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AN EVALUATION STUDY ON THE SOCIAL EXPERIMENT OF MODAL SHIFT TO REDUCE CARBON DIOXIDE EMISSION

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Abstract: The Japanese Government has established a subsidy system in 2002 to assist enterprises that are planning modal shift from truck to rail or ship. Projects were chosen by auction procedure in order to maximize the impact of the subsidy. A questionnaire survey conducted by the government determines the reasons why enterprises initiated modal shift and their views or policies concerning the problem of CO_2 emission and green gas. Most of the enterprises had planned modal shift from truck to rail instead of ship transport because of the higher CO_2 emission rate per unit ton-km of railway as compared with ship. The annual budget for modal shift, however, is limited to 300 million yen which corresponds to only 1/12 of CO_2 reduction volume expected in the grand plan through modal split.

Key Words: modal shift, CO_2 emission, social experiment, freight transport

1. BACKGROUND AND STUDY'S OBJECTIVE

The Japanese Government in 1997 has promised to cut emissions of greenhouse gases by 6 % until 2012 to lower its level the same that of 1990. Transportation sector has a large share of CO_2 emission and in 2000, it occupied 20.7% (256 million ton) of which about 90 % come from automobiles as shown in Figure 1 and Figure 2. In particular, the share of trucks is around one fourth of emission volume of transport sector.

According to the government plan, the reduction target of CO_2 emission by 2010 in the field of physical distribution are composed of 4.4 million ton by modal shift and 4.7 million ton by improvement of efficiency of physical distribution. However, the share of truck in freight movement and consequently in CO_2 emission has been increasing these days which cast a doubt to the achievability of the reduction target.

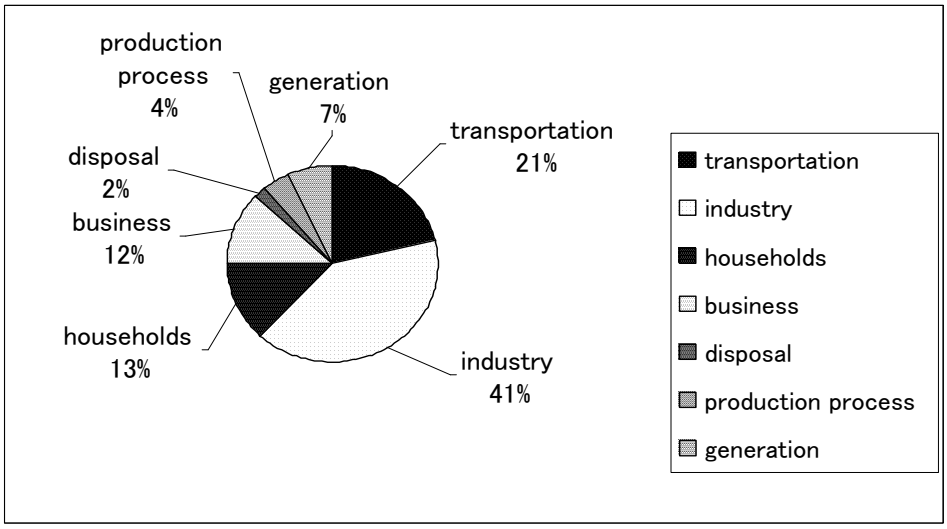

Figure 1. CO_2 Emission's Share of Transportation

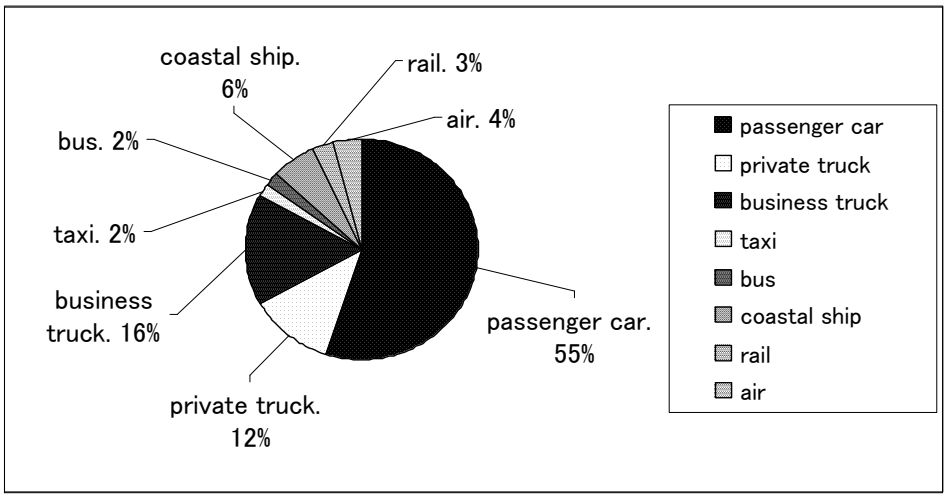

Figure 2. Share of CO_2 Emission by Transportation Mode

In 2002, the Ministry of Land, Infrastructure and Transport (hereinafter referred to as the Ministry) had established a subsidy system which assists enterprises who plan to introduce modal shift from truck to rail or ship. In this study, modal shift is defined as an enterprise's action of changing transportation mode of carrying freight from truck to less CO_2 emitting mode such as rail or ship as shown in Figure 3.

A review to the past studies reveals that there have been a number of papers which tried to evaluate or design a policy that could change the volume of CO_2 emission. Itoh and Imura (1994) produced a study that explores several factors that could change the volume of CO_2 emission caused by inter-regional freight transportation, while Nagaminami and Matsuzaki (2000) conducted a simulation study which observes the change of CO_2 emission depending on the location of harbors. Both studies, however, are not focused to modal shift. Similarly, Yamanaka *et al* (1999) made a system dynamic model which examined the changing pattern to the decreased level of CO_2 emission as a result of transport policy such as model shift. But, this study is general in nature regarding the share of each mode to CO_2 emission and comes

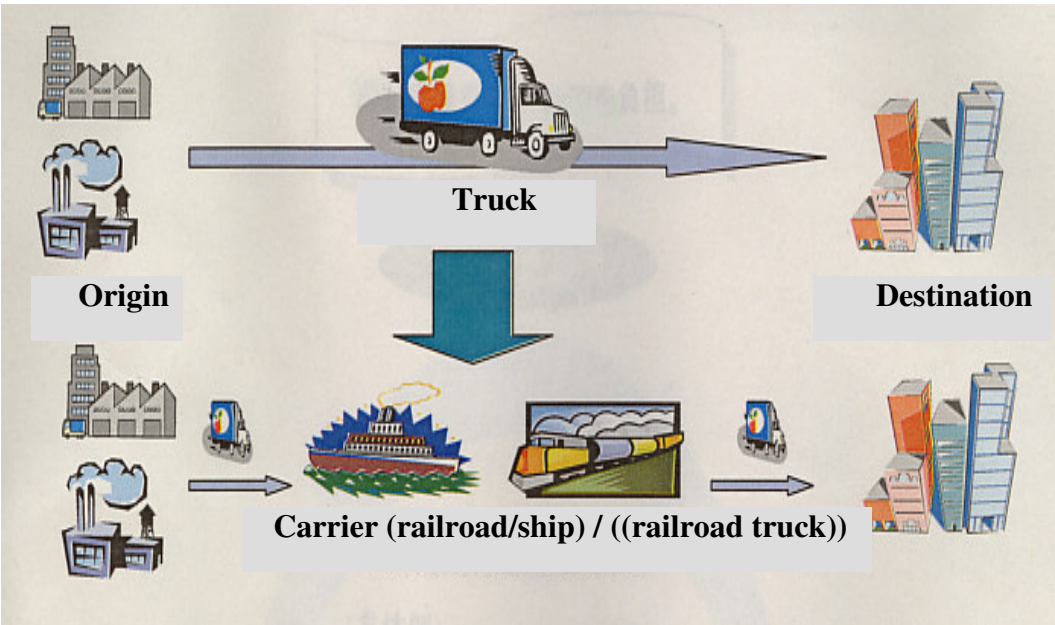

Figure 3. Concept of Modal Shift

short of producing an actual data as basis for analysis, therefore it is quite difficult to evaluate the relationship between modal shift policies and enterprises' strategies. On the other end, Tho *et al* (1993) dedicated their efforts in forecasting the reduction volume of CO_2 emission in Tokyo's 23 Wards by introducing cooperative freight depots that could reduce total pick-up and delivery distance. This study is particular only to intra-city physical distribution. Further, of all modes in freight transport, only truck was considered.

The above review confirmed the absent of a study which tried to forecast quantitatively the reduction volume of CO_2 emission by means of modal shift. The same is true to a study which utilizes real data of enterprises. With the above understanding, this study would fill the void in literature regarding the enterprise's real data and the knowledge to what has been achieved so far by the subsidy system. The objectives, therefore, are 1) to analyze the characteristics of modal shift projects subsidized by the government; 2) to clarify the enterprise's policies concerning with the modal shift; and 3) to evaluate the subsidy system by clarifying the reduction volume of CO_2 emission as a result from projects of enterprises.

With regard to the process of the study, modal shift projects authorized by the Ministry are first analyzed before estimating the reduction volume of CO_2 as an effect of the subsidized projects. The study would then focus to the policies of consignors and carriers regarding on modal shift and their own initiated measures against environmental problem by interpreting the questionnaire survey. It would end by evaluating the subsidy system and suggest reform measures to the Ministry to advance the project.

2. OUTLINE OF THE SUBSIDY SYSTEM

The subsidy system has been established to encourage enterprises to initiate modal shift projects of which transportation distances extend over more than two prefectures or exceed 100 km, that is;

a) Projects shifting mode from truck to ship or train;
b) Projects improving the efficiency of trucking through the introduction of lorries or the cooperative transportation system;
c) Projects introducing advanced technology like nonpolluting cars or ships; and
d) Joint projects proposed by more than one consignor or one carrier.

The Ministry selected projects of which the reduction volumes of CO_2 emission are more than 81.48 ton per year and per million yen by auction method, depending on their reduction rate of CO_2 per million yen, in order to maximize the impacts of subsidy within the limit of the annual budget of 300 million yen. This figure is equivalent to 34,900 yen per year and per one ton of CO_2 emission - estimated to be the amount of green gas tax in the future. Applying this standard of choosing a project is necessary in order to meet the national goal in 2010 as stated by the report of the Ministry of Environment.

In 2002, thirty (30) projects were submitted to the Ministry of which fourteen (14) were authorized but only eight (8) were subsidized as best projects of modal shift. In 2003, subsidized projects were increased to 36 out of 38 submitted projects.

3. REDUCTION VOLUME OF CO_2 AND EVALUATION OF THE SUBSIDY SYSTEM

3.1 Computational Procedure of the Reduction Volume of CO_2 Emission by Modal Shift

Enterprises were requested to estimate the reduction volume of CO_2 emission based on their modal shift plans. The volume of CO_2 emission per one ton by shipping differs depending on type of ship, horsepower, speed and loading cargo, while the volume of CO_2 emission per ton by truck depends on average speed, volume of cargo and weight of truck [Yashima, H. *et al* (1997), Minato, K. *et al* (2003)]. In addition, the volume of CO_2 emission by truck changes also depending on the frequency of stop and acceleration, and loading ratio (Noda, A. *et al*, 2003). However, simplified data were utilized in this study because of not only difficulty in collecting detailed data concerning with modal shift of enterprises, but also the characteristics of macroscopic study. The computation of CO_2 emission by mode per ton-km was based on the data in Table 1.

Table 1. Unit Volume of CO_2 Emission

Transportation Mode	Unit volume of CO_2 emission（g-co_2/t.km）
Railroad	21
Shipping	38
Business truck over 3 tons	174
Private truck over 3 tons	388

Source: Japan Federation of Freight Industries, 2000

The computational process of CO_2 reduction volume derived from shifting of mode from truck to rail is illustrated in Figure 4. In the said example, a 73.4 % reduction rate is achieved.

a) Volume of CO_2 emission before modal shift
$174 \times 7{,}000 \times 500 \times 10^{-6} = 609$ t
b) Volume of CO_2 emission after modal shift
$A \rightarrow A1 = 174 \times 7{,}000 \times 45 \times 10^{-6} = 54.81$ t, $A1 \rightarrow B1 = 21 \times 7{,}000 \times 480 \times 10^{-6} = 70.56$ t,
$B1 \rightarrow B = 174 \times 7{,}000 \times 30 \times 10^{-6} = 36.54$ t Therefore, in total $A \rightarrow B = 161.9$ t
c) Reduction volume of CO_2 emission
Volume of CO_2 emission by modal shift = 609 t - 161.9 t = 447.1 t
Reduction rate of CO_2 emission = 447.1 / 609 × 100 = 73.4 %

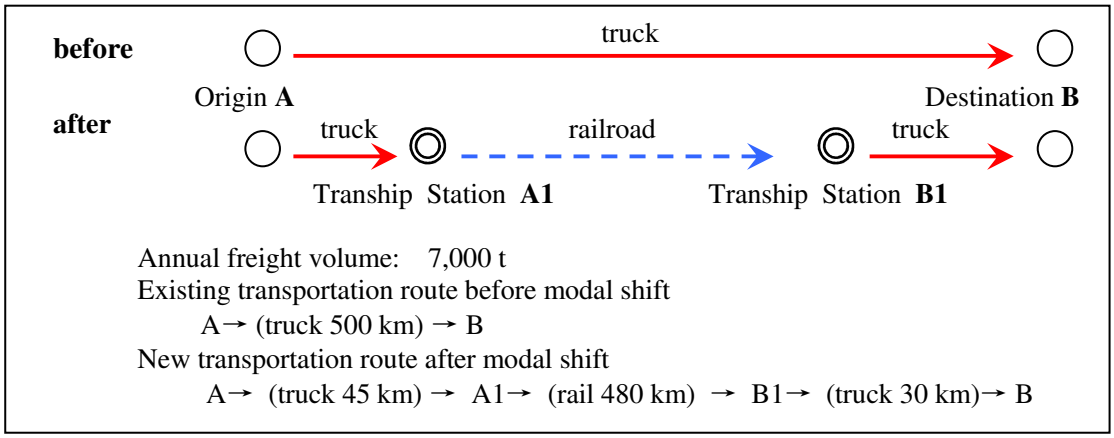

Figure 4. Example of Modal Shift

3.2 Computation of the Reduction Volume of CO_2 Emission

An example of modal shift from line-haul truck to ship is shown in Figure 5 and illustrated in Table 2. In this example, an enterprise that used to transport textile materials by line-haul truck between Tokuyama City and different cities in Kanto Area shifted the transportation mode to ship, which resulted in the reduction of CO_2 emission by 59.6%.

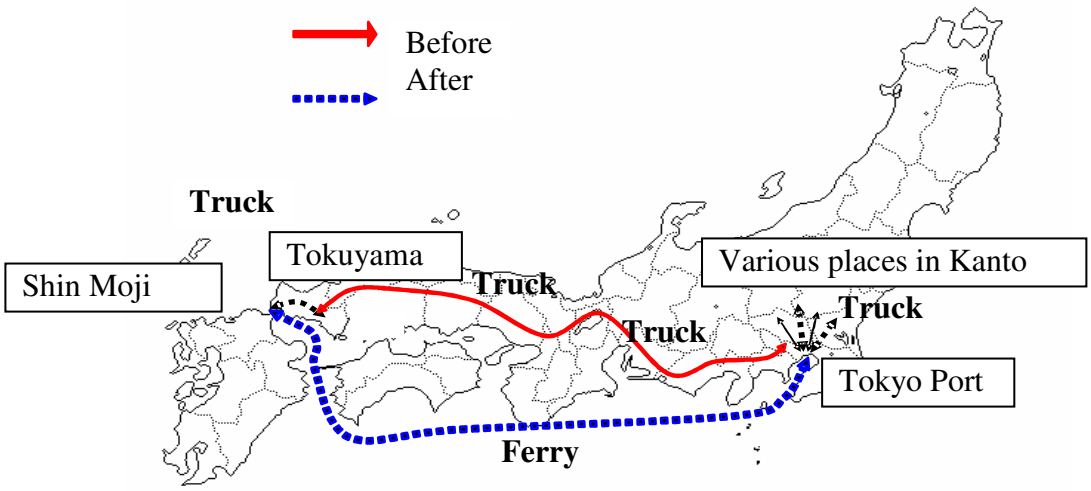

Figure 5. Example of Modal Shift in 2002

Table 2. Example of Projects in 2002

Project name		Kyusyu to Kanto modal shift project
Outline		Modal shift from long-haul 20t trucks to ferries
Applicant	Consignor	Dainippon Unyu, Inc.
	Carrier	Ocean Tokyu Ferry, Inc. & Nihon Koun, Inc.
Period of project		September 2002 to September 2006（4 years）
Transportation route	Before modal shift	Various places in Kanto → (truck) → Tokuyama City
	After modal shift	Various places in Kanto → (truck) → Tokyo Port → (ship) → Sin Moji port → (truck) → Tokuyama City
Freight	Item	Textile material
	Volume	21,600 ton
Reduction volume of CO_2 emission	Before modal shift	5,816.4 t - CO_2 / year
	After modal shift	2,348.2 t - CO_2 / year
	Reduction volume	3,468.2 t - CO_2 / year
	Rate of reduction	59.6 %
Amount of subsidy		25,250,000 yen (10,100,000 yen in 2002, 15,150,000 yen in 2003)
Effects of the project		137.4 t - CO_2 / million yen.year
Note		One way

Figure 6 and Table 3 is an example of a modal shift from the line-haul truck to railroad which reduced 71.5% CO_2 emission.

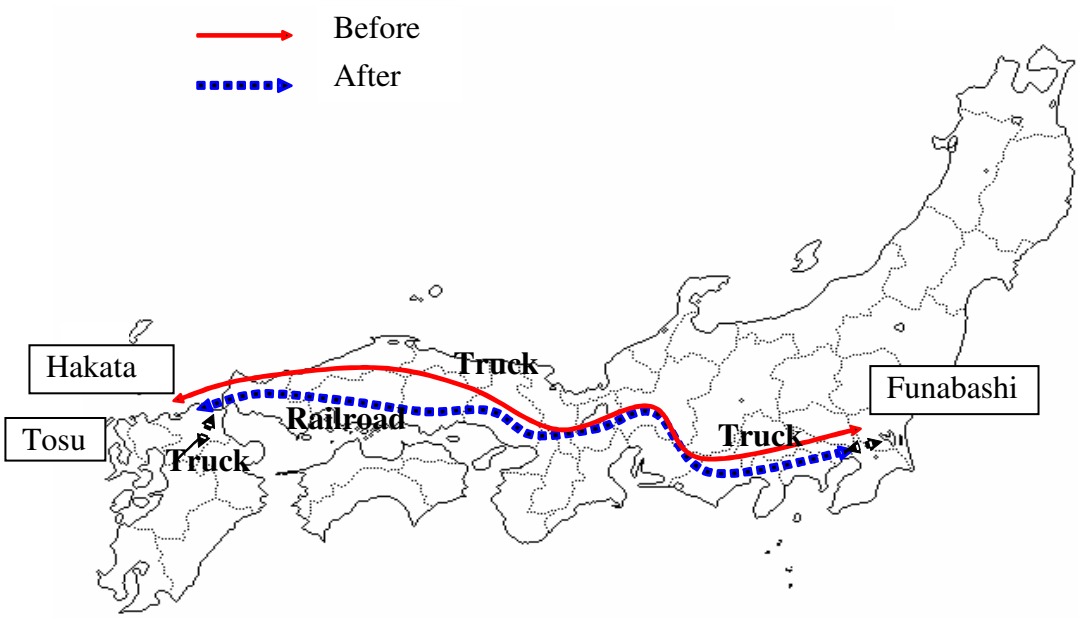

Figure 6. Example of Projects in 2003

Table 3. Example of Projects in 2003

Project name		Kanto to Kyusyu Rail Use Project
The outline		Modal shift from line-haul truck to railroad 31ft large-sized freezing container
Applicant	Consignor	Nichirei, Inc.
	Carrier	Nihon Tsuun Kanto Branch, Inc. Nihon Sekiyu Yusou, Inc. Logistics Planner, Inc.
Period of project		November in 2003 to November in 2004 (one year)
Transportation Route	Before modal shift	Funabashi → Hakata,Tosu
	After modal shift	Funabashi ←(truck)→Tokyo Terminal ←(railroad) →Fukuoka Terminal ←(truck)→ Hakata,Tosu
Freight	Item	Frozen food
	Volume	Round-trip: 3,000 t (One way: 1,500 t)
Reduction volume of CO_2 emission	Before modal shift	706.9 t - CO_2 / year
	After modal shift	211.5 t - CO_2 / year
	Reduction volume	505.40 t - CO_2 / year
	Rate of reduction	71.5 %
Amount of subsidy		900,000 yen (in 2003 900,000 yen)
Effect of the project		561.56 t - CO_2 / million yen.year
Note		Round-trip

4. ACTUAL SITUATION OF CONSIGNORS AND CARRIERS APPLYING FOR THE SUBSIDY SYSTEM

4.1 Outline of the Survey

The view of enterprises is important to consider in the modal shift project because their participation largely determines the success of such undertaking. In essence, the subsidy system should be attractive enough to encourage enterprises to introduce modal shift on commercial basis. With the idea of improving the subsidy system by considering their policies, the Ministry conducted a questionnaire survey on the enterprises which seeks to clarify the following:

a) Reasons why enterprises are applying for the subsidy system;
b) Enterprises' views and policies for CO_2 emission and green house gas problems;
c) Enterprises' demand for the subsidy system;
d) Reasons why enterprises are reluctant to introduce modal shift; and
e) Effects of the subsidy system.

Questionnaires were sent by mail to 116 enterprises which authorized by the Ministry eligible for subsidy. The period of the survey was from 24 October to 12 November in 2003, and 92 enterprises, 32 were consignors and 60 were carriers, returned the questionnaires by mail, which put the return rate to 79.3%.

4.2 Result of the Survey

The survey conducted to the enterprises reveals some unexpected results such as policies initiated by companies to advance their market image and as a preemptive measure to the implementation of strict regulation if the problem of green house gases continues to rise. Detailed discussions of the result of the survey are listed below:

a) As far as transportation modes are concerned, about 70% of the projects had shifted to railroads, over 20% of the projects to ships and only 5% to large-sized trucks, respectively. As for the share of items, foods is the biggest (26%), chemicals is the second (20%), iron and steel (11%) and machines (10%) follows.
b) More than 80% of enterprises have already initiated measures with the reduction of CO_2 emission by themselves before the Subsidy System started.

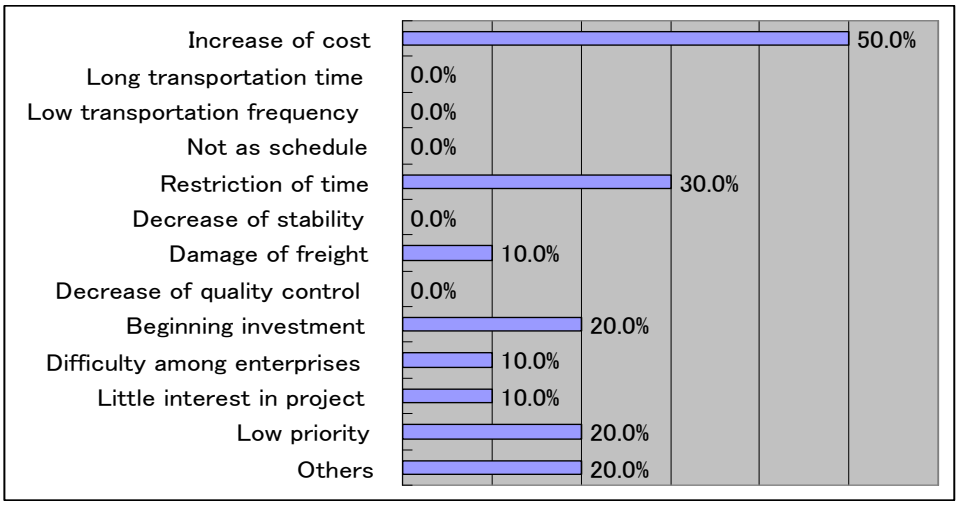

Figure 7. Reasons for not Initiating Measures to Reduce CO_2 Emission

c) Some of the reasons why enterprises did not initiate measures against CO_2 emissions by their own initiative were "increase of cost", "restriction of time" (Figure 7).
d) Figure 8 shows that there are many objectives stated by the enterprises who initiated measures to reduce CO_2 emission by their own such as "decrease of CO_2 emission" and "decrease of harmful gases".
e) Regarding with the measures initiated by the enterprises on their own to reduce CO_2 emissions, "modal shift to railroads" is first, "improvement of mileage of truck" is second, and "modal shift to ships" is third as reflected in Figure 9.
f) Figure 10 shows that 85% of enterprises have decreased harmful gases as a result of the subsidy system. Other positive results of the subsidy are the reduction of cost (68.3%) followed by the diversification of mode in freight transport. When they were asked to the other effect of the subsidy, most of them have a favorable opinion to the reduction of physical distribution cost (68.3%) and decrease of harmful gases (65%) as reflected in Figure 11. Furthered inquired on how they could save physical distribution cost, "the improvement of loading factor" cited the most followed by "investment in equipment" and "change of transportation route".

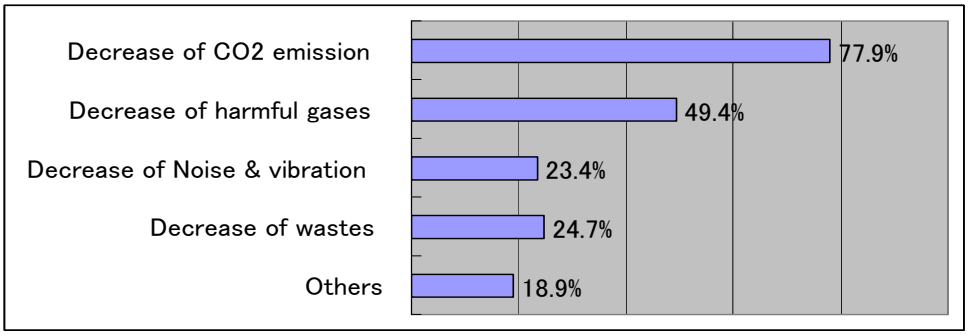

Figure 8. Enterprises' Objectives for Initiating Measures to Reduce CO_2 Emission

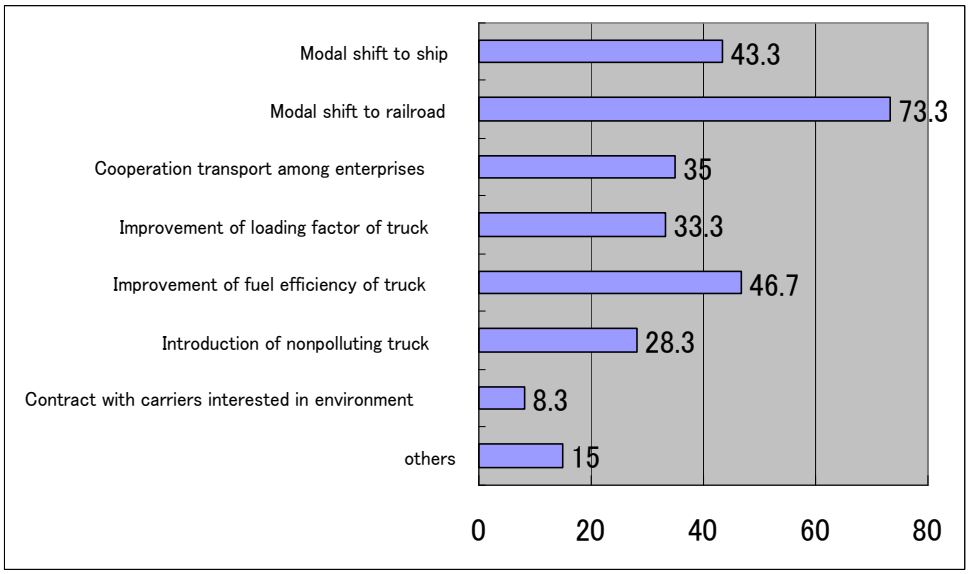

Figure 9. Enterprises Policies concerning to the Reduction of CO_2 Emission

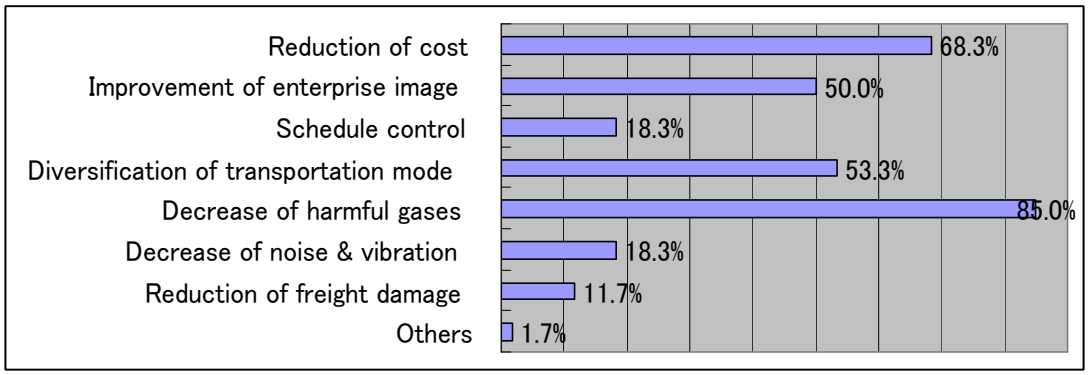

Figure10. Effects of the Reduction of CO_2 Emission

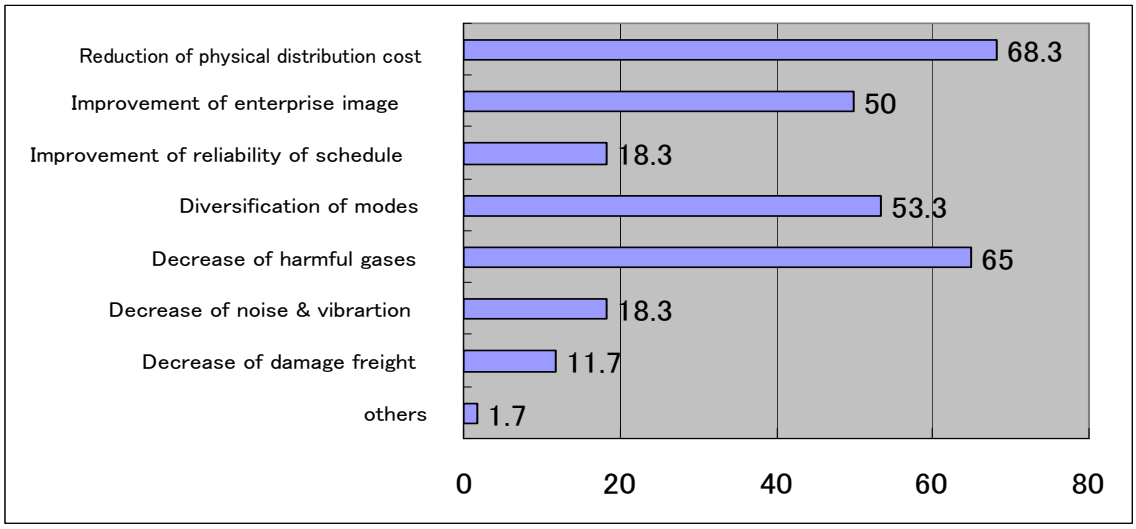

Figure 11. Effects other than the Reduction of CO_2 Emission

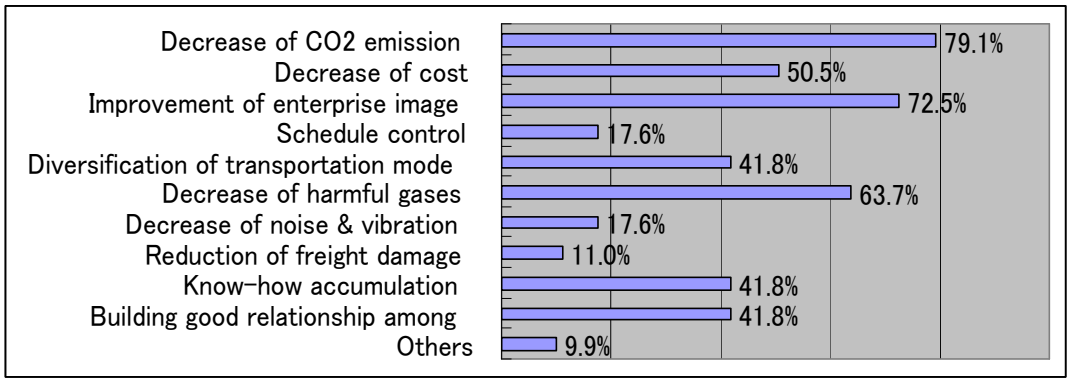

Figure 12. Effects of the Subsidy System

g) The subsidy system has the strongest effect on decreasing CO_2 emission (79%), followed by improving the image of enterprises (72.5%) as shown in Figure 12. This revelation is notable in a sense that enterprises are now recognizing the market advantage of companies that have positive image toward the environment.

h) Of the 38 enterprises, over 40% have already initiated measures against environmental problems as advanced measures to halt the introduction of "green effect gas tax" or at

least delay its implementation. In addition, 12 to 13 of enterprises are also considering initiating the same countermeasures. It was apparent that enterprises were apprehensive to the possibility of introducing strict regulation in the future and they recognized modal shift as a countermeasure to such regulation.

5. EVALUATION OF THE SUBSIDY SYSTEM AND PROBLEMS OF MODAL SHIFT

5.1 Analysis on the Goal of the Subsidy System

It is necessary to estimate the reduction volume of CO_2 emission for evaluation of the subsidy system. It is difficult, however, to collect detailed data concerning with the volume of CO_2 emission and transportation cost by enterprises themselves. This shortcoming from the nature of data made it difficult to produce a simplified and macroscopic computation. In spite of these limitations, the volume of CO_2 emission that can be reduced through the subsidy system using the data reported by the enterprises is possible to estimate.

Regarding the 19 projects which have introduced modal shift for at least one month, four enterprises had achieved more than 100% of CO_2 reduction, four were between 80% to 100%, 6 were between 60% to 80% and 5 were less than 50% of their goal. Concerning with the six projects in 2002, they had achieved 88.3% of their goal while 13 projects in 2003 had achieved only 75.4%. Some of the cited reasons of these rather poor results are “failure of building good relationship among carriers and consignors”, “little freight in the period of experiment for modal shift”, “inefficient transportation as compared with the plan”.

It was evident that the reduction of CO_2 emission by modal shift was not easy for enterprises for the reasons mentioned above. However, it is interesting to note that 10 enterprises of 19 answered that they had also saved transportation cost by carrying out modal shift which implies that modal shift would not necessarily give enterprises only negative effects.

5.2 Effect of the modal shift to CO_2 Volume

The average volumes of CO_2 emissions were 140.1 ton in 2002 and 152.7 ton in 2003, and the average achievement rates of enterprises in 2002 were 88.3% and 75.4% in 2003. On the other hand, the average volumes of CO_2 emission per one million yen of the subsidy scheme are 123.7 ton in 2002 and 115.1 ton in 2003, respectively. Assuming that the average reduction volume of CO_2 emission per one million yen of the subsidy is 120 ton, which is equivalent to 36,000 ton for a year for 300 million annual budgets. Then, the achievable reduction volume would be 360,000 ton for 10 years. This number is only one twelfth of the volume of the goal which is 4.4 million ton.

Although the achievement ratio of the subsidy might change from year to year, it is believed that it is necessary to increase the budget to 3.7 billion yen in order to achieve the goal set up by the government. Interestingly, this increased will level it to the budget of “Marco Polo Plan” in EU – a program intends to help transport and logistics industry to achieve sustained modal shifts of road freight to short sea shipping, rail and inland waterway.

5.3 Problems of the Subsidy System

The preceding analysis reveals the inadequacy of the subsidy system in meeting its goal if modifications are not made. The problems identified with the system are listed below.

a) The auction method has achieved the reduction of CO_2 emission effectively and had a tendency to choose rather small-scale projects.
b) There were many modal shift projects from truck to railroad because of its smaller CO_2 emission volume per one ton or ton-km as compared with other modes. However, the capacity of the railroad network for freights in Japan is extremely limited because most of it has been utilized by passengers and there are only very little opportunity for time windows for freights. In addition to this, railway companies are reluctant to invest to improve railroad networks because of financial difficulty. It is not, therefore, realistic to expect much can be achieved from the modal shift of truck to rail in the future.
c) Although there are not many modal shift projects from truck to ship because of its larger CO_2 emission as compared with railroad, ship must be the most important mode for modal shift in the future. It is extremely important to design ship-mode form of transport that is both efficient and profitable for the purpose of achieving the goal of reducing CO_2 through modal shift.
d) On the contrary, there was less number of projects which shifted from truck to ship. This trend is not desirable and it became obvious that modal shift in large-scale could not be achieved because of the limited capacity of railroad.
e) Projects which shitted from ship to rail were observed to be increasing. These projects did not meet the primary objective of the subsidy system which aims to reduce the CO_2 emission caused by truck.
f) The subsidy system does not cover short distance transportation like pick-up and delivery service from the beginning in spite of large quantity of freights in urban areas.

6. CONCLUSION

The subsidy system is one of the strategies of the government to meet its obligation to reduce greenhouse gases under the Kyoto Protocol. The central goal is to transfer the billion tones/kilometers of freight annually off truck to ship or railroad. A shift of mode from railroad to ship or vice versa is contrary to this goal although found to be true to some projects. Based on the analyses performed, the following conclusions were drawn:

a) The effect and problems of modal shift to reduce CO_2 emission by the subsidy system have been analyzed positively by the study.
b) Policies and opinions of enterprises have been clarified through questionnaire survey.
c) In order to achieve the national goal of decreasing CO_2 emission through modal shift, the budget of the subsidy system should be raised drastically.
d) The promotion of modal shift from truck to ship is extremely important because of the shortage of the railroad capacity.
e) It is necessary to increase the efficiency of truck-based transportation in urban areas because truck is the only transportation mode available in urban areas.
f) Regarding with the policies that promotes modal shift, the Government must take taxation on fossil fuel into consideration along with the subsidy.
g) It has been cleared that enterprises have neither recognized the Guideline nor the

Subsidy System, and therefore information campaign would be extremely important for making enterprises aware of the projects to decrease the volume of CO_2 emission.

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