropolitan Area	Tokyo Special Ward	34,236	15,426.0	11,390	15.67	30.9%

The averaged value of travel speed, energy-consumption unit and carbon dioxide emission unit of each main travel mode are shown in Table-2.

Table-2: National average of Energy-consumption unit and carbon dioxide emission unit

Main Travel Mode	Average Speed of Travel (km/h)	Energy Consumption Unit (kcal/person·km)	Carbon Dioxide Emission Unit ($g\text{-}CO_2$/person·km)
Walking	4	0	0
Railway	30	109 (47)	20.59
Bus	13	155	44.62
Private Car	20	579	161.95

Note1: The value is the national average that the total amount of energy consumption is divided by the total length of transport volume in Japan, 1990.

Note2: ( ) means the final efficiency of electric power.

3. The Present Situation of Carbon Dioxide Emission

The classification of source of carbon dioxide emission in Japan is shown in Table-3.

Table-3: The classification of emission source and the amount of carbon dioxide in 1990 Japan

Classification			Quantity ($Gg\text{-}CO_2$)
Energy			1,075,000
	Burning fuel		1,075,000
		Electric generation	82,000
		Industry	489,000
		Public-welfare (Office)	123,000
		Public-welfare (Home)	139,000
		Transport	215,000
		Others	9,000
		Burning non-fossil fuel	18,000
	Leaking		NE
Industrial Process			53,000
	Chemical industry		NE
	Nonmetal mineral industry		43,200
	Others		9,800
Others			45,000
Total discharge			**1,173,000**
Total Absorption (Management of forests)			90,000

NE=Not estimated

The transition of carbon dioxide emission generated by burning fossil fuel is shown in Figure-1. In this figure, the index of the total carbon dioxide emission in 1995 is 108, and is 116, particularly growing in the fields of public-welfare and transport, which is contrasted with the standard year 1990.

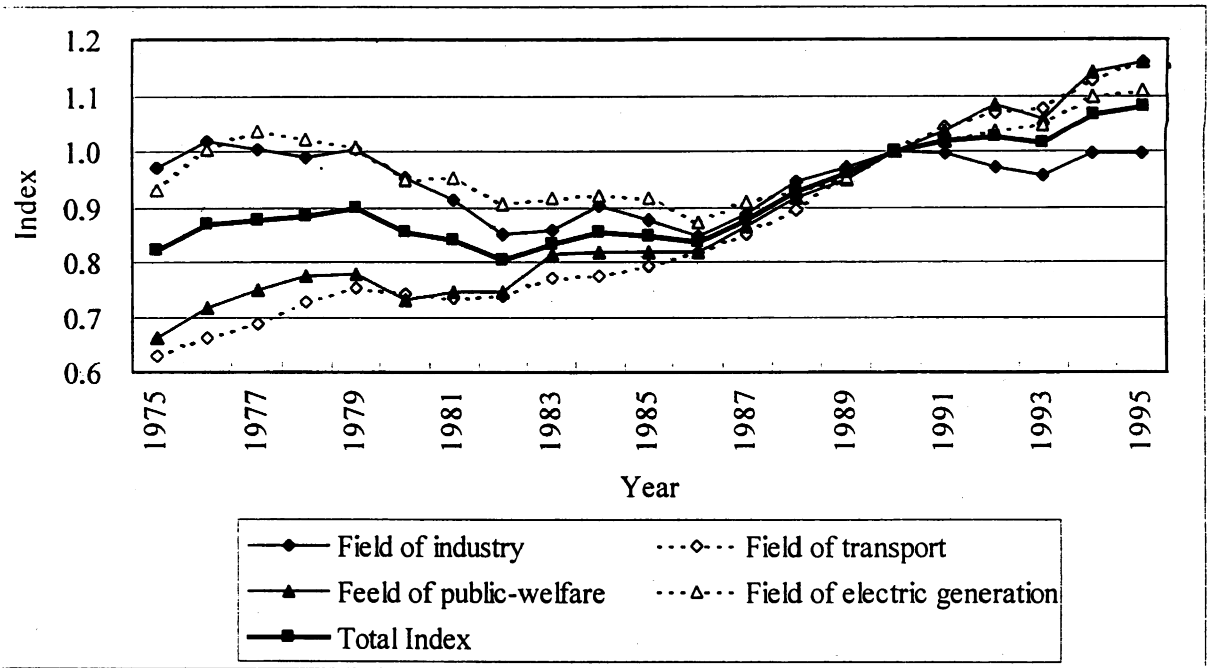

Figure-1: The transition of carbon dioxide emission by major fields

4. Analysis of Energy Consumed by Commuting

A relation of the average trip length and the energy consumption by commuting is shown in Figure-2. From this figure, it can be found that the energy consumption is roughly proportional to trip length.

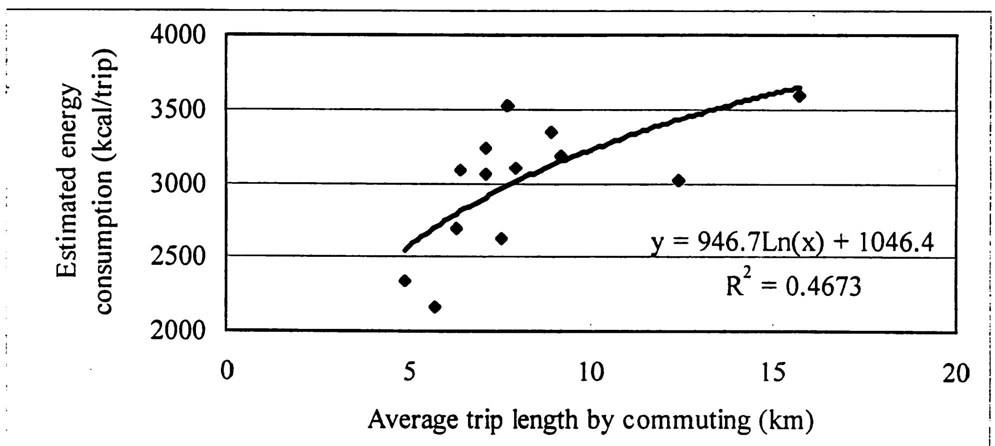

Figure-2: A relation of the average trip length and the energy consumption by commuting

The urban area size is also proportional to the modal choice rate for public transport, which is more efficient in energy use than private car modes (Figure-3). So, the relation between the expansion of urban area size and the increasing of energy consumption of transport by commuting is not proportional definitely, depending on the high level of the modal choice rate for private car in the relatively small urban areas, as shown in Figure-4.

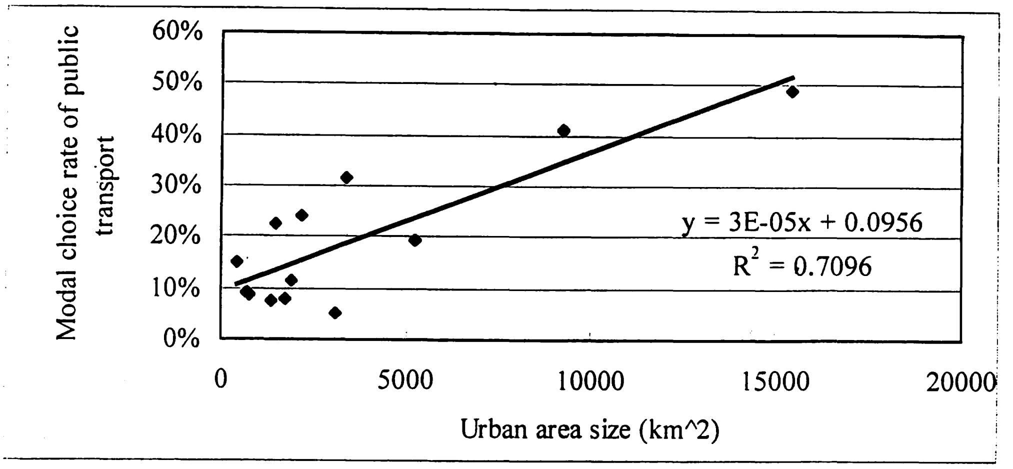

Figure-3: A relationship between the urban area size and the modal choice rate for public transport

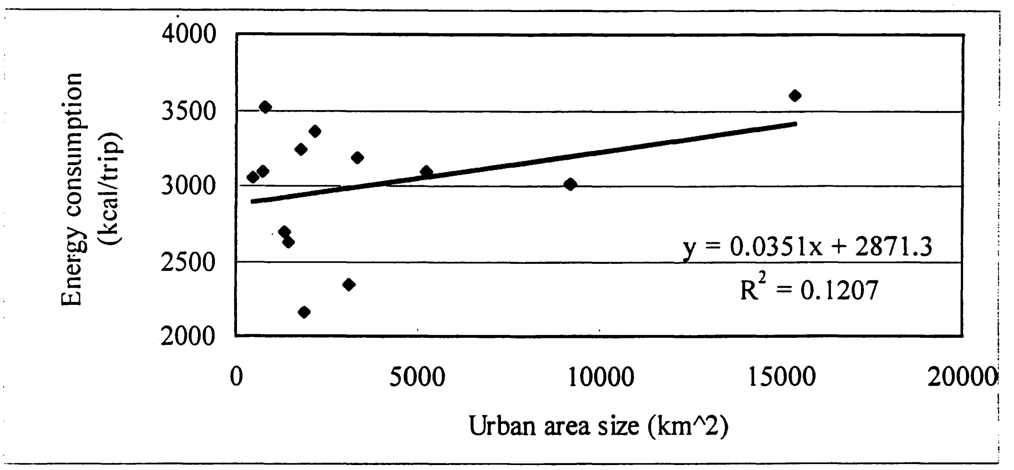

Figure-4: A relationship between the urban area size and the energy consumption of transport by commuting

5. Analysis of Carbon Dioxide Emission by Commuting

The present amount of carbon dioxide emission, which is estimated by making use of the result of analysis in section-3, is shown in Figure-5. The carbon dioxide emission and energy consumption of five urban areas, which are under 5000km^2 of urban area size and located under the regression line in Figure-5, is relatively small because the trip length by commuting in these areas is shorter than in others.

Following this, the amount of carbon dioxide emission by commuting in the analyzed urban area was estimated. Table-4 shows the volume of carbon dioxide emission compared with the three biggest metropolitan areas (i.e. Tokyo, Keihanshin and Chukyo urban area) with others.

From this table, the 13 urban areas produce 25.7 million trips, and discharge 22 thousand tons of carbon dioxide per day by commuting. The amount of carbon dioxide emission per 1 trip by commuting in the three biggest metropolitan areas is 3% more than in others. Compared with the amount of carbon dioxide per 1 trip·km, other urban regions discharge 1.7 times more than the amount of carbon dioxide in the three biggest metropolitan areas.

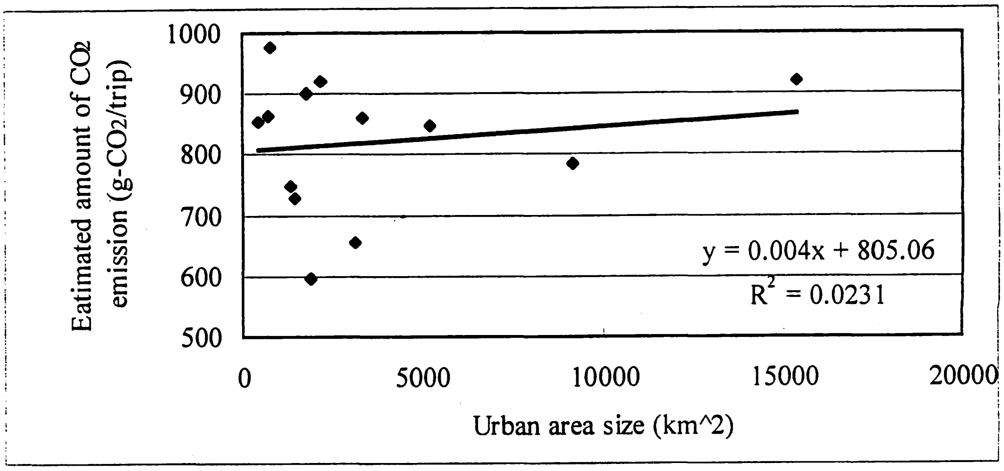

Figure-5: A relationship of the urban area size and the estimated amount of carbon dioxide emission

Table-4: Estimated amount of carbon dioxide emission by commuting

Urabn area name	Trip generated (1000 trips)	Amount of CO_2 emission	Average discharge of CO_2 per trip	Discharge unit per trip·km
		ton-CO_2	g-CO_2/trip	g-CO_2/trip·km
Total of three biggest metropolitan areas*	20,858	17,931	859.7	63.4 (93)
Total of other urban areas	4,080	3,327	815.4	108.6 (160)
Total	24,938	21,258	852.4	67.9 (100)

note * including Tokyo, Keihanshin and Chukyo metropolitan areas

6. Summary and Issue

The result will be summarized as follows:

(1) It was observed that the modal choice rate of public transport as main traffic mode is roughly proportional to the urban area size.

(2) Regardless of the urban area size, the amount of energy consumption for commuting holds almost similar level because of travelling long distance with high rate of more efficient public transport in larger urban areas and travelling short distance with high rate of more inefficient private cars in smaller urban area.

(3) The amount of carbon dioxide emission also shows almost the same relation as in (2).

The remaining issues we must consider are as follows:

(1) The units for the efficiency of energy consumption and carbon dioxide emission were used in this paper which were developed as the mean values in 1990, Japan. Improvement of the unit is necessary.

(2) It is necessary to improve for the various assumptions and simple estimation methods introduced in this paper.

It is necessary to develop a model structure, which is more appropriate to deal with the problem, and keep up with present traffic characteristics of each urban area.

Acknowledgement

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References

1) The Environment Agency, 1992, *Earth Warming Preventive Measures Handbook part 4: Transport* (English equivalent, written in Japanese)

2) The Ministry of International Trade and Industry, 1997, *The Synthetic Energy Statistical Table 1997* (English equivalent, written in Japanese)

3) The Environment Agency, 1994, *Warming the Earth, Measures of Japan* (English equivalent, written in Japanese)

4) *Person Trip Survey Reports*