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The effect evaluation of the energy consumed by regions in Japan for environmentally sustainable transport based on the DEA method

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1.0 INTRODUCTION

Sustainable development is a permanent topic around the world in these years. Its basic sprit is to meet human being's needs as well as preserving the resources and environment of the world, so that the needs of human can be met not only at the time being, but also in the future for the next generations. Sustainable is the systematically combination of environment, economic and social. Based on this spirit, we have to make more consideration on the city planning and construction.

Japan confronted a boom of economic development after the World War II, and is becoming one of the most advanced countries all over the world. At the same time, the consumption of energy in Japan is growing up steadily, which most of the energy consumed is non-renewable resources such as coals and oil. It is not considered sustainable for the ratio to consume so much non-renewable resources especially after the experience of the oil crisis. And now, the accident of the Fukushima Daiichi Nuclear Plant makes the public uneasy for the safety of nuclear power particularly for the places where suffers from natural disasters easily. Other means of clean energy is restricted by the nature conditions crucially and the cost remains high. Overall, there is a long way for the development of the renewable resources. Therefore, it is more important to control the amount of energy consumption.

In order to reducing energy consumption, the introduction of environmental sustainable transport just meets the needs. Transport planning plays an important role in designing the city plan. The strategy of transportation of sustainability is also indispensable for the construction of eco-cities. At the same time, transportation management is essential for the region planning and governance as well.

The share of energy consumption which the transport sector occupied is about 20% and is growing up gradually. In 2005, the ratio has reached 23.7%, near to a quarter of the total in Japan[1]. The energy consumption in the transport sector in Japan from the year 1965 to 2005 is shown in Figure.1. We can draw some impression from the figure that the energy consumption in transport sector is increasing successfully although Japan itself is not abundant on energy. Regarding to this, Japan has done much effort on the improvement on contributing sustainable society. Now, Japan has already built up the system of constructing Environmentally Sustainable Transport in some model cities and prefectures. Various kinds of policies are proposed to make the transportation smoothly in order to consume less energy and emit less greenhouse gases. This paper mainly focuses on the effect evaluation of the transportation energy consumed by the regions in Japan and utilizes the case of the model of Environmentally Sustainable Transport places to do analysis on the evaluation.

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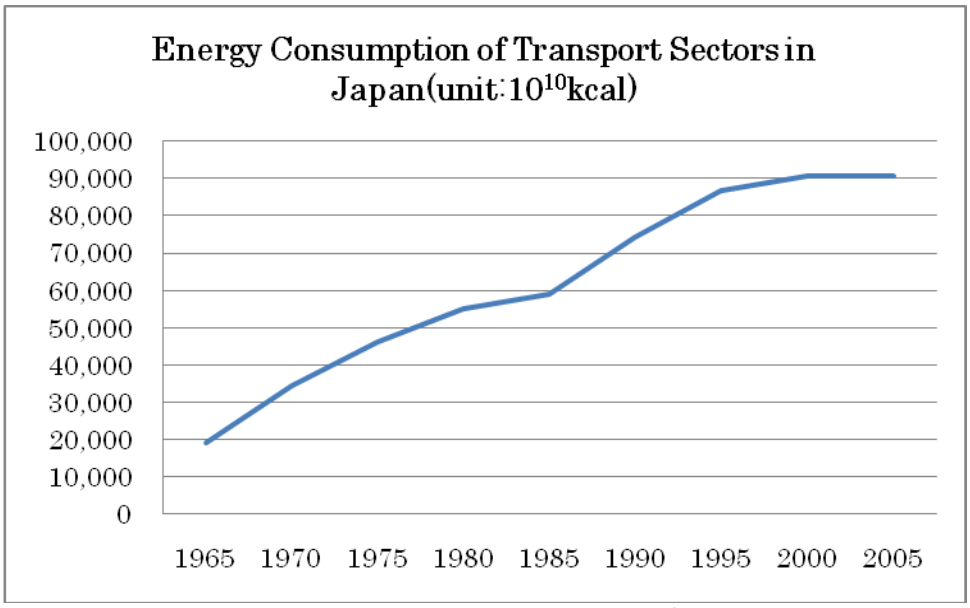

Figure 1: The energy consumption in the transport sector in Japan from the year 1965 to 2005

2.0 METHODOLOGY

2.1 Introduction to DEA

Data Envelopment Analysis (DEA for short) is considered to be a useful operational research tool and becoming more and more popular on the field of evaluation analysis. It is a linear programming methodology to measure the efficiency of multiple decision-making units when the production process presents a structure of multiple inputs and outputs. It is proposed by Charnes, Cooper & Rhodes at first and developed into some other models with the years went by and is basically used to empirically measure productive efficiency of decision making units [2]. Now it is spread and used widely in many fields for efficiency evaluation. For this reason, it can be also adopted for the evaluation of the effeciency by environmentally sustainable transportation policies.

DEA method focuses on the evaluation given some input variables and output variables. There is no need to set weight on each variables but only consider the mathematical relationships of the variables. It can be used for both production and cost data. Utilizing the selected variables such as unit cost and output, DEA method searches for the points with the lowest unit cost for any given output, connecting those points to form the efficiency frontier. It is also useful because it takes into consideration returns to scale in calculating efficiency, allowing for the concept of increasing or decreasing efficiency based on size and output levels. A drawback of this technique is that model specification and inclusion/exclusion of variables can affect the results.

Compared with other evaluation methods, some of the main advantages of DEA are as follows:

- No need to explicitly specify a mathematical form for the production function;
- Proven to be useful in uncovering relationships that remain hidden for other methodologies;
- Capable of handling multiple inputs and outputs;
- Capable of being used with any input-output measurement;
- The sources of inefficiency can be analyzed and quantified for every evaluated unit.[3]

We draw an intuitive graph for a better understanding of the basic concept of DEA method as is shown in Figure.2

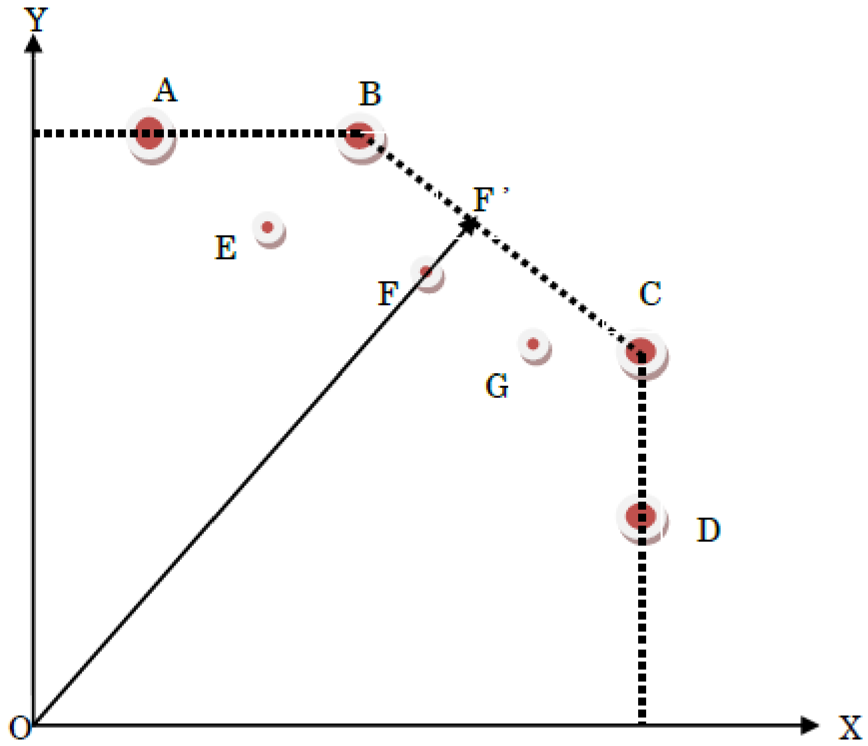

Figure 2: The explanation graph for DEA method

For the convenience of explanation, we assume that there are only two output variables X and Y, the amount of X and Y are both the more the better. The spot A~G are the Decision Making Units to be evaluated and their positions are located by their amount of X and Y index of output. Apparently, the DMU of B is better than E surely as the output of both X and Y of B is better than E, but for the other pairs in the DMU, it is hard to tell which one is better because we don't know the relatively relationship of the importance between the output variables X and Y. By the basic theory of DEA, it is considered that a DMU which has any largest output is an effective DMU (A, B, C, D in the figure above), and the lines connecting them is called the efficient frontier (dotted line in the figure above), DMUs on the efficient line are considered to be the efficient DMU and its efficiency is 1, draw a line from O to the inefficient spot of DMU (e.g. F in the figure) and intersect to the efficient frontier in a spot(F' in the figure), this spot is the imagined destination for the inefficient DMU, the ratio by the two spots from O is considered the efficiency of the DMU (OF/OF'). Obviously, the closer a DMU to the efficient frontier, the higher its efficiency is. B and C are the referring efficient DMU for the inefficient DMU F to follow. By the way, if a DMU is on the efficient frontier but is left to A or under D, the efficiency is 1 but it would also be considered as an inefficient DMU for A or D is apparently better. If there are many outputs for the decision, the diagram should be drawn in an n-dimension space. Case that contains multiple input variables can be explained in the same way.

As this method is proposed by Charnes, Cooper & Rhodes, the initial model of this method is called the CCR model. After that, other improved models such as BCC model which takes production scale into consideration are developed. In this paper, there is no need to draw the frontier line of each decision making unit which is the function of the BCC model, so we choose the initial one for the analysis to solve for the efficiency of the energy consumption in the places for Environmentally Sustainable Transport.

2.2 The setting of variables

The output of the analysis should show the characteristic of sustainability in transport sector. The energy consumption is no doubt in the index and it is easy to calculate. Besides, the emission of greenhouse gas also affects the level of sustainability, but the precise estimation of the emission remains a problem. The speculation of the emission mainly based on the transportation survey, but the concrete amount by cities and prefectures cannot be inferred concisely. Furthermore, the amount of the energy consumption is accompanied with greenhouse emission. So we decide to use the energy consumption as the only output variable in the analysis. By the way, the BCC model expects the amount of the output the more the better, but in the case of this paper, less energy consumption is apparently expected. Regarding this, we can do the treatment to reverse the amount of the output oppositely by many means according to other papers for matching the methodology exactly, but we remain to keep the data still for the deal on reversing the data oppositely make it complicated for the relationships between the data. Note that the result for this study makes a different view of conclusion for the efficiency.

On the other hand, the input variables of the analysis should be the fundamental parameters which could represent the transportation characteristic in the regions. For ensuring the availability of the data, we review the yearbook of transportation statistics in Japan and decide to choose the intensity of population, the number of cars, the length of road, and the area of roads as input variables of this analysis. All the data is available by the investigation of road survey in Japan so we can do the analysis thoroughly.

3.0 DATA AND RESULT

Environmentally Sustainable Transport is a new policy vision which was proposed by the Organization for Economic Co-operation and Development and its commitment is to plan and implement policy on transport and environment based on a long-term perspective. By presenting the specific vision for future transportation, it is expected to increase awareness and choose transport activities and lifestyles with reduced environmental loads. The regions are selected by Japan's government as Environmentally Sustainable Transport model by three times from the year 2004, 2005 and 2006 across almost all the country. The model regions are not only cities, but also prefectures, and mainly focused in the Kansai region and Kanto region [4]. For the consistency of analysis, we start with all the prefectures in Japan and focused on the areas includes the regions which are selected as EST model regions and contains EST model cities most. Table 1 shows the input datas of the year 2010 in detail from Hokkaido to Okinawa.

First, we analysis the EST efficiency by geographic regions like Kansai, Kanto, Kyushu, Tohoku and so on to find the relatively efficiency of places in almost the same geographic situations. The DEA analysis software we used is the College Analysis Version 4.0 developed by Fukuyama Heisei University. We select the output data of the year 2010 as well and the results are as follows:

Analysis 1: Kansai Area

Prefecture in Kansai Area	Efficiency:
Shiga	0.731
Kyoto	1.000
Osaka	1.000
Hyogo	1.000
Nara	0.813
Wakayama	0.798

Analysis 2: Kanto Area

Prefecture in Kanto Area	Efficiency:
Ibaraki	0.943

Tochigi	1.000
Gunma	1.000
Saitama	1.000
Chiba	1.000
Tokyo	1.000
Kanagawa	0.944

Analysis 3: Kyushu Area

Prefecture in Kyushu Area	Efficiency:
Fukuoka	1.000
Saga	0.828
Nagasaki	0.970
Kumamoto	0.992
Oita	0.940
Miyazaki	0.897
Kagoshima	1.000

Analysis 4: Tohoku Area

Prefecture in Tohoku Area	Efficiency:
Aomori	0.999
Iwate	1.000
Miyagi	1.000
Akita	0.958
Yamagata	0.873
Fukushima	1.000

For the conclusion of this result of analysis, it is found that in all the areas, the efficiencies of sustainability environmental transportation are not obviously separated. Good balance is taken among the prefectures in the geographic regions. Among all the areas analyzed, the Kanto Area is the most balanced area, while in Kansai, the efficiency differs a little much from center area to outside area. In Kyushu, Fukuoka and Kagoshima are the energy-consuming high efficiency prefectures while Shiga and Miyazaki are the prefectures more environmental. While in Tohoku, Yamagata is considered to be the environmental prefecture.

After that, we analysis the EST efficiency of the prefectures which are selected as an EST model region: Ishikawa, Kanagawa, Kyoto, Hyogo, Nara, Mie.

Analysis 5: EST model areas

Prefecture as EST model area	Efficiency:
Ishikawa	0.771
Kanagawa	1.000
Kyoto	1.000

Hyogo	1.000
Nara	0.817
Mie	0.669

The efficiencies of the six prefectures selected as EST model regions differ seriously. Obviously that advanced place with more population and traffic consumes more energy and low efficiency compares with less developed place. It demonstrates that city planning for EST is more important than that in the countryside, and further research for making corresponding policies should be done more on the city planning in detail.

By the way, as it is very crucial for big cities to do proper city planning for EST, we also do analysis for the six main prefectures with high population density and the result is as follows.

Analysis 6: High population density areas

Prefecture as EST model area	Efficiency:
Tokyo	1.000
Kanagawa	0.952
Osaka	0.851
Hyogo	1.000
Aichi	1.000
Fukuoka	0.904

The result may be out of imagination that Osaka is the best prefecture for EST although the amount of population and traffic is very large. There are many EST model districts in Osaka which maybe the reason for the result. Tokyo regarded as a cosmopolitan should do more on the energy resuming and do effort on the sustainable of the country as to the world.

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