S-3 Low-Carbon Society Scenario toward 2050: Scenario Development and its Implication for Policy Measures

5. Long-term CO_2 reduction strategy of transport sector in view of technological innovation and travel demand change（Abstract of the Final Report）

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I. Overview

The purpose of this study is developing transport visions towards Low Carbon Society in Japan with the combination of forecasting approach for middle-term goal and backcasting approach for long-term goal. Fig. 1 shows the framework of this study across time horizon.

In sub-theme (1) of assessment of effectiveness of new technologies and their policy measures taking lead time into account, the EST 2020 scenario is constructed relying mainly on technological innovation, for there seems to be little feasibility on the demand change options in the near future. To see the trends of technological innovations, the energy consumption and CO_2 emissions of various vehicles and automotive fuel toward 2020 and 2050 have been estimated from the viewpoint of the Well-to-Wheel analysis, which is a framework to estimate the environmental advantages of alternative fuel vehicles and their fuels over an entire automotive fuel pathway. The traffic demand forecast data are derived from the survey by the Ministry of Land, Infrastructure and Transport, or derived from the revised version of the survey corresponding to the socio-economic trend provided by the Scenario Team of the S-3 research project. The lead-time spent for changes in the production capacity and the purchase behavior has been taken into consideration.

In sub-theme (2) of proposal of long-term emission reduction scenarios with backcasting approach, the EST 2050 scenario is drawn with backcasting approach. The required amount of reduction is the gap between the amount of emission of BAU case and EST target. The reduction by the demand change options is thought to cover the shortage of the reduction by the technological innovation options to achieve the reduction target.

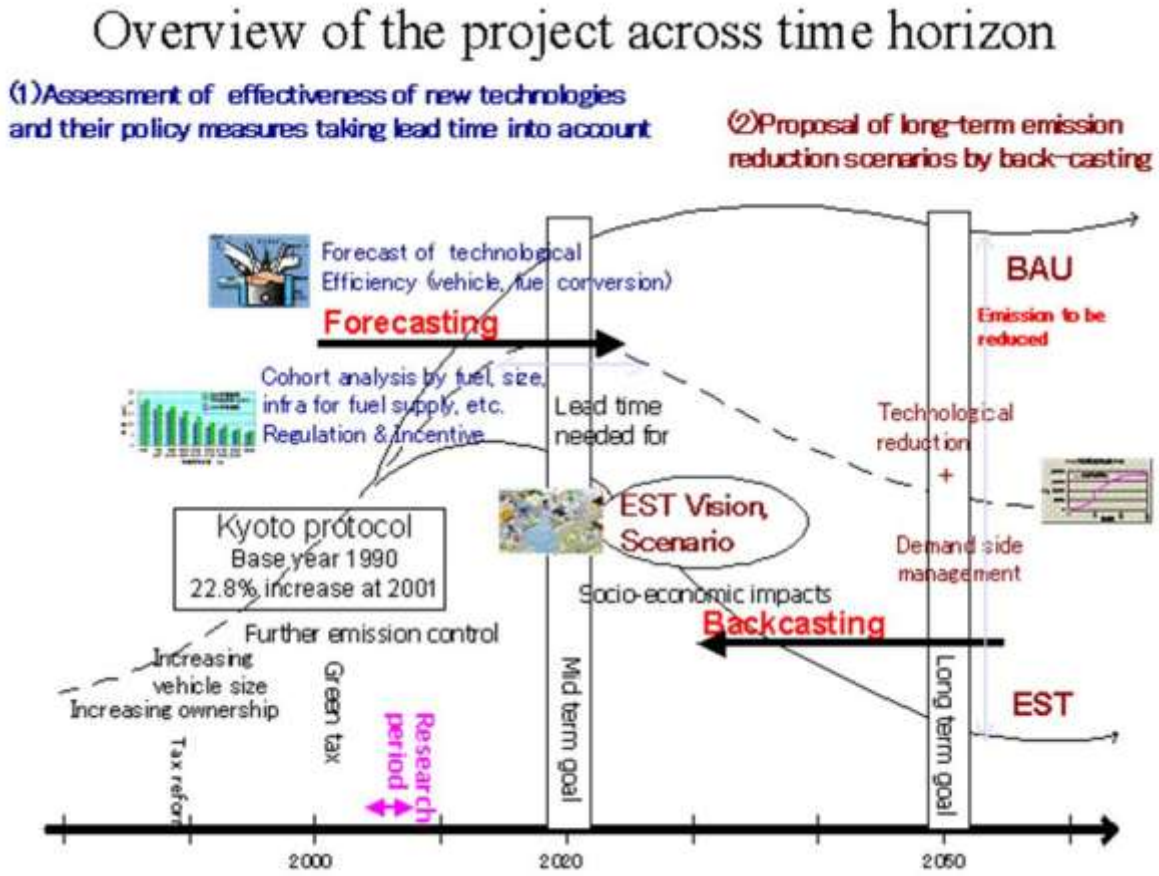


Fig.1 Overview of transport scenario study

II. Scientific outcomes

The followings were revealed through this study;

1) The efficiency of the Hybrid Electric Vehicles (HEVs) was high, based on the life cycle emissions over the entire automotive fuel pathway evaluated in JHFC (Japan Hydrogen & Fuel Cell Demonstration Project). The efficiency of Fuel Cell Vehicles (FCVs) depended on hydrogen production pathway. It was revealed quantitatively by the simulation considering the actual running mode that the FCVs and Battery Electric Vehicles (BEVs) had large potential of emissions reductions especially in urban or metropolitan areas where average travel speed is low compared with rural areas.
2) From the survey through actual fuel consumption database based upon the voluntary reported fuel log data collected from all over Japan, it was revealed that about 45% of fuel consumption could be reduced by hybridization of gasoline vehicle.
3) Through the survey of the automotive technology, it is expected that passenger vehicles and small freight vehicles can be substituted to gasoline HEV by 2020. Improvement of fuel consumption for freight vehicles is assumed to be difficult owing to their compliance for the new long-term emission regulation. BEV is suitable for personal use with short distance. By 2050, the conventional vehicles using internal combustion engine and liquid fuel would remain to be

the major powertrain for vehicles, but fuel consumption or CO_2 emissions can be reduced by hybridization of vehicles and broad introduction of biofuels. If the technology level of lithium ion battery is improved, small-sized BEV can be widely used in the urban area. 30~40 % weight reduction of vehicle can lead to 20~30 % emission reduction.

4) With the trip simulations, about 90% of the private passenger vehicles can access to alternative energy supply stands easily, if the stands are located in busy 23 zones among 89 zones in the southern area of Ibaraki Prefecture. Based on the investigation of the mileage of household, BEVs with 100km cruising distance could be introduced in about 20-32% household with plural vehicle possession.
5) Production capacity model of HEVs and cohort-model to evaluate their diffusion effect were developed. About 40% of the owned vehicles would be substituted for HEVs with the expansion of the production capacity that enables to make all of the new cars HEV in 2020. In this scenario, 3% reduction of CO_2 emission from 1990's was possible. Though the production expansion of HEVs was delayed, it was shown that the reduction can be achieved by the revision of the traffic demand estimation. 20% of reduction at maximum was possible with the combination of traffic demand management and biofuel introduction.
6) Consumers' preference for alternative vehicles had been evaluated, whose results show that their willingness to pay for HEVs was high and the environmental advantages of HEVs were widely recognized.
7) From life cycle inventory and uncertainty analysis of imported bioethanol, it was confirmed that ethanol made from Brazilian sugarcane showed the minimum GHG emissions. Since nitrogen fertilizer inputs for biomass production and cultivation stage showed large difference, it was concluded that soil or climate conditions of where biomass feedstocks are produced and cultivated would affect GHG emissions of bioethanol. In addition, the estimated potential CO_2 reduction of bio-diesel showed that 10% introduction of diesel passenger vehicles and 5% biodiesel blended fuel lead to 1.30% and 1.82% reduction, respectively. Cost reduction by producing biofuels with "local production for local consumption" basis was estimated to be important. It was shown that the reduction potential of biofuel introduction was high with the trips of 100-300km distance between the terminals for freight vehicles of the load capacity 10-15 tons.
8) The possible contribution of establishing transfer centers with multi-activity facilities (MAFs) to alleviating transfer impedance was equivalent to about 12 minute reduction in on-board time. The effect of bus network reorganization into trunk-feeder system, which can be one of effective measures to improve the operational efficiency and the ridership, on CO_2 emission was about 5% reduction.
9) Long-term plans with backcasting approach were reviewed to find that the feasibilities of large reduction could become improved by the combination of the various means including travel demand changes, instead of the heavy dependence on technological innovations.
10) Through the group interviews with the intellectuals, immigration policies, the economic growth of China and India, the system of decision making and oil prices were pointed out as critical

factors for the socio-economic vision for 2050. And residential preferences, fundamental needs for mobility and travel speed, the scale of the resources circulation and the diffusion possibility of FCVs were pointed out as factors which decide transport visions.

11) The current automotive CO_2 emissions of all the cities in Japan were calculated by regional categories. A low carbon regional passenger transport vision in 2050 was built to achieve 70% CO_2 reductions which consist of various countermeasures suitable to each regional categories.
12) A low carbon freight transport vision and an inter-regional passenger transport vision had been made to reduce 70% of CO_2 emissions.
13) To realize the visions, economical incentives are critical, for example introduction of environmental fuel taxes and subsidizing LRT (Light Rail Transit) constructions.
14) Planning dense land uses is important for regional passenger transport policies in local governments.
15) From the established model that selects main public transport considering low life cycle CO_2 emissions and economic efficiency, EST policy packages had been obtained by regional characteristics.
16) The road map plan of the EST policy was presented for local cities.
17) A simplified long-term forecasting model of passenger transport demand was established to obtain the outlook of 40% decrease from BAU in 2050 by improvement of fuel consumption and enhancement of railway. It was shown that modal-shift plan which made additional aviation CO_2 reduction by half was required to achieve 70% reduction.
18) A simplified long-term forecasting model of freight transport demand was established to obtain the outlook of 70% decrease in 2050 by the combination of the various policies.

III. Contribution to policy of global environmental issues for decision makers

These outcomes of this study were contributed to followings;

1) The future diffusion scenario and achievement plan of various biofuels for automotive fuel and heat use from 2010 to 2030 are examined and summarized in the reports "eco-fuel use promotion council" of the Ministry of the Environment (MoE).
2) We played a leading part in the summary of "Study on the comprehensive transport plan" of Iida city of Nagano prefecture in 2004. "Nagoya environment strategy"(2004.6)
3) Some of the results of this project had been cited in the report of the joint research project "Building the sustainable transport toward 2050 target" of Japan Research Center for Transport Policy.
4) Some of the results of this project had been cited and utilized in the report "Committee on the global warming countermeasures and city planning" of the MoE in 2005.
5) Some of the results of this project had been utilized in "Stakeholder dialogue for EST" of MoE project in 2005.
6) Some of the results of this project had been utilized in the decision of fuel standard of the heavy vehicles beyond the vehicles gross weight 3.5 tons at the 2015.
7) Some of the results of this project had been utilized in "Specialist committee on estimation of

carbon dioxide emissions of municipalities" of the MoE in 2005.

8) Some of the results of this project had been utilized in "EST promotion committee" of The Foundation for Promoting Personal Mobility and Ecological Transportation in 2006-2008.
9) Some of the results of this project had been reflected to the vision through the "Subcommittee on the decision of sustainable Shiga society vision" of Shiga Prefecture in 2007.
10) Some of the results of this project had been reflected to car fuel standard in 2015.
11) Some of the results of this project had been utilized in "The committee for the environment promotion city (and its steering subcommittee and the working group of transport)" of Tsukuba City in 2008.
12) Some of the results of this project had been utilized in "the CO-DO30 road map of transport section working team" of Yokohama City in 2008.
13) Some of the results of this project had been utilized in "the revised manual for executive plan of local government for global warming countermeasure" of the MoE in 2008.

1. Introduction

Only the emissions from transport sector have continued to increase almost proportionally with GDP when we see the trend of CO_2 emissions by sectors during the last 30 years after the first oil crisis. Although transport CO_2 per capita of Japan accounts for 2.0t-CO_2/year, which is lower than OECD's average (3.0t-CO_2/year) but higher than world average (0.8t-CO_2/year), it is still important to take measures to reduce transport CO_2 emissions, for the modal share of automobiles has continued to increase and additional reduction target beyond Kyoto Protocol is being under discussion.

We have already examined Japanese case study for EST (Environmentally Sustainable Transport) at the "International Conference on Environmentally Sustainable Transport in the Asian Region, 2003 Nagoya". In the case study, we have experienced that the transport model should be revised to be more comprehensive and detailed. And a back-casting approach should be examined in a more sophisticated way for construction of longer-term strategies.

2. Research Objective

In this study, the EST (Environmentally Sustainable Transport) scenarios are developed that can achieve CO_2 reduction targets for both 2020 and 2050 by the combination of technological innovation and demand change. The EST 2020 scenario is constructed mainly based on technological innovation, for there seems to be little feasibility on the demand change options in the near future. The EST 2050 scenario is drawn with a back-casting approach.

3. Research Method

The EST 2020 scenario is constructed mainly based on technological innovation, for there seems to be little feasibility on the demand change options in the near future. To see the trends of technological innovations, the energy consumption and CO_2 emissions of various vehicles and automotive fuel toward 2020 have been estimated from the viewpoint of the Well-to-Wheel

analysis, which is a framework to estimate the environmental advantages of alternative fuel vehicles and their fuels over an entire automotive fuel pathway. The traffic demand forecast data are derived from the survey by the Ministry of Land, Infrastructure and Transport, or derived from the revised version of the survey corresponding to the socio-economic trend provided by the Scenario Team of the S-3 research project. The lead-time spent for changes in the production capacity and the purchase behavior has been taken into consideration.

The EST 2050 scenario is drawn with a back-casting approach. The required amount of

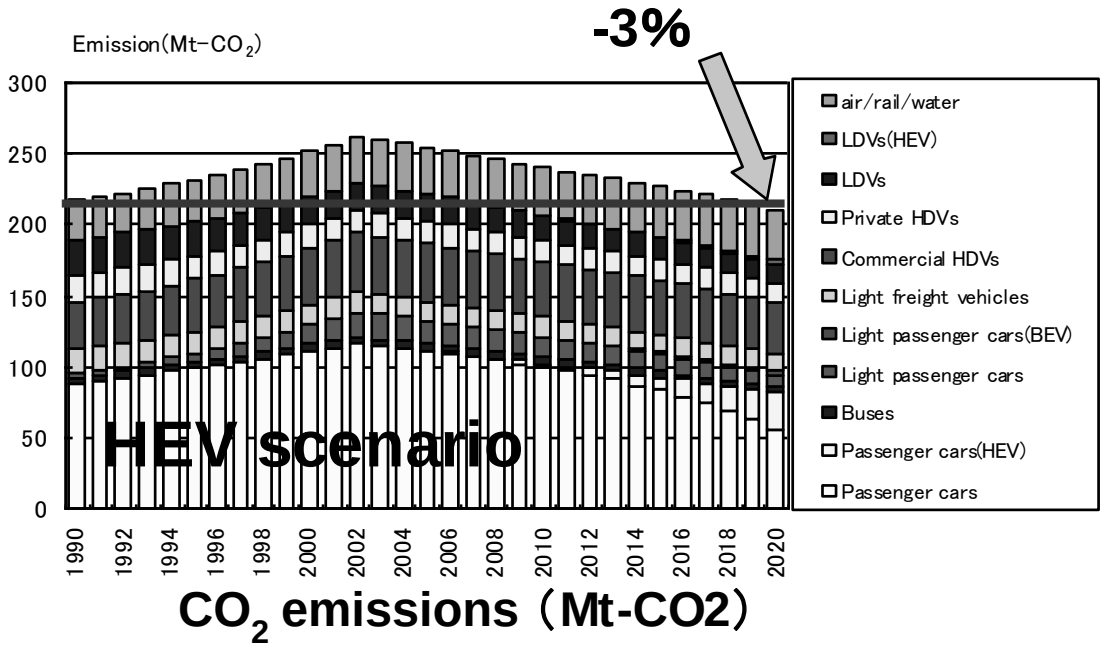


Fig.2 CO_2 emissions change of EST 2020 HEV scenario

Table 1. Outline of revised 2020 scenarios

Scenario	**Baseline**	**HEV**	**+Demand Management**
Penetration of HEVs and BEVs	Pass. Car (PC) HEVs 20% Low duty vehicle (LDV) HEVs 10%	PC- HEVs 37% LDV-HEVs 20% Light PC-BEVs 37%	
Fuel consumption of HEVs	40% reduction compared with the current fuel consumption of gasoline / diesel vehicles. LDV-HEV reduce 20% of fuel consumption of current LDV's）		
Improvement of fuel consumption（to 2002）	PCs, buses, LDVs reduce 10% of fuel.	PCs 20%, Buses 10%, Mini car 10% Heavy duty vehicles 5%, LDVs15%	
Traffic volume（to 2002）	3% decrease of PCs 7% decrease of freight vehicles (FVs)		PCs -13% FVs -16%
Air, rail, marine transport	5% reduction of fuel consumption of air, rail and marine transport Air transportation increase by 20% compared with current volume		

reduction is the gap between the amount of emission of BAU case and EST target. The reduction by the demand change options is thought to cover the shortage of the reduction by the technological innovation options to achieve the reduction target.

4. Result

1) 2020 scenarios

The production capacity model of HEVs and cohort-model of the diffusion were developed. The EST 2020 scenario which was focused on penetration of HEVs had been revised to reflect the comments from intellectuals and the change of forecasted transport demand by MLIT (Ministry of Land, Infrastructure, Transport and Tourism). The efficiency of hybrid light duty vehicles (HLDVs) was changed from 60% to 80%. In primary EST scenario, traffic volume was still increasing about 10% in 2020, stabilizing CO_2 emissions onto 1990's was possible. And about 80% of the owned vehicles were substituted for HEVs in 2020 with the rapid expansion of the production capacity as to provide all new passenger cars with Hybrid systems in 2010. In revised HEV scenario as shown in Fig.2, traffic volume becomes decreasing in 2020 as shown in Table 1, 3% reduction of CO_2 emission from 1990's is possible. And about 40% of the owned vehicles were substituted for HEVs with the expansion of the production capacity that enables to make all of the new cars HEV in 2020. 20% of reduction at maximum was possible with the combination of traffic demand management and biofuel introduction.

The potential of penetrating BEVs was examined with simulation model based on detailed traffic data. It was found that 30% to 90% of household with plural vehicle possession could introduce BEV for secondary-use with 100km cruising distance.

From a statistical analysis of the actual fuel consumption database of passenger vehicles that has been established from voluntary reported fuel consumption log data of passenger vehicle users collected through internet-connected mobile phone system and vehicle specification data, it was estimated that CO_2 emissions can be reduced by approximately 45% by hybridization of current passenger vehicles equipped with conventional gasoline engines.

Average pay-back time of HEVs was calculated by comparing the total amount of gasoline cost of 10,000km drive per year and difference between vehicle prices of HEV and ICEV (internal combustion engine vehicle). In 2010, the payback time of HEV will be nearly three years. HEVs are thought to be one of the promising and feasible options from the viewpoint of not only environmental merits but also cost efficiencies.

The effect of bus network reorganization into trunk-feeder system, which could be one of effective measures to improve the operational efficiency and the ridership (Fig.3), on CO_2 emission was analyzed through travel demand forecasting in Aomori city and Nagano city. The possible contribution of establishing transfer centers with multi-activity facilities (MAFs) to alleviating transfer impedance from analyses of bus users' stated preference data was also took into account. The alleviating effect of MAFs on impedance of transfer itself is equivalent to about 12 minute reduction in on-board time. In other case, the impedance per one minute of waiting time is reduced in proportion to the strength of one's intention to do activities at MAFs.

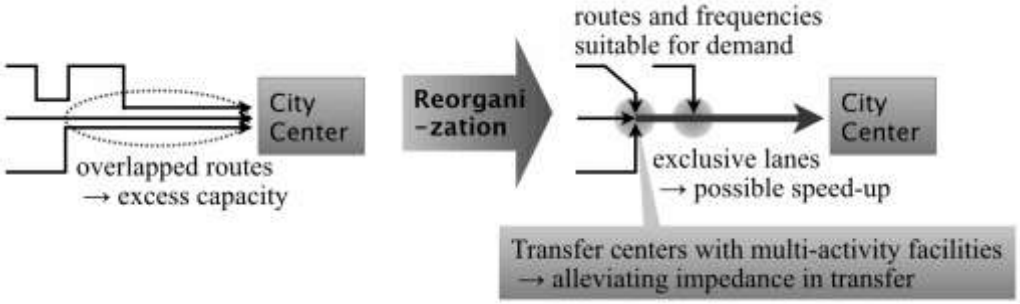


Fig.3 Image of bus network reorganization in this study

Travel demand forecasting was conducted for Aomori city and Nagano city in order to estimate CO_2 emission from cars and buses before and after the reorganization, considering modal split and traffic/transit assignment.

In case of Nagano city, a bus network reorganization plan was developed in light of current demand pattern, which reduced the number of bus routes and operational vehicle kilometers significantly. The alleviating effect of MAFs was also taken into account so that the on-board time was reduced by 10 minutes, by reference to the value mentioned above, for origin-destination pairs which included transfer between trunk and other lines at transfer centers. The result showed the increase in bus ridership, the more efficient bus operation and about 5 percent reduction in CO_2 emissions(Table 2) .

Table 2 CO_2 emissions before and after reorganization in case of Nagano [t-CO_2/year]

	Bus	Car	Total
Before reorganization	11,830	244,448	256,278
After reorganization without MAFs (change)	4,550 (-61.5%)	240,659 (-1.6%)	245,209 (-4.3%)
After reorganization with MAFs (change)	4,545 (-61.6%)	239,438 (-2.0%)	243,983 (-4.8%)

2) 2050 scenarios

Regional CO_2 emissions of passenger vehicles in local government scale were estimated. It was found that the emissions per capita increased in the local government where population had decreased recently, and that population decrease especially in areas with density lower than 2,000 person/km^2.

For developing EST 2050 visions, group interviews have been held to obtain rough sketch of the situations of society, economy, urban form, transport, energy system and environment in 2050. There are some different opinions on the probabilities of the depletion of oil, dissemination of fuel cell vehicles and possibility of natural/simple lifestyles and so on. These various visions will help to draw the 2050 scenario. EST 2050 visions were built which correspond to the framework developed to estimate the national total reduction with the combination of the countermeasures to control travel frequencies, trip length, mode, load factor, fuel economy and carbon intensity which are applicable to each regional categories (Table 3 and 4).

Countermeasures to accomplish EST 2050 vision were discussed. Preferential tax treatments for desirable land-use and desirable transport system were thought to be effective tool to

Table 3. EST 2050 Vision: Passenger transport

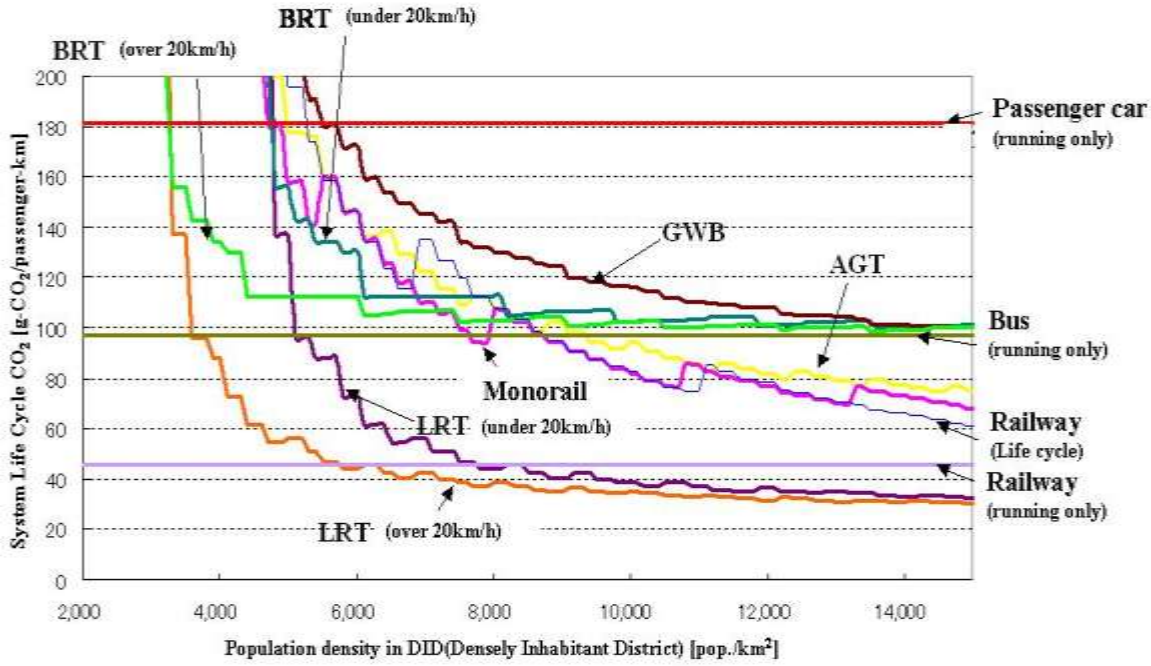
	Metro Urban	Metro Suburb	Provincial Urban	Provincial Rural	Total
Compact neighborhood	△ Rehabilitation	○ Rehabilitation	△ Rehabilitation	○Compact Settlement	112->33M To 1990 − 70% Including (Inter-city Passenger: 30km-) Index: ◎: − 30% ○: − 20% △: − 10% ×: no room
Compact city	△City center renewal	△Withdrawal	△City center renewal	×	
Enhance public transit	△Pricing	△Park & Ride etc.	○LRT	△van pool, shared taxi	
Improve load efficiency	△Utilize small vehicles		△Enhance sharing	×	
Improve fuel consumption	◎Urban mode	○local mode			
Low carbon energy	△less room for improve	○biofuel, Low Carbon Electricity for EV and PHEV etc.			

Table 4. EST 2050 Vision: Freight and inter-city passenger transport

	Inter-local Freight: 300km-	Inter-city Freight: 30-300km	Inner-city Freight: -30km	(Inter-city Passenger: 30km-)	Total
Supply Chain Management	○SCM		△SCM		106->32M To 1990 − 70% Excluding (Inter-city Passenger: 30km-) Index: ◎: − 30% ○: − 20% △: − 10% ×: no room
Compact city			○Short route	△～× Enhance modal shift	
Enhance public transit	○Marine transport, Rail	△Rail	△Hand cart	◎Rail, Expressway bus	
Improve load efficiency	△Low delivery frequency	△Cooperative delivery	○Cooperative delivery	○Car pooling	
Improve fuel consumption	○ITS, Fuel-efficient truck	◎ITS, Fuel-efficient truck	○ITS, Fuel-efficient truck	◎ITS, Fuel-efficient car	
Low carbon	△biofuel			○biofuel, PHEV	

enhance the combination of efficient and comfortable land-uses and transport system in longer term. Long term regional plan of land-use and transport from the viewpoint of Low Carbon Society would be a good guidance for residents and investors to prepare for the future uncertainties.

The estimation tool based on cohort analysis was extended to consider regional categories and countermeasures to change travel demand so as to draw EST 2050 scenarios. It was shown that the path to reduce 70% of CO_2 emissions in 2050 with constant ratio went through 14% reduction in 2020. It meets the case of the EST 2020 scenario with combination of penetration of



LRT(Light Rail Transit)・BRT(Bus Rapid Transit)・
AGT(Automated Guideway Transit)・GWB(Guideway Bus)

Fig.4 Impacts of population density on life cycle CO_2 of various transit system

HEVs, reducing traffic volume and partly introducing bio fuel.

Life-cycle CO_2 emissions of various public transport systems were compared considering population density of densely inhabited district, travel demand, construction of infrastructures and load capacities as shown in Fig.4. It was found that Light Rail Transit was the best public transport system from the viewpoint of CO_2 emissions for most regions.

In order to achieve the long-term target of transport system for low carbon society, it is necessary to explore ways of offering suitable and efficient “roadmaps” for each area with distinct local characteristics. Firstly, based on the reviewing of existing challenges of how well Japan has utilized low carbon policies, a matrix of the relationship between the order of execution and

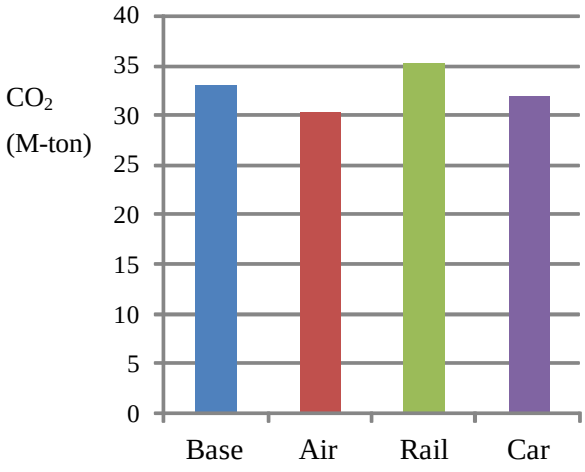


Fig. 5 Relation between CO_2 Emission and 20% Fare Increase of Each Mode

synergy effects of the associated policies is identified. Secondly, each area is classified with its local transport characteristics. Finally, the overall low carbon policy strategy is clarified and three separate road maps are proposed for guiding local passenger transport policy making in Japan.

We calibrated amount of CO_2 emission of interregional transportation in 2005 by using MLIT (Ministry of Land, Infrastructure, Transport and Tourism) Air Demand Forecasting Model 2007. It was clarified that the longer distance market evacuates more CO_2. We tested a sensitive analysis of transportation fare and CO_2 emission (Fig.5). Differences of the unit of emission cause positive or negative effects on the increase of fare. Especially, the emission factor of airplanes is higher than others', therefore the appropriate fare structure by distance or aircraft types should be discussed in future.

The structure of the demand forecasting model was created based on the existing models and present situation analyses. The 70% reduction scenarios was drawn with diffusion of low emission freight vehicles and modal-shift especially in Tokaido (from Tokyo to Osaka) areas.

A study committee was held in which committee members other than research members of the "Japan Low Carbon Society Scenarios toward 2050" have discussed in order to create a comprehensive vision and scenario of transport sector. Based on much new knowledge achieved from the discussions, two policy-packages "The combination of multi-scale centered land uses and networks of suitable transport modes" and "Penetration of light-weighted electric passenger cars" were developed.

5. Discussion

It can be said that HEVs should be the most feasible and promising technology to mitigate CO_2 emissions toward 2020. Construction of alternative fuel station is thought to be one of the key issues to promote fuel cell vehicles in longer-terms. To reduce CO_2 emissions in 2020 under 1990's level, EST 2020 [HEV+DM] scenario is developed by adding demand management (DM) to prevailing HEV scenario. It requires to make the production capacity increase 20% every year from 2005 to 2020 until 3 millions HEVs per year covering most of Japanese domestic passenger car demand.

For developing 2050 scenarios, there are various visions on the probabilities of the depletion of oil, dissemination of fuel cell vehicles and possibility of natural/simple lifestyles and so on. The national 70% reduction in 2050 was examined with the combination of applicable countermeasures to each regional category.

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