Ministry of Environment, Global Environment Research Fund S-3-5 (2004-2008)

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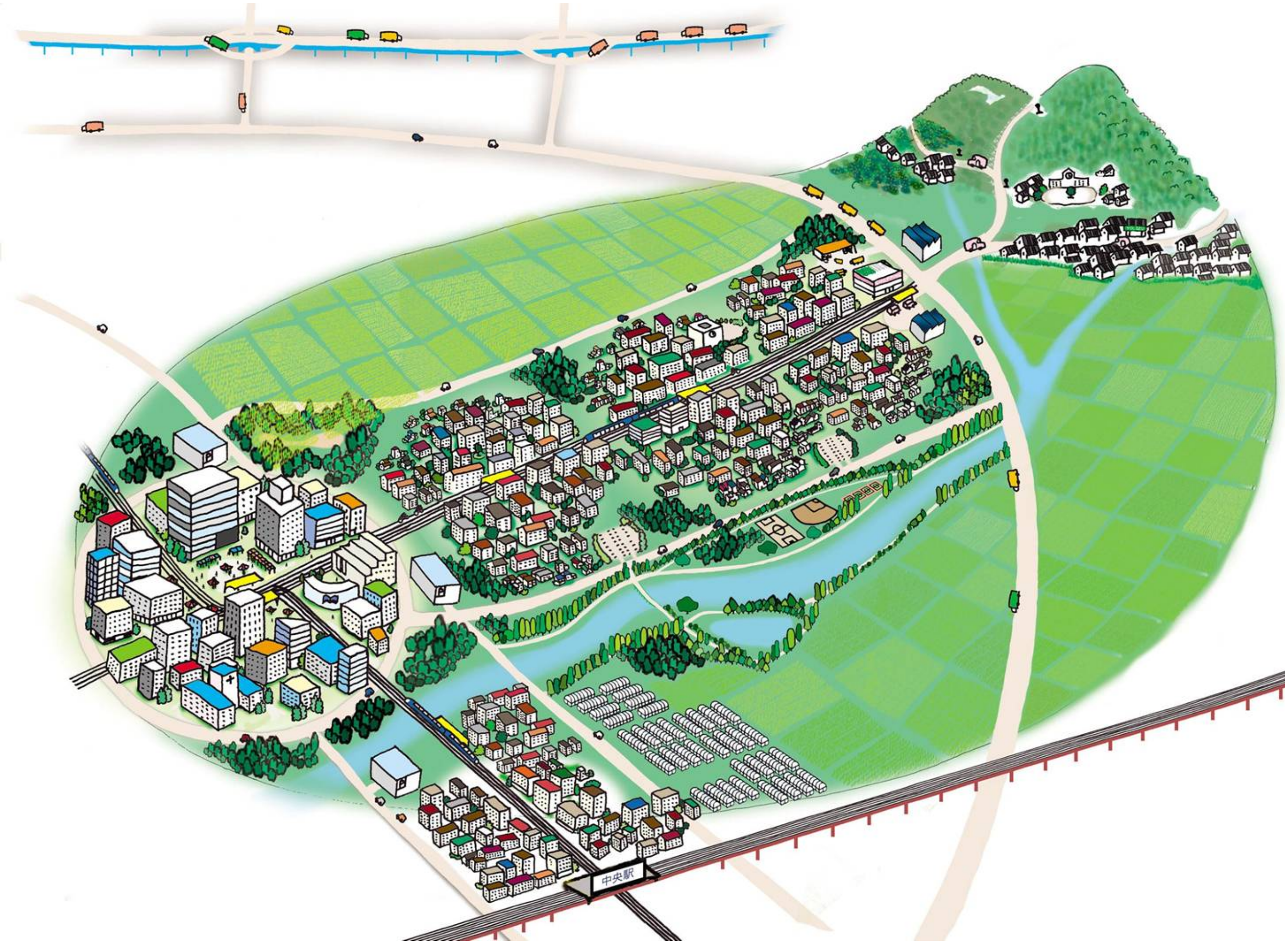

Evaluation and Medium- to Long-Term Strategy regarding Transportation Systems toward a Low-Carbon Society

2011

LCS 2050 Project - Transportation Team

INTRODUCTION

In order to achieve a low-carbon society, there is a need to consider mid- and long-term policy options in the transport sector, as in other sectors. The transport sector accounts for some 20% of sector-specific CO_2 emissions in Japan, which is somewhat less than in other industrially developed countries. However, the modal choice rate of automobiles continues to increase, so selection of fuel supplies and potential technical innovation to reduce automobile fuel consumption could be said to be key to potential CO_2 emission reductions in the transport sector at least for the short- to mid-term.

Interest in fuel-efficient vehicles has rapidly increased with heightened environmental awareness in recent years and experiences of sudden oil price increases not long ago. Hybrid vehicles driven by a combination of an engine and a motor are becoming a popular alternative to conventional engine-driven vehicles. Mass production of rechargeable plug-in hybrid and electric vehicles is also being planned. In general, there are signs of a shift from engine-driven to motor-driven vehicles, including fuel cell vehicles, though challenges remain in their widespread adoption. Progress in providing low-carbon supplies of electricity and hydrogen as well as development of energy supply facilities in the field are prerequisites for these alternative technologies to achieve wide adoption and sufficient effectiveness in reducing CO_2 emissions. Such steps will require clear policy guidance and sufficient lead time. Meanwhile, the shift to railway and other non-automotive means of transportation will also require long lead time and strong policy guidance.

Nowadays, automobile manufacturers have been placing fuel-efficient cars and hybrid cars on the market one after the other; the CO_2 emissions per vehicle have been reduced greatly compared to conventional automobiles. However, the CO_2 emission reduction effect of improving the fuel efficiency of vehicles has been cancelled out by increases in the number and size of vehicles owned. Though technology policies are expected to contribute to CO_2 emission reductions to some extent, they alone cannot be expected to achieve drastic reductions; transportation policies prompting changes in the transportation demand are thought to be imperative in the future. In considering such policies, it is necessary to keep in mind that transportation demand is highly dependent on local characteristics. In other words, in order to achieve drastic reductions by 2050, it will be important to prepare and implement suitable transportation policies with due consideration of regional characteristics, while keeping an eye on technical innovations in the interim.

In this context, we have been engaging in "research on long-term CO_2 reduction strategy of transport sector in view of technological innovation and travel demand change" as a part of the "research project on establishing of methodology to evaluate, middle to long-term environmental policy options toward Low Carbon Society in Japan" (http://2050.nies.go.jp/index.html) of the Ministry of Environment Global Environment Research Fund (S-3) in FY 2004-08.

This leaflet highlights the various outcomes of the research work under this project pertaining to CO_2 emission reduction strategies in the transportation sector. It is our hope that this leaflet will contribute to actual CO_2 emission reductions in society through debates, etc., on strategies to develop low carbon transportation systems adapted to local characteristics.

July 2009

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MEDIUM-TERM POLICY OPTIONS FOR 2020

LONG-TERM POLICY OPTIONS FOR 2050

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OBJECTIVES OF RESEARCH

The present research was conducted with the objective of developing a medium- and long-term strategy to achieve a drastic reduction in CO_2 emissions in the transportation sector over two time spans, namely, from now until 2020 and until 2050, as indicated in Figure 1.

The effect of massive adoption of technologies available or nearly ready for practical use in reducing CO_2 emissions was forecast up to 2020. It was aimed to develop methods for evaluating the effect of reduction measures in light of the time lag (lead time) between the decision to introduce a technology and the time its effect is observed, as well as automotive energy supply technologies, development of fuel supply facilities and other relevant conditions, and on this basis to elucidate reduction scenarios resulting from measures to promote fuel-efficient vehicles and to change travel behavior.

Furthermore, it was aimed to estimate the projected reduction levels required in each region to achieve the numerical target for reduction of CO_2 emissions in the transportation sector, employing a backcasting method with 2050 as the target year, in order to depict scenarios for achieving the target by combining technological innovation and changes in transportation-related behavior with due consideration of local characteristics.

To this end, policies requiring an early start were considered, a road map for long-term policy implementation was lined out, its social and economic impacts were analyzed, and scenarios to achieve the vision of EST (Environmentally Sustainable Transportation) were presented.

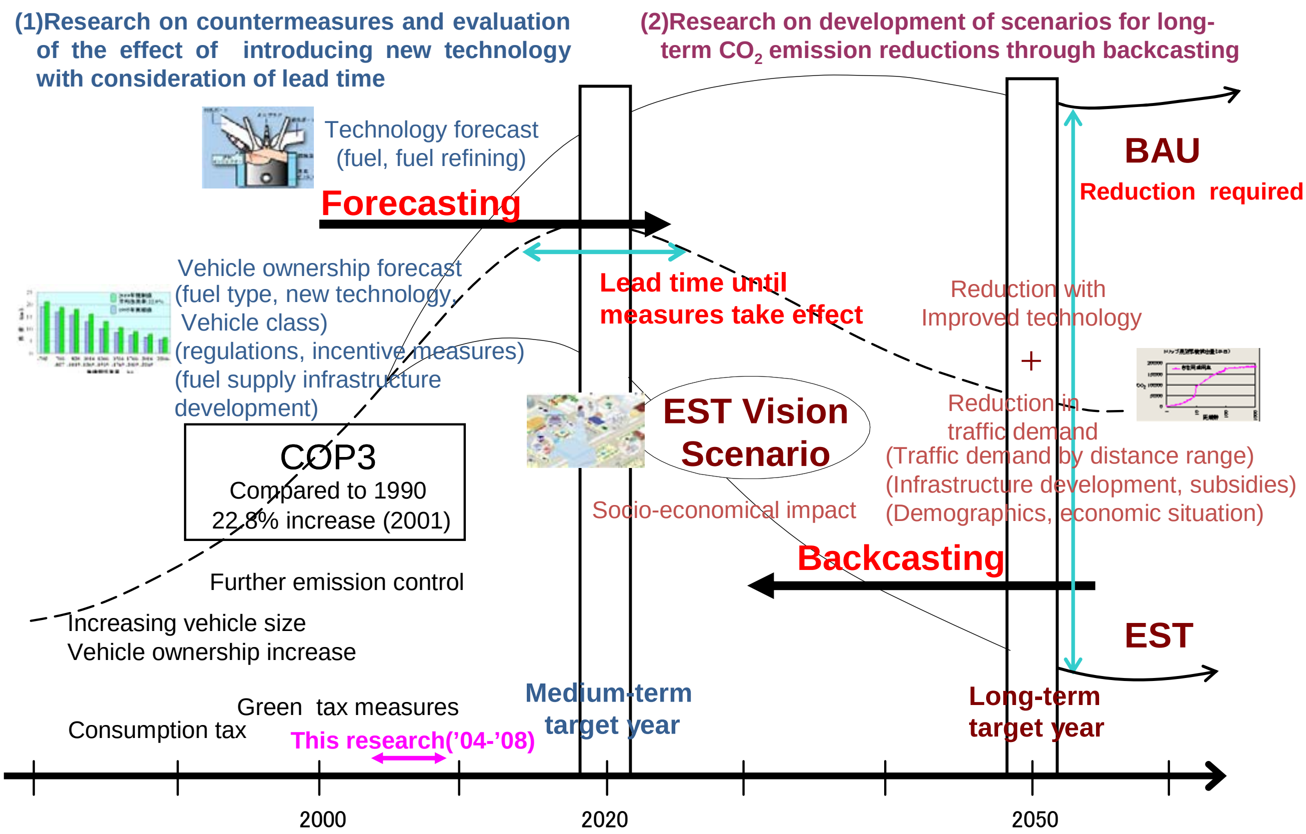

Figure 1: Target Years and Approaches of the Research

RESEARCH METHODOLOGY

MEDIUM-TERM POLICY OPTIONS FOR 2020

Technological forecasts were made regarding conventional technology vehicles and new technology vehicles, thought to be important for predicting technological trends. Furthermore, trends of automotive fuel supply technology were analyzed; and strategies for development of fuel supply infrastructure were considered. Meanwhile, on the basis of the above, a model was developed to evaluate the CO_2 emission reduction effect of massive technology adoption and the time lag until the effect becomes apparent. This was used to build a baseline scenario and countermeasure scenarios for 2020. Furthermore, the possibility of widespread adoption of new technology vehicles was analyzed and the CO_2 emission reduction effect of consolidating bus routes was estimated in order to quantitatively grasp the effect of policies.

When making technological forecasts, CO_2 emissions were calculated on the basis of the results of "well to wheel" analyses considering the fuel refining supply chain, as well as analyses of interviews and literature research. When evaluating CO_2 emission reduction effects, CO_2 reduction tools and a [new technology] adoption model were developed giving consideration to increased passenger vehicle production capacities and shifts in the types of vehicles owned; emissions were calculated by multiplying transportation demand figures with emission factors estimated for different vehicle types and transportation modes.

When considering the potential for adoption of new technologies, questionnaire data was subjected to conjoint analysis to elucidate consumer preferences with regard to power-train, price, etc., when purchasing passenger vehicles. The conditions required to achieve price superiority for wide-scale adoption were also estimated. The required capacity of fuel supply facilities was also calculated through simulation of fueling behavior on the basis of actual traffic data. With regard to measures to consolidate bus routes, world-wide trends of realigning routes into trunk routes + feeder routes were studied, a questionnaire survey was conducted to identify whether construction of transit terminals would alleviate resistance to such changes, and traffic distribution model calculations were used to compute CO_2 emission reductions.

LONG-TERM POLICY OPTIONS FOR 2050

Various reports, plans and vision statements regarding transportation of the future were collected and reviewed, and the employed methodologies were compared in order to identify how their long-term reduction scenarios were developed. Furthermore, in order to ensure the appropriateness of the future vision to be set forth, experts in various fields such as environmental issues, transportation, urban development, etc., were interviewed to identify the general direction of the prerequisite social and economic changes and to see the big picture of urban and transportation systems.

Forecasts of technological change can utilize accumulated knowledge concerning technology selection models pertaining to medium-term countermeasure options up to 2020, but possible changes in transportation demand need to be considered separately when considering long-term countermeasures. Therefore, an attempt was made to identify the composition of CO_2 emissions in the transportation sector by region type for the entire country. Next, implementable measures to alleviate transportation demand in the future were identified for each region type; the CO_2 emission reduction effect of these measures was used as a basis to build a framework to estimate possible changes in nationwide transportation demand; and policy packages regarding passenger transport in urban areas were developed. With regard to inter-city passenger and freight transport, a separate inter-city transport model was developed. Projected emission reductions due to a combination of measures such as improvement of the emission factor, modal shifts, etc. were evaluated quantitatively. Furthermore, projected emission reductions from a combination of measures including improvement of transport efficiency with SCM (supply chain management) were calculated for a number of trip distance ranges, and added up.

WELL-TO-WHEEL CO_2 EMISSIONS OF NEW FUEL- AND NEXT GENERATION VEHICLES

As a result of evaluating the entire lifecycle (from fuel supply to actual driving) of fuel-efficient vehicles and vehicles using petroleum substitutes, it was found that the CO_2 emissions were quite low for hybrid vehicles, but not necessarily for fuel cell vehicles, depending on the hydrogen manufacturing method. Furthermore, simulations considering actual driving modes showed quantitatively that fuel cell vehicles and electric vehicles have higher potential for reducing CO_2 emissions when introduced to urban areas with low average travel speeds.

New fuel- and next generation vehicles were evaluated using Well-to-Wheel (WtW) Analysis, which is a framework to quantify the environmental load of the entire lifecycle from manufacture of automotive fuel from primary energy sources including renewable energy sources, to its supply and use to drive vehicles (the energy chain cycle). The study results of the Japan Hydrogen & Fuel Cell Demonstration Project(JHFC), Special Committee for Comprehensive Efficiency Study[1] conducted by the Ministry of Economy, Trade and Industry, in which the writer has participated as a working group member and provided inventory data on various energy conversion processes, were referred to when calculating energy consumption and CO_2 emissions of various automotive fuels during the fuel supply (Well-to-Tank, WtT) phase. Likewise, energy consumption during the vehicle driving (Tank-to-Wheel, TtW) phase was analyzed by reviewing the energy consumption and CO_2 emissions of fuel-efficient vehicles and vehicles using petroleum substitute fuels when running according to the 10-15 mode cycle, which is the standard mode for measurement of fuel consumption of automobiles in Japan.

Gasoline hybrid electric vehicles (HEVs) already on the market and electric vehicles(EVs) soon to become commercially available are expected to achieve lower WtW CO_2 emissions. The WtW CO_2 emissions of fuel cell vehicles (FCVs) with a direct hydrogen system are lower than those of gasoline HEVs if by-product hydrogen obtained from COG (coke oven gas), etc., is used, but their WtW CO_2 emissions may be greater if other hydrogen manufacturing and supply methods are used. FCVs are characterized by the fact that they can use a wide variety of primary energy sources, but for them to achieve further reductions in CO_2 emissions, it will be important to increase the efficiency of the fuel cells themselves as well as of various energy conversion processes at the hydrogen manufacturing phase, *i.e.*, the WtW phase.

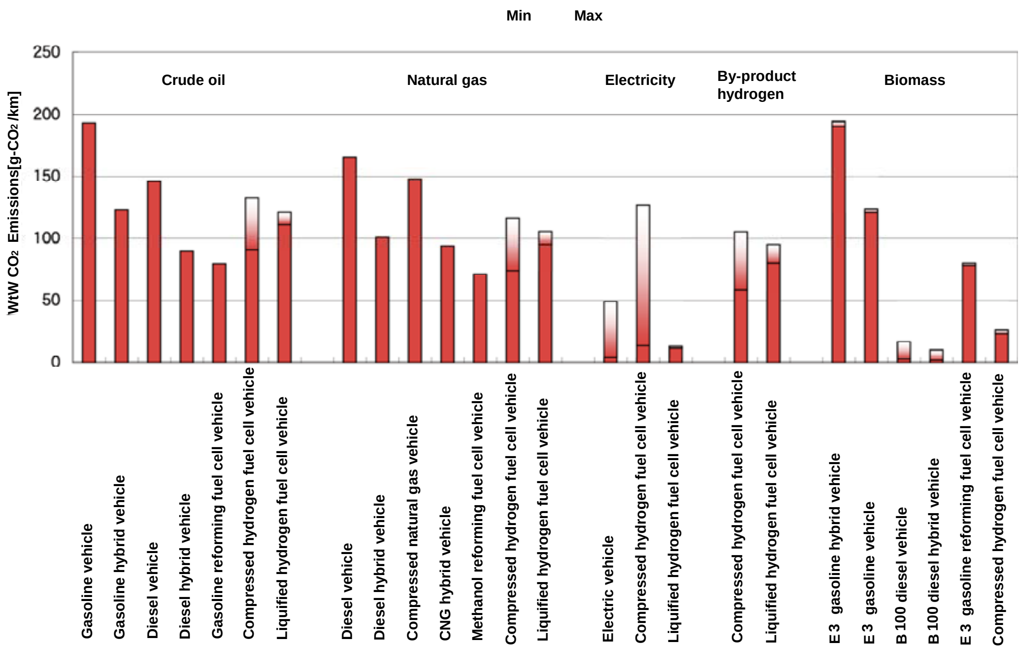

Figure 1: 10-15 Mode Well-to-Wheel CO_2 Emissions of Fuel-Efficient Vehicles and Vehicles using Petroleum Substitute Fuels

Furthermore, Figure 2 was prepared by calculating the actual drive time energy consumption and CO_2 emission characteristics of FCVs and EVs using a running vehicle simulation model capable of simulating the states of the powertrain (the drive assembly from the engine to the drive wheel) of the assembled vehicle. FCVs and EVs, which are able to regenerate energy, are vastly superior to gasoline-powered vehicles (GVs) with regard to energy consumption under low average speed traffic conditions. However, the superiority of FCVs and EVs vis-a-vis GVs with regard to CO_2 emissions lessens as the average speed increases. The WtW CO_2 emissions of FCVs in particular may exceed those of GVs depending upon the hydrogen manufacturing and supply method adopted. Considering the potential of FCVs and EVs to reduce CO_2 emissions, this suggests that prioritizing introduction of FCVs and EVs in large cities with low average travel speeds would be effective for reducing CO_2 emissions from automobiles.

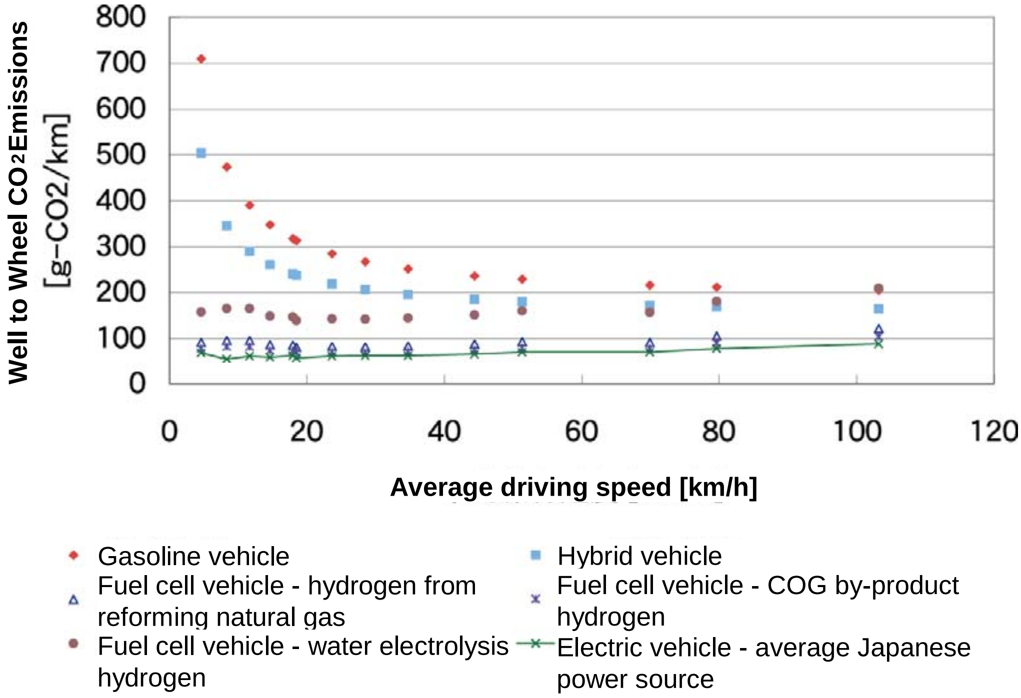

Figure 2: Actual Drive Time WtW CO_2 Emissions

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FUEL EFFICIENCY IMPROVEMENTS FROM CONVERTING PASSENGER VEHICLES TO HYBRIDS

It was found from an actual fuel consumption database constructed from fueling record data that the fuel consumption levels of hybrid passenger vehicles are reduced to about 69% of those for gasoline vehicles of equal performance.

The actual driving fuel efficiency (actual fuel efficiency) of existing automobiles is often inferior to the fuel efficiency performance in test mode (10-15 mode). In order to analyze actual fuel efficiency, which changes due to various factors, in a statistically reliable manner, the writers constructed a database of the actual fuel efficiency of passenger vehicles using fueling log data that was reported voluntarily by automobile users and collected nationwide using a mobile internet service. Some of the findings from this database have been published in references 1) and 2) and elsewhere. However, in order to understand how the steadily improving 10-15 mode fuel efficiency of new vehicle models using various fuel efficiency improvement technologies has impacted actual fuel efficiency, and to further increase the reliability of the actual fuel efficiency data in the database, the writers extended the period of analysis of fueling log data, and updated the database.[3] Using this database of the actual fuel efficiency of passenger vehicles, it was possible to ascertain the actual fuel efficiency according to engine displacement and powertrain type, which had not been possible with previously available statistical data.

A comparison of the actual fuel consumption (unit: [l/100 km]) of gasoline-powered vehicles (GV) and hybrid electric vehicles (HEV) at current technological levels was made using the updated passenger vehicle actual fuel efficiency database. First, 6 HEV models belonging to 4 groups with information in the database, and GVs thought to have equal automotive performance were selected from the same automotive manufacturer as follows.

- When there were GV and HEV models in the same line up and brand, a GV model from the same brand was selected.
- If the HEV had an engine which was an improved version of the engine mounted on the GV, a GV with the earlier version of the engine was used.

The distribution of actual fuel consumption data submitted by owners of the 6 HEV models in 4 groups, and the corresponding GVs is shown in Figure 1. Figure 1 shows the minimum value, first quartile point, median value, third quartile point, and maximum value of the actual fuel consumption for each vehicle model, with statistical outliers indicated as open circles. It is apparent that actual fuel consumption varies according to the user's driving habits and regional differences, even when the same vehicle model is used. Furthermore, the actual fuel consumption levels of HEVs relative to GVs varied among groups depending on the vehicle shape, the hybrid control system used in the HEV, and the motor output (minimum 58% to maximum 85%). It is estimated that conversion of a GV to a hybrid results in actual fuel consumption levels that are an average of about 69% of former levels with current automotive technology. This means that the fuel efficiency of HEVs is about 1.4 times that of GVs in ([km/l]), the unit commonly used for automotive fuel efficiency.

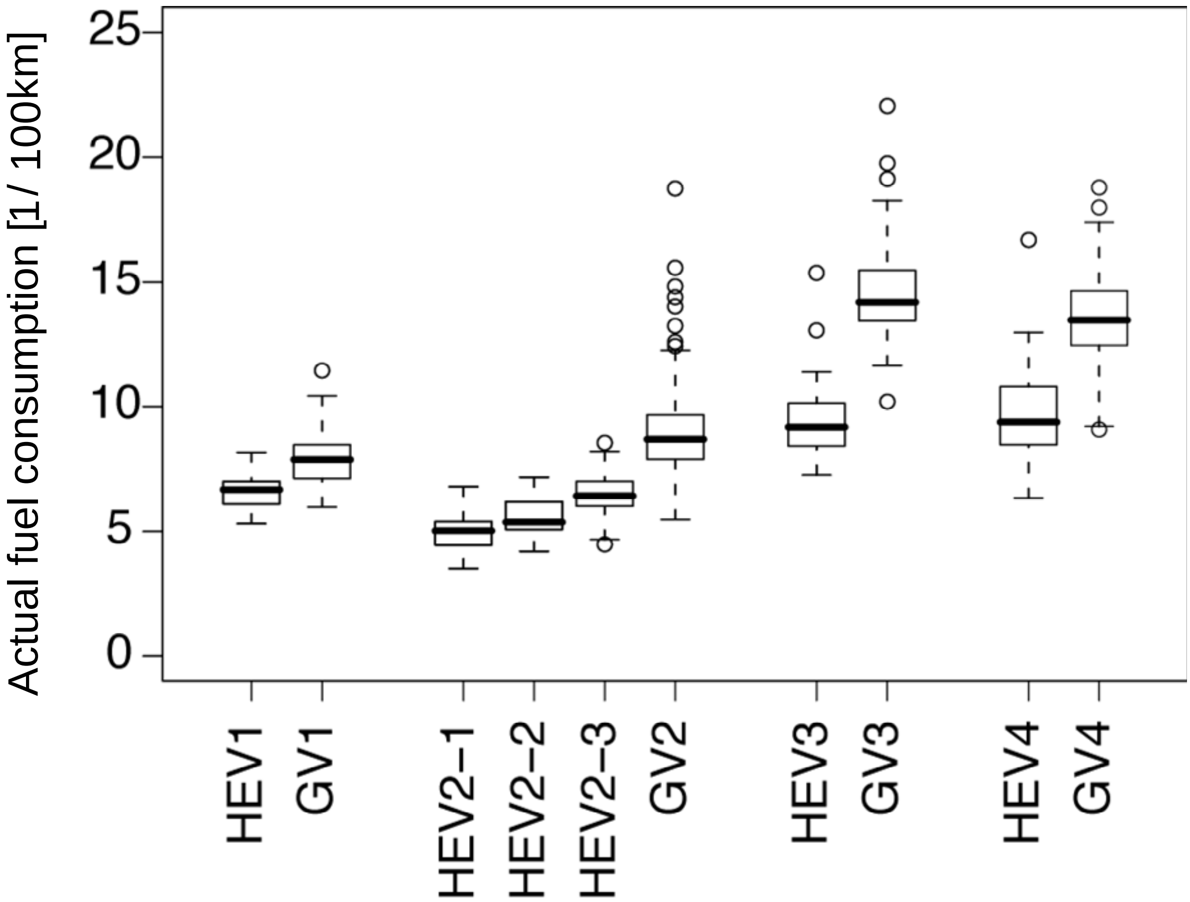

Figure 1: Distribution of Actual Fuel Consumption of HEVs and GVs

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FORECAST OF CAR FUEL EFFICIENCY IMPROVEMENTS AND CO_2 EMISSION REDUCTIONS

Table 1: Comparison of Overall Efficiency and CO_2 Emissions of Various Vehicle Types

Forecasts for 2020 - 2030

Vehicle Types	Overall Relative Efficiency	Relative CO_2 Emissions
■Today's gasoline vehicles	100 (baseline %)	100 (baseline %)
☆Future gasoline vehicles	120-135	83-74
■Today's diesel vehicles	115-125	87-80
☆Future diesel vehicles	140-150	71-67
☆Future Gasoline HEVs	150-220	67-45
☆Future Diesel HEVs	160-240	63-42
☆Future EVs (mini-size)	200-250	25-20
●Biomass fuel usage	-	97-93
●Reduction of vehicle weight	115-125	87-80
[Assumptions] Overall Efficiency = Fuel Efficiency x Vehicle Efficiency ・ Percentage of heat for thermal power generation from fossil fuels; 50% ・ Mixture ratio of biomass (heat equivalent): 5-10% ・ Vehicle weight reduction: 20-30%		

Forecasts for 2050s

Vehicle Types	Overall relative efficiency	Relative CO_2 emissions
■Today's gasoline vehicles	100 (baseline %)	100 (baseline %)
☆Future gasoline vehicles	130-140	77-71
■Today's diesel vehicles	115-125	87-80
☆Future diesel vehicles	145-155	69-65
☆Future gasoline HEVs	160-250	63-40
☆Future diesel HEVs	180-280	56-36
☆Future EVs (mini-size)	220-280	19-14
●Biomass fuel usage	-	90-80
●Reduction of vehicle weight	125-135	80-74
[Assumptions] Overall Efficiency = Fuel Efficiency x Vehicle Efficiency ・ Percentage of heat for thermal power generation from fossil fuels; 40% ・ Mixture ratio of biomass (heat equivalent): 10-20% ・ Reduction of vehicle weight: 30-40%		

A study of elemental technologies of automobiles indicated that by 2020 there is high feasibility of widespread use of gasoline hybrid vehicles as passenger vehicles and small freight vehicles, that fuel efficiency improvements of freight vehicles are likely to stagnate due to the need to comply with Post New Long Term Exhaust Regulations, that there is a possibility of increased use of electric cars primarily for short distance personal use, and that widespread use of fuel cell vehicles seems unlikely due to issues of cost and hydrogen supply.

It was indicated that until 2050, the combination of an engine and liquid fuel would continue to be used as a drive unit for automobiles, that there would be increased use of biomass fuels, that fuel efficiency would improve with increased use of hybrid vehicles, that there is a possibility of wider use of small electric vehicles in urban areas as the performance of lithium ion batteries improves, that further study of hydrogen supplies for fuel cell vehicles is required, and that reducing vehicle weight by 30% - 40% can be expected to reduce CO_2 emissions by 20% - 30%.

The fuel efficiency of various vehicles such as conventional gasoline vehicles, diesel vehicles and fuel-efficient, low-emission vehicles (green energy vehicles), and the engine/motor systems and related elemental technologies useful for reducing CO_2 emissions and expected to be available in 2020 were investigated and identified, and their effect as well as future issues were considered. The future prospects were summarized in Table 1.

As a result of investigating the fuel-efficiency technologies of electric vehicles (EV), hybrid electric vehicles (HEV), fuel cell vehicles (FCV) and other next generation vehicles, it was found that there is high feasibility of popularizing gasoline hybrids as passenger vehicles and light duty trucks, which can be expected to reduce CO_2 emissions 30-50% compared to conventional vehicles. In the case of freight vehicles, efficiency improvements of existing diesel engines are conceivable, but improvement of fuel efficiency technology is expected to stagnate, making major improvements in fuel efficiency difficult, due to the need to comply with Post New Long Term Exhaust Regulations that will come into effect around 2010. There is a possibility that EVs will be introduced, primarily for business use over short distances and personal use. FCVs are thought to be unlikely to achieve wide enough adoption by 2020 to have a positive effect, as it will take time to overcome issues of cost and hydrogen supply.

From 2020 until 2050, engines with improved fuel efficiency (spark-ignition engines and compression-ignition engines) are expected to be used as the drive unit for most automobiles, which are expected to use liquid hydrocarbon fuels as at present. The combination of an engine and liquid fuel exhibits exceptional characteristics in terms of power density as well as energy density for automobiles, and further improvements in fuel efficiency are expected in the future through sophistication of mechanisms and control systems presupposing extreme reduction of exhaust fumes. Petroleum fuels as well as biomass-derived and other renewable fuels are expected to be mixed and used together. Specifically, spark-ignition engines will use gasoline, bio-ethanol and ETBE (ethyl tert-butyl ether) and compression-ignition engines will use diesel and bio-diesel. Furthermore, BTL (Biomass-to-Liquid) fuel that is prepared synthetically by gasifying a wide range of biomass raw materials is also expected to be used in both types of engines after adjustment of the octane value (for anti-knocking) and the cetane value (for compression-ignition). These biomass fuels can be used mixed with conventional petroleum fuels in any proportion, and present almost no issues with regard to conventional engine technology or infrastructure technology for transport, storage and supply, exhibiting extremely favorable characteristics for gradual conversion of fuels on the long term. Furthermore, by converting such engine vehicles into hybrids, it is possible to achieve improvements of 50%-150% in terms of the driving distance per unit of fuel consumption.

EVs are also expected to be used widely in the future. Improving the performance of lithium ion and other batteries in terms of power density, energy density, fast recharging, reliability and durability is the main challenge. If this is achieved, it is expected that they will achieve CO_2 emission reductions of some 70% to 80% compared to conventional vehicles, assuming reduced size. Electric vehicles are most suited to short distance driving, and need to be promoted with thought to their use as compact vehicles for transportation and small freight delivery in urban areas. As for battery charging, further reductions in CO_2 emissions can be achieved by primarily recharging batteries at night and reducing fossil fuels in the generation mix (increasing the proportion of nuclear power and renewable energy). Widespread use of FCVs will depend not only on improved durability and reduced cost, but particularly on supplies of low-carbon hydrogen as a fuel, so concrete long-term plans need to be considered in these regards.

Furthermore, reducing vehicle weight will contribute greatly to improving fuel efficiency of all vehicle types; this will require efforts to utilize high tensile strength steel, light metals, plastics, etc. Weight reductions of 30% to 40% through such efforts would achieve 20% to 30% improvements in fuel efficiency. Reducing vehicle weight is somewhat contradictory to safety, but provides a motivation for developing more advanced vehicular safety technology.

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SITE LOCATION STRATEGY FOR ALTERNATIVE FUEL STANDS

Upon conducting simulations of automobile travel (trips), it was found that about 90% of automobiles would be able to access alternative fuel stands with relative ease if the stands were placed in 23 zones with heavy traffic out of a total of 89 zones in southern Ibaraki prefecture, but that fuel stands would need to be located in 39 (roughly half) of the zones in the case of vehicles with a cruising distance of 100 km, which is typical of electric vehicles at present.

Furthermore, studies on the driving distances of households owning multiple vehicles showed that it would be possible for about 20-32% of households to begin using electric cars.

Wide-scale adoption of electric vehicles (EVs), fuel cell vehicles (FCVs) and other currently available vehicles using non-petroleum alternative fuels will require construction of new fuel supply facilities. In the present research, the characteristics of automobile travel in southern Ibaraki Prefecture were modeled in order to consider strategies for placing such facilities. Data from the FY1999 Road Traffic Census by the Ministry of Land, Infrastructure, Transport and Tourism (official name: Nationwide Road and Street Traffic Status Survey) was used to obtain a large sample of data on automotive travel on a given weekday and holiday, respectively. Furthermore, safety recorders (SR) were mounted in the automobiles of test users, whose driving patterns were monitored over a long period of time in an independent study. Data from both sources was used to analyze and model trends such as automobile trip patterns and driving distance distributions, in order to reenact and simulate traffic in the target region for a month (30 days). Major trip patterns, monthly vehicle kilometers, household automobile ownership status and fueling timing were used as inputs to the model. The small zones of the Tokyo Metropolitan Person Trip Survey were used to judge access to alternative fuel stands.

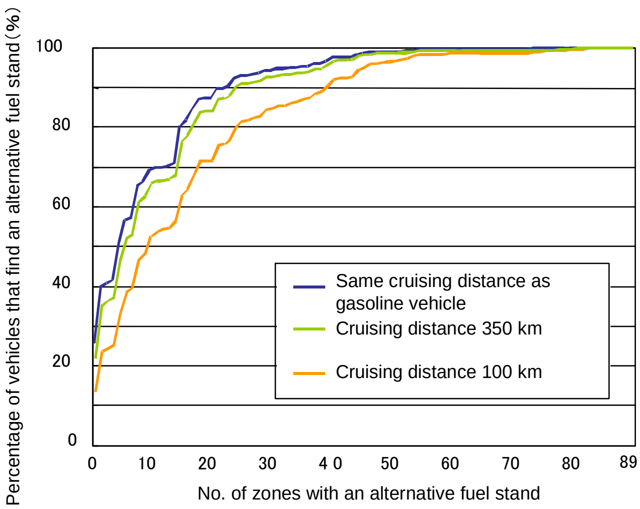

Figure 1: Zones with Alternative Fuel Stands and Rate of Coming Across the Stands

It was assumed that refueling would be possible if the subject passed through a zone in which an alternative fuel stand was located after refueling became necessary, and the percentage of vehicles that would come across an alternative fuel stand was calculated. The results are shown in Figure 1. It was found that about 90% of the automobiles would come across an alternative fuel stand if the stands were placed in 23 of the 89 zones in order of descending traffic volume, assuming a cruising distance equal to that of existing gasoline vehicles. The results for a cruising distance of 350 km (equal to that of natural gas vehicles) were roughly the same as for travel ranges equal to those of conventional gasoline vehicles. However, the proportion of vehicles coming across alternative fuel stands was lower with a cruising distance of 100 km (equal to that of electric vehicles). In this case, the proportion of vehicles coming across the stands exceeded 90% only when stands were placed in 39 or more zones, even when they were placed according to traffic volume. It was thus found that an alternative fuel stand would need to be placed in roughly every one out of two zones.

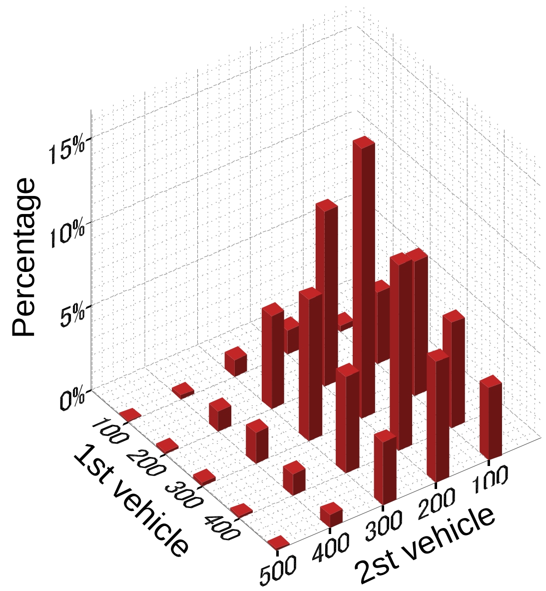

Figure 2: Maximum driving distance of households with two vehicles in January (rounded to the nearest 100 km)

Next, using data on actual automobile use of households with multiple automobiles, the maximum driving distances of the first and second car were compared, and the feasibility of substitution with an electric car was considered. As shown in Figure 2, only about 0.5% of the households drove neither of their two vehicles more than 100 km. Meanwhile, the proportion of households that drove either of their two vehicles 100 km or less was 32.1%. So it is thought that even under current usage conditions, about one third of households could switch to an electric vehicle. In particular, the second vehicle as defined in the present study, i.e., the vehicle used primarily by others than the head of the household, was driven no more than 100 km by more than 20% of all households; it was found that the so-called second car tended to be used for short distance travel. Sixty percent of the households that drove both vehicles more than 100 km in a day drove either of the two vehicles no more than 200 km, indicating that nearly 70% of households could substitute one of their vehicles if the cruising distance of electric vehicles really was 200 km as indicated in the catalogs.

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2020 TRANSPORTATON CO_2 EMISSION REDUCTION SCENARIOS

A model of ownership of different vehicle types was developed assuming increased manufacturing capacity and widespread adoption of hybrid vehicles. It was used to prepare a scenario to reduce CO_2 emissions 3% below 1990 levels through expanding manufacturing capacity so that all new passenger vehicles and 40% of all owned vehicles are hybrid vehicles in 2020. Traffic demand projections were also reviewed to show that reductions were possible even if expansion of hybrid vehicle manufacturing capacity is delayed. A 10% or greater reduction in CO_2 emissions compared to 1990 levels was also shown to be possible by combining traffic volume reductions with introduction of biofuels.

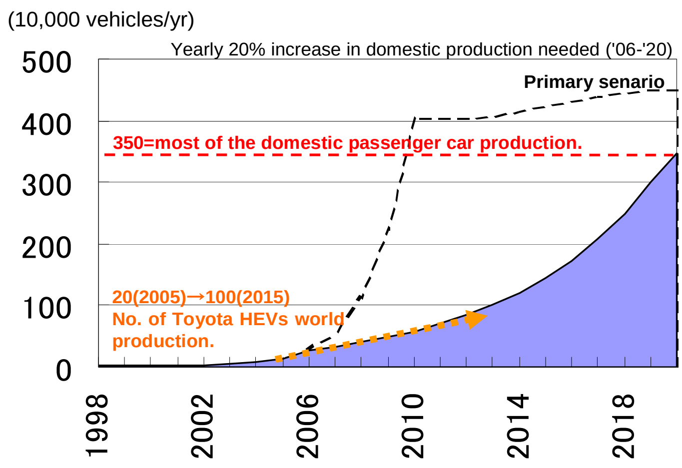

Figure 1: Increasing Hybrid Vehicle Production Capacity

It is thought that the most realistic and effective measure to achieve CO_2 emission reductions by 2020 is to promote broad adoption of hybrid electric vehicles (HEVs). The reasons are that HEVs are already widely recognized to be better for the environment, and that conversion of conventional models to hybrids can be expected to reduce fuel consumption by about 40%. However, there will inevitably be a time lag between the start of promotion measures and widespread adoption because passenger vehicles have a lifespan of more than a decade and HEV manufacturing facilities also need to be expanded. For this reason, a model was built for evaluation of technology introduction measures based on vehicle ownership figures by vehicle type and vehicle age, with due consideration of the number of years needed to replace currently owned vehicles. The model was used to evaluate various scenarios for widespread HEV adoption.

First, a wide-spread HEV adoption scenario in which the majority of vehicles owned in 2020 are HEVs was developed. Given that the HEV manufacturing facilities were expanded at a rate of 1.5 to 2 times year-on-year each year from 2001 to 2003, this CO_2 reduction scenario assumed that the construction of such facilities would continue to double each year compared to the previous year until 2010, after which almost all new passenger vehicles would have been converted to hybrid vehicles, as indicated by the dotted line in Figure 1. In this case, the adoption rate of HEVs would reach about 80% in 2020. Furthermore, it was assumed that conventional vehicles would incorporate fuel efficiency improvements, Battery electric vehicles (BEVs) would be introduced as mini-size passenger cars, and that up to 50% of small freight vehicles would be deployed as HEVs with CO_2 emissions per driving distance only 80% of those of conventional vehicles. Future projections by the Ministry of Land, Infrastructure, Transport and Tourism in 2003 were used regarding transportation demand. It was found that the resulting CO_2 emissions were reduced only ±0% compared to 1990 levels in the HEV scenario as compared to an increase of 19% in the baseline scenario assuming BAU (business as usual), due to significant increases in vehicle kilometrage.

In other words, it was concluded that technological measures alone would be inadequate to achieve a drastic reduction such as a 30% reduction compared to 1990 levels by 2020. Therefore, a countermeasures scenario called the "+ Demand Management (HEV+DM) scenario" that included reductions in automotive transportation demand (a 20% reduction in passenger traffic, unchanged bus traffic and a 10% reduction in freight traffic compared to the baseline scenario) was developed as a scenario including traffic volume reductions. Specifically, a shift from automobile to bus transportation, etc., due to measures to promote use of public transportation was assumed. The result was that CO_2 emissions from automobiles would be reduced about 13% compared to 1990 levels by 2020.

Furthermore, as it is somewhat unrealistic to assume that HEV manufacturing capacity would double every year even

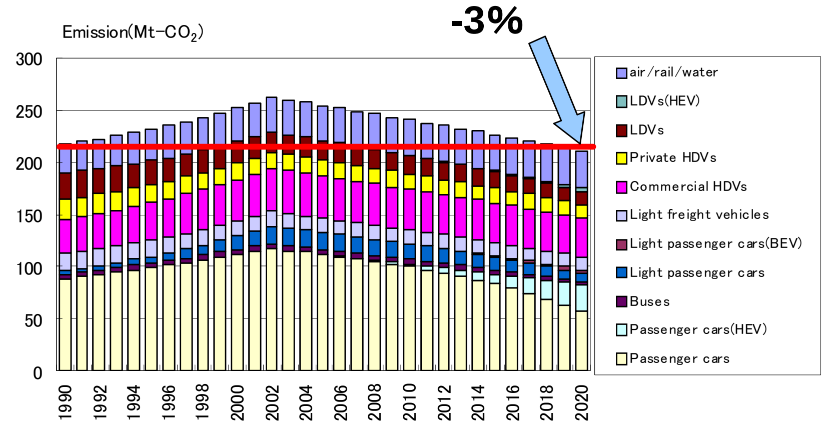

Figure 2: 2020 HEV Massive Adoption Scenario

Table 1: 2020 Transportation Scenarios

Scenarios	(0) Baseline	(1) HEVs	(2) +Demand management
Adoption of HEVs and BEVs	・Pass. Car (PC) HEVs 20% ・Low utyvehicle(LDV) HEVs 10%	PC-HEVs 37% LDV-HEVs 50% Light PC-BEVs 37%	
Fuel consumption	40% reduction compared with the current fuel consumption of gasoline/diesel vehicles (LDV-HEV reduce 20% of fuel consumption of current LDV's)		
Fuel efficiency improvement (compared to now)	PCs, buses, LDVs reduce by 10%	Passenger 20%, buses 10%, mini Car 10%, Heavy duty vehicles 5%, small freight 15%	
Traffic volume (compared to '02)	PCs 3% less (+39% compared to '90) FVs 7% less (-7% compared to '90)		PCs 13% less FVs 16% less
Air, rail and ship	Efficiency of air, rail and ship increases 5% while air transport volume increases about 20%		
CO_2 emissions (compared to '90)	+8%	-3%	-10%

after it reaches a level of several hundred thousand vehicles per year, an analysis of sensitivity to a slower rate of increase of HEV manufacturing capacity was also carried out. With a manufacturing facility expansion rate of 1.5 times year-on-year, the HEV adoption rate would be about 60% in 2020, and the CO_2 emissions would be 3% above 1990 levels. Thus it was found that traffic volume would have to be reduced 24% for passenger vehicles and 14% for freight vehicles compared to the baseline scenario in order to achieve approximately a 13% reduction in CO_2 emissions compared to 1990 levels in 2020. This corresponds to reductions of 12% and 18% respectively compared to 2002 levels, requiring reductions of traffic volume at a pace of 1-1.5% per year.

The future demand forecast by the Ministry of Land, Infrastructure, Transport and Tourism was revised in 2008. The future demand forecast in 2003 predicted that traffic volume would peak around 2020, but it was subsequently found to be flat or decreasing slightly, so the traffic volume for 2020 in the new forecast is 10% less than in the previous one. After applying the new traffic demand projections, emissions under the BAU scenario were found to be 8% above 1990 levels. For this reason, the HEV scenario was revised such that HEV manufacturing capacity would be expanded at a pace of 1.2 times year-on-year until 2020, after which almost all new passenger vehicles could be converted to hybrid vehicles, as shown by the solid line in Figure 2. In this case, as of 2020, the adoption rate of HEVs would be about 40% and the CO_2 emission level would be 3% less than 1990 levels, as shown in Figure 2.

As detailed in Table 1, the HEV+DM scenario was able to reduce CO_2 emissions 10% below 1990 levels, due to a 10% reduction in passenger and freight vehicle traffic volume compared to the baseline scenario. There is room for additional reductions by introducing biofuels for up to 10% of the fuel supply at most. In order to aim for an approximate 70% reduction by 2050 assuming reductions at a fixed rate year by year, it is necessary to reduce to 14% below 1990 levels by 2020. In other words, it will be difficult to achieve the long-term target only with measures to promote widespread adoption of HEVs. Adopting simultaneous measures to control traffic demand is thought to be desirable to facilitate achievement of long-term targets.

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(K.Matsuhashi, Y.Moriguchi: NIES)

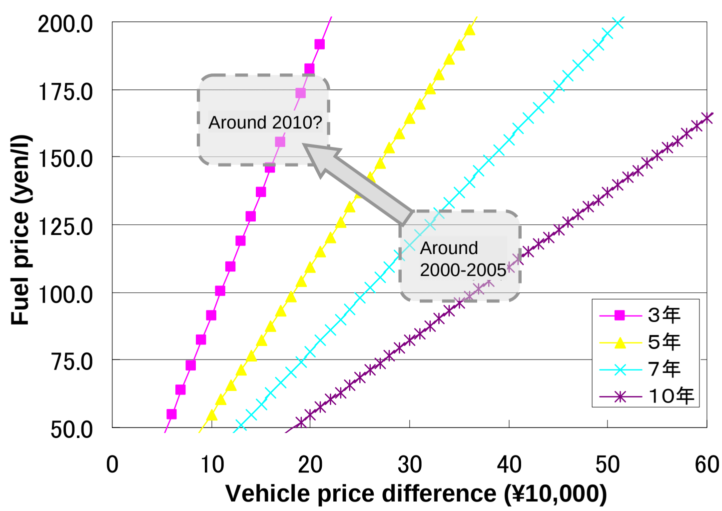
BASIC CONSIDERATIONS REGARDING ECONOMIC INCENTIVES TO ACHIEVE THE VISION OF A LOW-CARBON SOCIETY

Measures to guide behavior through economic incentives were thought to be effective to realize the vision of a low-carbon society. A basic study of feasibility of introducing such measures was conducted, focusing on cost. The payback time for hybrid vehicles and cost of developing LRT infrastructure were estimated, and the possibility of using the gasoline price as an incentive was considered.

Multi-stakeholder dialogues on measures to achieve the vision of a low-carbon society suggested that guidance through economic incentives might be the most effective way to proceed. The automotive green taxation system is thought to have been effective in improving fuel efficiency as consumer choice provided an incentive to automobile manufacturers, even though the system has been unable to put a brake on the shift to heavier models due to its application to vehicle weight categories. Requiring beneficiaries to bear part of the cost of public services and fixed property tax incentives are thought to be effective for intensifying land use.

The payback time to compensate for the higher price of hybrid vehicles (HEVs) was estimated assuming an annual driving distance of 10,000 km as shown in Figure 1. The fuel consumption of HEVs is about 60% of conventional vehicles whereas their price is about 300,000 - 400,000 yen higher at present; however, it was assumed that the price difference would drop to about 100,000 - 200,000 yen with introduction of new hybrid systems expected to be available around 2010. It was found that the payback time is about 7-10 years depending on the fuel price range (¥100-¥120/liter) at present as subsidies are being reduced, but the payback time will shrink to 3-5 years even without subsidies in 2010 when hybrid systems are expected to become less expensive. Specifically, it was inferred that rapid replacement of conventional models is likely once hybrid systems become less expensive and HEVs gain price competitiveness after 2010.

It has been pointed out that developing LRT, etc., with separate management of infrastructure and operations is a promising approach to promoting a modal shift. If the infrastructure is developed by the public sector and the service is operated by the private sector in a public-private partnership, a positive cycle of lower fares and increased passengers can be expected. It was pointed out in interviews with experts, etc., that funds earmarked for roads would need to be used for this purpose. For instance, if 10% of the road construction budget (6 trillion yen over ten years, equaling 50,000 yen per capita) were invested in developing LRT at a cost of roughly 2 billion yen/km for 20 years, it would be possible to extend LRT tracks 10 km in all cities with a population of more than 200,000. Otherwise, it would be possible to construct 1 km of track in each of 6000 meshes (about 1 km^2) nationwide with a population density of 4000 people/km^2 or more but



(Assumes driving 10,000 km/yr.
Conventional vehicles 11.7 km/l, HEVs 20.3km/l)

Table 1: Hybrid Vehicle Payback Time

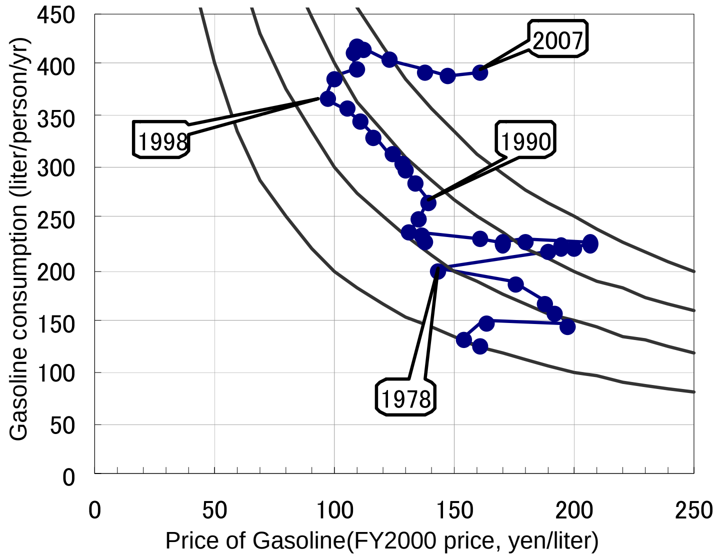


Figure 2: Gasoline Price and Consumption Trends

without railway stations, almost all of which would correspond to densely inhabited districts (DID). Though it will cost a total of 12 trillion yen, considerable infrastructure could thus be developed by delaying road construction about one tenth. Of course it will be important to consolidate urban facilities along the LRT lines and to coordinate with other means of transportation in order to promote a modal shift.

The relationship between gasoline prices and gasoline consumption was investigated and analyzed in order to observe how automobile users respond to price. There are some studies analyzing price elasticity with regard to the effect of gasoline price on gasoline consumption. However, most analyses cover only a short period of about ten years. For the present study, the relationship between gasoline prices and per capita gasoline consumption from 1971 to 2007 has been identified as shown in Figure 2. Prices were converted to 2000 price levels using a deflator.

The slope varies according to the target period, showing that there can be significant variation in price elasticity. Nonetheless, per capita annual consumption of gasoline has generally been stable in the range of 30,000 to 40,000 yen for the quarter century of 1975-1999, except during the oil shocks. It can be inferred that a decline in the actual price of gasoline led to a significant increase in gasoline consumption in the 1990's when the kilometrage of private passenger vehicles increased notably.

Gasoline prices rose continuously from 2000 until the summer of 2008, pushing the value of per capita annual gasoline consumption above 60,000 yen. This is thought to have been a reason for a decline in gasoline consumption volumes and car purchases. Whether or not another gasoline price hike will occur in the next decade and beyond will be a bifurcation point with decisive influence on the future. Another bifurcation point is whether the value of annual per capita gasoline consumption will come back down to 40,000 yen or increase to 50,000-60,000 yen. Depending on these two trends, the annual per capita gasoline consumption, which had increased to as high as 400 liters, may decline to 300 or even 200 liters. It is possible that use of passenger vehicles might decrease if there is a need to drastically reduce the gasoline consumption volume per household due to a gasoline price hike or effective measures to achieve a low-carbon society.

If the fuel efficiency of each vehicle can be improved to adequately conserve gasoline, and if the additional cost of purchasing fuel-efficient vehicles is not too high, it will be possible to continue to use passenger vehicles to fulfill mobility needs. Otherwise, households may have to choose to reduce the frequency or distance of car trips or meet their accessibility needs with electric cars or other means of transportation, in order to reduce their energy use and CO_2 consumption.

(K.Matsuhashi: NIES)

CONSUMER PREFERENCES REGARDING HYBRID VEHICLES AND ELECTRIC VEHICLES

A survey of consumer preferences regarding hybrid vehicles, electric vehicles and other electric-powered vehicles was conducted. It was found that the willingness-to-pay for hybrid vehicles is high, and that their environmental merits are well recognized.

Since hybrid vehicles, electric vehicles and other electric-powered vehicles differ from conventional gasoline vehicles in terms of vehicle price, fuel cost and cruising distance, there is a need to increase consumers' receptiveness to such vehicles if the possibility of CO_2 emission reductions through their massive adoption is to be considered. Thus a consumer preference survey was conducted via the internet to understand the current level of consumer receptiveness to fuel-efficient vehicles and alternative fuel vehicles.

The respondents were men and women aged 20-50 nationwide who owned automobiles and had driving licenses.

・A pretest (23-27 January 2009, 1,323 responses, response rate 18.0%) and

・the main survey (13-17 February 2009, 6,935 responses, response rate 32.1%) were conducted.

The pretest was conducted to verify the appropriateness of the level settings for various properties. Only the data from the main survey was used for analysis of survey results. On the assumption that the respondents would purchase a new vehicle to replace the automobile they currently owned in three years, they were asked to choose from among combinations of the five properties of drive unit, cruising distance, driving cost, riding capacity and vehicle price. Data on the respondents' stated preferences was collected and subjected to conjoint analysis to calculate how much they were willing to pay (WTP) for environmental and convenience features of the automobiles. Conjoint analysis is a methodology developed in the fields of environmental economics, computational psychology and marketing to estimate the effect of certain aspects of a product or service as well as the selected object's overall effect from data on consumers' order of preference for products or services.

The analysis results are shown in Table 1. The WTP figure is the extra amount respondents were WTP in the case of a baseline gasoline vehicle-either a standard or mini-size passenger vehicle. In the case of both the standard size and mini-size passenger vehicle, the willingness to pay was highest for passenger capacity. This suggests that electric-powered vehicles with specifications such that passenger capacity is sacrificed may not be accepted by consumers. With regard to WTP for drive unit, the figures were highest for hybrid vehicles, and also positive for electric mini-size passenger vehicles. This is thought to be due to high awareness of the

Table 1: Conjoint Analysis Results

Mini-size passenger vehicle. Reference vehicle = gasoline vehicle, ¥1.2 million, 500 km, ¥6/km, 4 seats

Properties		Coefficient	t value	Willingness-to-pay [¥10,000]	
Drive unit	Hybrid vehicle	0.577	14.7	34.8	*
	Plug-in hybrid vehicle	-0.592	-11.6	-35.7	*
	Electric vehicle	0.186	7.56	11.2	*
Cruising distance [km]		0.00236	30.6	0.143	*
Driving cost [¥/km]		-0.263	-44.0	-15.9	*
Capacity [seats]		0.745	62.4	45.0	*
Vehicle price [¥10,000]		-0.0166	-65.1		*

N: 2,045 log-likelihood: -15,018 likelihood ratio index: 0.338
*: significant at 1% level

passenger vehicle. Reference vehicle = gasoline vehicle, ¥1.8 million, 540 km, ¥7/km, 5 seats

Properties		Coefficient	t value	Willingness-to-pay [¥10,000]	
Drive unit	Hybrid vehicle	0.307	12.7	29.3	*
	Plug-in hybrid vehicle	-0.0162	-0.865	-1.55	*
	Electric vehicle	-0.175	-7.34	-16.7	*
Cruising distance [km]		0.00150	41.2	0.143	*
Driving cost [¥/km]		-0.185	-62.2	-17.7	*
Capacity [seats]		0.313	51.7	30.0	*
Vehicle price [¥10,000]		-0.0105	-75.5		*

N: 3,158 log-likelihood: -29,549 ikelihood ratio index: 0.156
*: significant at 1% level

environmental benefits of hybrid vehicles and because the respondents knew that mini-size electric vehicles were due to become commercially available in 2009. Meanwhile, the WTP for standard size electric passenger vehicles and plug-in hybrid vehicles (PHVs) was negative; statistically significant results could not be obtained for PHVs (significant level is 1%). This is thought to be because there was no information about commercial availability of electric passenger vehicles, or because the existence of PHVs was not yet widely known so that the respondents avoided or deferred selecting such vehicles. The fact that the willingness-to-pay for driving cost is negative indicates that consumers do give importance to fuel efficiency and fuel cost when buying a car. The willingness-to-pay for cruising distance is extremely low compared to other attributes; there does not seem to be an intuitive understanding that electricity-driven vehicles driven just with a battery have shorter cruising distances. It can be concluded from these findings that it is necessary to continue to provide information on the environmental benefits of electric-powered vehicles other than hybrid vehicles.

The questionnaire included a free answer section in which respondents could write their views about automobiles and the environment. On tabulation of the results, it was found that 1,257 or 24.2% of the total of 5,203 people whose responses were analyzed in Table 1 expressed the view that "they would like to purchase an environment-friendly car, but are unable to because the vehicle price is too high, and would buy if it became more affordable." The lifecycle cost of vehicle ownership is the sum of the vehicle price, fuel costs and maintenance costs; these results suggest that consumers consider these costs separately, and are particularly concerned about the vehicle price, *i.e.*, the initial investment. As stated by 52 of the 1,257 respondents, it is thought that subsidies for vehicle purchases will be necessary to achieve widespread adoption of low-emission vehicles and alternative fuel vehicles. Automobiles are designated as specified equipment subject to top-runner criteria according to the Revised Act on the Rational Use of Energy. Whether or not an automobile meets the fuel efficiency target based on the top-runner criteria can be identified by a sticker affixed to the window. However, the sticker does not give any estimate of energy use costs such as indicated on the standardized eco-labels for certain electrical appliances. In the future, as vehicle prices come down, it is likely that lower fuel costs, etc., will make it possible to recoup the extra initial cost of the vehicle. These findings suggest that providing subsidies for vehicle purchase and information on fuel costs and payback time compared to the lifecycle cost of conventional vehicles would be effective in promoting widespread adoption of electric-powered vehicles.

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(Y.Kudoh, AIST)

CO_2 REDUCTION POTENTIAL OF BIO-FUEL USE

Bio-ethanol is drawing attention as a gasoline substitute with the potential to reduce CO_2 emissions. Though manufacture of ethanol from ligneous or waste biomass is thought to be necessary in the medium- and long-term, use of bio-ethanol derived from imported food is also thought to be necessary in the short-term for domestic market development. Inventory analysis of GHG emissions from the manufacture and import to Japan of bio-ethanol derived from sugar (sugar beet, sugar cane and sweet sorghum) and starch (corn, wheat and cassava) was conducted on the basis of literature research as well as interviews on the production of ethanol from molasses conducted on Miyakojima island in Okinawa prefecture in December 2008. The uncertainty was evaluated with Monte Carlo simulation. There were considered to be three system boundaries for analysis, namely, biomass production, conversion to ethanol and marine transport, and it was assumed that the harvested biomass resources would be converted to ethanol locally. It was also assumed that the ethanol derived from corn and sweet sorghum would be imported from the USA (Los Angeles harbor), that from wheat from the United Kingdom (Southampton harbor) , that from cassava from Thailand (Bangkok harbor), that from sugar beet from France (Marseilles harbor) and that from sugar cane would be imported from Brazil (Rio De Janeiro).

The feasibility of introducing bio-fuels was studied, and GHG emissions at the stages of manufacture and supply of imported bio-ethanol were calculated. The findings suggested that GHG emissions pertaining to imported bio-ethanol vary greatly depending on the soil and meteorological conditions in the crop producing region. It was shown that shifting 10% of passenger vehicles to diesel and using fuel with 5% bio-diesel content would achieve CO_2 emission reductions of 1.3% and 1.8%, respectively, and that introducing fuel with 5% bio-diesel content calls for reducing costs by promoting local production for local consumption.
Meanwhile, it was shown on the basis of freight vehicle trip data that the potential for introducing biomass fuel as an alternative to diesel is high for ordinary freight vehicles with a load capacity of 10-15 tons used for freight transport between terminals with trip distances of around 100-300 km.

The results are shown in Figure 1. The energy consumption and GHG emissions at the ethanol conversion stage are lowest for cassava using a conventional boiler that uses fossil fuels, but they are lowest for sugar cane if by-product is used as boiler fuel. When by-products are used as boiler fuel, the energy consumption and GHG emissions are reduced in the case of sugar cane and sugar beet, but actually increase in the case of wheat. This is because wheat straw is normally plowed into the soil as fertilizer, so its use as boiler fuel would necessitate additional inputs of fertilizer, resulting in greater GHG emissions than if using a conventional boiler. In the case of Japan, when using bioethanol derived from energy crops, the GHG emissions are the least for ethanol from sugar cane grown in Brazil, where heat from the by-product bagasse is used. Furthermore, it was found that there is wide variation in the amount of nitrogen fertilizer input at the stage of biomass production, suggesting that GHG emissions can vary greatly depending on the soil and meteorological conditions in the crop producing region from which the bio-ethanol is imported.

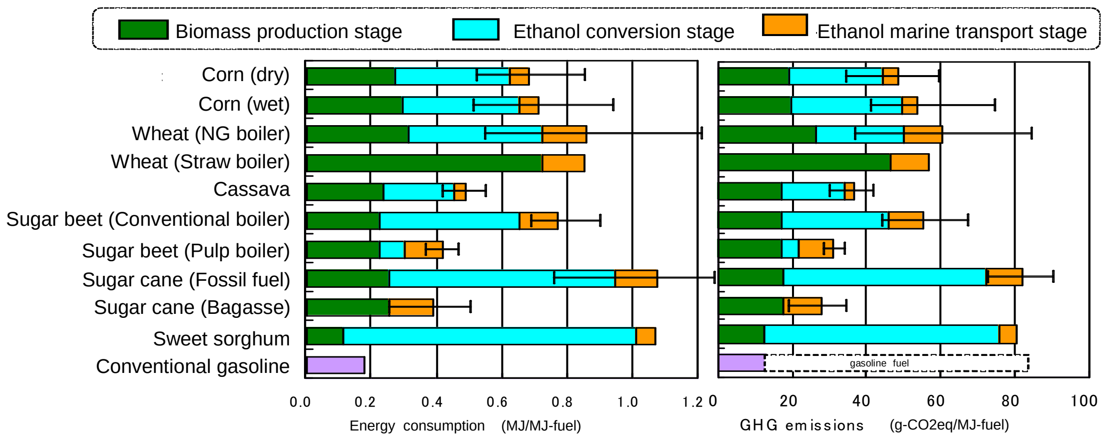

Figure 1: Energy Consumption and GHG Emissions at Each Stage of Bio-ethanol Manufacture & Supply

Next, the CO_2 emission reduction effect of shifting passenger vehicles to diesel and introducing bio-diesel fuel was calculated with consideration of differences in average driving speed, actual fuel efficiency and vehicle ownership figures. It was estimated that shifting 10% of 1,500-4,000 cc gasoline vehicles to diesel vehicles of the same size class, and using diesel with 5% BDF content (B5 fuel), would achieve CO_2 emission reductions of 1.30% and 1.82%, respectively (including CO_2 emissions at the fuel manufacture and supply stages). Furthermore, even if CO_2 emission reductions can be expected from a shift to diesel and introduction of B5 fuel, widespread adoption cannot be expected unless automobile users gain a cost advantage by doing so. For this reason, an analysis was made of the diesel vehicle specifications (Figure 2) and BDF price (Figure 3) required for the total cost of operation (sum of vehicle price and lifetime fuel cost) to be less than that of gasoline cars. The reference gasoline vehicle was assumed to cost 2 million yen and to have a catalog fuel-efficiency of 10.2 km/liter and a use life of 10.66 years; retail prices inclusive of tax as of February 2009 were used for fuel prices. Clean diesel vehicles currently available on the market cost 400,000 yen more than gasoline vehicles in the same size class, and have a catalog fuel efficiency of 131% compared to them. Diesel vehicles of similar specifications are expected to provide the cost advantage of diesel vehicle use regardless of regional differences in annual driving distances. Meanwhile, the cost advantage of using B5 fuel can only be achieved in regions with high average annual driving distances at current costs of ¥102/liter to manufacture BDF from waste food oil. This suggests that there is a need to reduce BDF manufacturing costs by promoting local production of bio-fuels for local consumption.

Furthermore, studies are underway regarding the feasibility of introducing biomass fuel as an alternative to diesel in order to reduce CO_2 emissions due to freight transport. The cruising distance of freight vehicles using biomass fuel tended to be less than that of conventional freight vehicles in verification tests. In light of the need to construct fuel stands and the uneven distribution of biomass resources, local production for local consumption is thought to be the most effective and efficient way to reduce CO_2 emissions through use of biomass fuel as an alternative to diesel in Japan. Under current conditions of freight transport, the size of trucks and trip distances vary depending on the freight type loaded. The feasibility of introducing biomass fuels for freight vehicles was studied by calculating fuel (diesel) consumption according to the freight type, load capacity and the trip distance of freight vehicles using data on the starting and ending points of automobile trips from the 2005 Road Traffic Census. Statistics on fuel consumption according to load capacity and driving distance for all freight types show a tendency for highest fuel consumption with load capacities of 10-15 tons and trip distances of 100-300 km. From these findings, it was surmised that the potential for introducing biomass fuel as an alternative to diesel is highest for ordinary freight vehicles used primarily for freight transport between terminals in lines of business with trip distances of around 100-300 km not requiring mid-trip refueling.

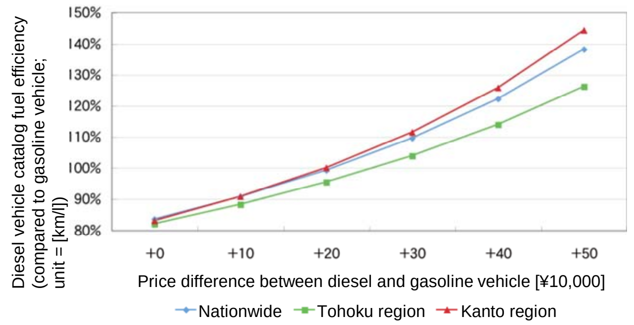

Figure 2: Requirements for shifting to diesel while breaking even in terms of total driving cost

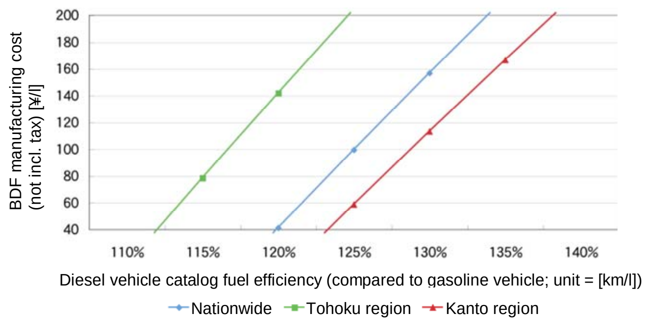

Figure 3: BDF price for shifting to diesel and using B5 fuel while breaking even in terms of total driving cost

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(Y.Kudoh: AIST)

THE EFFECT OF BUS ROUTE REORGANIZATION AND DEVELOPMENT OF TRANSIT TERMINALS

Using data from a questionnaire on bus users' preferences, the extent to which providing facilities for various activities in bus transit terminals would alleviate users' resistance to changing buses was analyzed quantitatively. The traffic demand after reorganization of bus routes was projected with consideration of this effect. It was shown that there is potential to increase the use and operational efficiency of bus service. The resulting reduction in CO_2 emissions from automotive and bus transportation was also quantified.

The importance of buses and other forms of public transportation is increasing in the context of environmental concerns and the increasing numbers of people with limited or low mobility due to trends of an aging population and families with fewer children. However, many cities suffer from a vicious cycle in which the number of users and the service level continue to decline.

It is anticipated that reorganization of bus routes will help to optimize the transport capacity in the inner city, which tends to be excessive due to all routes converging downtown; it is expected to contribute to increased efficiency of operations by enabling routes and trip frequencies to be set according to demand. Establishing dedicated lanes along trunk routes could also increase speed and punctuality. Though transfers between trunk and branch routes are generally disadvantageous for users, the inconvenience of transferring and waiting could be reduced by constructing user-friendly transit terminals with facilities enabling various activities during waiting time (Figure 1).

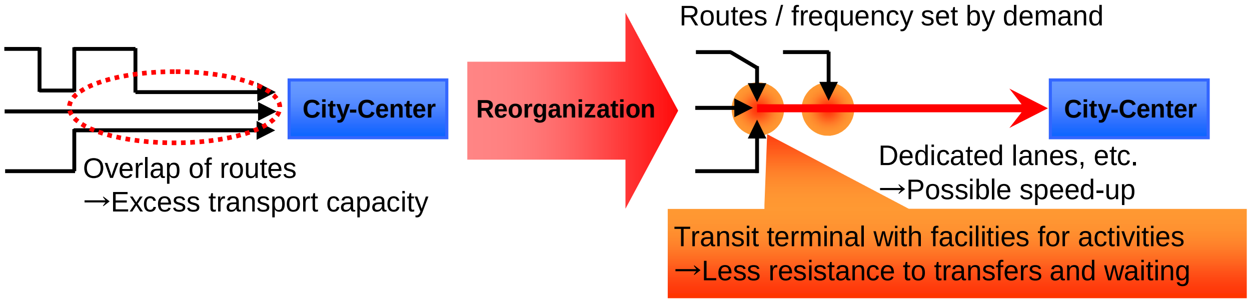

Figure 1: Conceptual Diagram of Bus Route Reorganization

The urban design of Curitiba (Brazil), a typical example of a city with a trunk and branch type bus route network, could be summed up as "high-density urban development centering on Bus Rapid Transit (BRT)." Specifically, it is characterized by interaction of three features:

① a road system with three trunk roads forming an urban hub
② a bus system with routes classified by function as trunk or branch routes, etc.
③ land use to densely concentrate functionality around the urban hub.

In recent years, "citizenship streets" with government offices and other public facilities as well as sports facilities and retail stores selling convenience items, etc., that are freely accessible by bus users, have been built next to the transfer terminals in a number of city districts.

Seoul began reorganizing its bus routes into trunk and branch routes in 2004, and is building transfer terminals in 22 locations. It is reported that it is now possible to carry more passengers with lower kilometrage and fewer buses in operation than before the reorganization.

A projection of transportation demand after reorganization of bus routes and estimation of CO_2 emission reductions due to route reorganization was carried out targeting Nagano City, Nagano Prefecture and Aomori City, Aomori Prefecture, both of which have been considering proposals on reorganizing routes since the beginning of the century. With the current inter-zone daily OD traffic volume (car trips + bus trips) as a given,

Table 1: Aomori City - CO2 Emissions before and after Bus Route Reorganization ［t-CO2/year］

	Buses	Cars	Total
At Present	16,781	85,243	102,024
After Reorg. (change %)	11,383 (-32.2%)	85,335 (+0.1%)	96,718 (-5.2%)

Table 2: Nagano City - CO2 Emissions before and after Bus Route Reorganization ［t-CO2/year］

	Buses	Cars	Total
At Present	11,830	244,448	256,278
After Reorganization (change %)	4,550 (-61.5%)	240,659 (-1.6%)	245,209 (-4.3%)
Reorg + Facilities (change %)	4,545 (-61.6%)	239,438 (-2.0%)	243,983 (-4.8%)

only the stages of modal choice between cars and buses and of allocating car/bus users and bus users to the network were handled. The modal choice model already estimated for both urban regions was used at the modal choice stage. The emission intensity per vehicle type and speed was applied to traffic volumes and speeds per link per vehicle type derived from the allocation calculation, in order to calculate CO_2 emission levels.

In the "Report on the Aomori City Bus Route Development Planning Study (Bus Transport Activation Plan)" published in Aomori City in 2002, the problem of excess supply due to overlap of bus routes in the inner city was pointed out, and a proposal was made to reorganize the bus routes to resolve this problem by establishing backbone, trunk and feeder routes, facilitating transfers by adjusting schedules and enabling transfers from the same location, as well as giving priority to buses in segments with multiple lanes. Estimates of the CO_2 emission reduction effect of this reorganization plan are given in Table 1.

In Nagano City, the current bus route network has many similar routes with overlapping segments; many routes are in a radial pattern starting or ending at Nagano station or the bus terminal. Concentration of many routes in these areas is not only inefficient use of buses but also is a cause of traffic congestion in the central urban district. Therefore, a bus route reorganization plan was developed using the functional categories of backbone, trunk and feeder route buses; large buses would be operated frequently along high-demand trunk routes centering on Nagano station, and small feeder buses would be used to pick up and drop off passengers in areas with lower demand. Estimates of the CO_2 emission reduction effect of this reorganization plan are given in Table 2. Furthermore, a questionnaire survey of 600 users of bus stops in southern Nagano City was conducted prior to the analysis, to estimate whether facilities enabling various activities in the transit terminals would alleviate users' resistance to transfers. It was found that such facilities had an effect equivalent to reducing riding time by 12.8 minutes when under time pressure and 11.7 minutes when not. This effect has been taken into account in the estimates of Table 2.

The results indicated that reorganization of bus routes would lead to a reduction in CO_2 emissions of about 4-5% in both cities. This is not only due to more efficient transport leading to a reduction in vehicle kilometers traveled, but also due to an increase in the modal choice rate of buses helping to reduce traffic volumes and improve travel speeds in Nagano City. Furthermore, facilities enabling various activities in the transit terminals were found to contribute slightly to CO_2 emission reductions.

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A BACKCASTING METHODOLOGY TO DEVELOP A VISION FOR THE FUTURE

Visions on the future of transportation were reviewed using backcasting methodology. It was found that the feasibility of drastic reductions in CO_2 emissions increases by combining a variety of means including not only technological innovation but also demand adjustment. Furthermore, factors influencing the direction of future scenarios were identified from interviews of experts.

The OECD/EST (Environmentally Sustainable Transport) Project [1] is an example of an attempt to develop scenarios of transportation using backcasting methodology. The "Sustainable Mobility Vision" of the World Business Council for Sustainable Development (WBCSD)[2] is in marked contrast to the OECD/EST Project in that it uses a forecasting methodology to predict emissions after implementation of a combination of measures. It also assumes that traffic demand should not be restrained but rather that technology will create additional demand. It considers a combination of the following four measures.

1) Carbon-neutral fuel (reducing CO_2 emissions at least 80%)
2) Extremely fuel efficient powertrains (drive systems)
3) Transition toward transport modes using larger vehicles
4) Improvement of traffic flow and transport activities due to better integration of transport systems using information technology (IT).

Though a modal shift toward railways and similar transportation systems is considered as a potential means for increasing transport efficiency, it is noteworthy that there is no mention of making cities more compact to facilitate walking.

As for studies that follow or improve upon the methodology of the OECD/EST Project, there is a case study[3] from Germany in which less aggressive traffic planning targets are set than in the OECD/EST Project and concrete figures for transport mode choice rate are given. There are also case studies in which a number of patterns of change in external factors are indicated, and the future direction to meet the goals with each pattern is determined.[4,5]

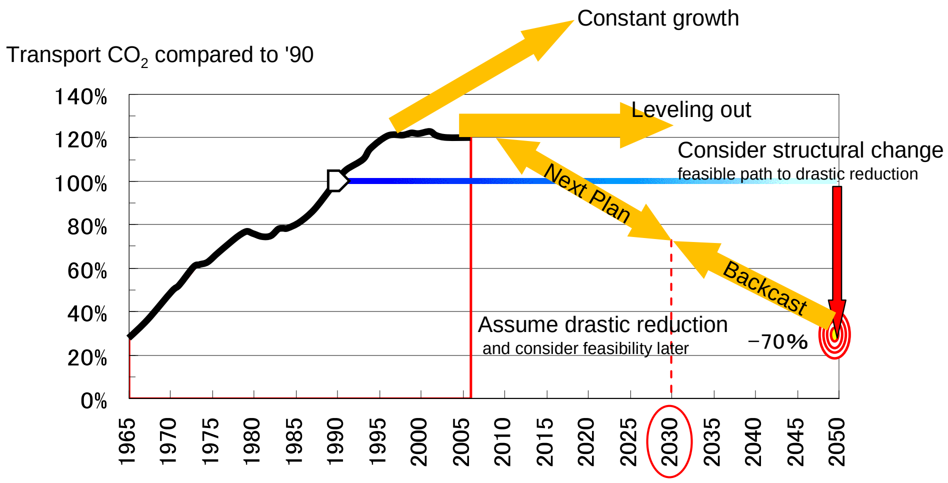


Figure 1: An Image of Drastic Reduction Scenarios using the Backcasting Method

The impact of external factors on the future direction is expected to be significant in Japan, particularly considering its declining population and changing position in international society.

On review of case studies concerning adoption of visions and/or scenarios regarding transportation, it was felt that envisioning the society, economy and lifestyles of the future was most important. Thus, views of experts were garnered in group interviews. The expert interviews were held as group interviews to listen to the views of 3-4 people gathered in a roundtable format. About 20 candidates who lead their respective fields of urban planning, transportation, the environment, energy, lifestyle, etc., were selected, and eleven of them

Table 1: Factors, etc., with a Major Impact on Scenarios, and Differences of Opinion

	Social (Driving Forces)	Cities & Transportation	Measures
Small Differences in Opinion	Trends of families with fewer children and an aging population Decline in GDP	Location of urban infrastructure is fixed Major changes are possible in transportation and land use and at a local level Increased need for travel	Use of tax incentives Building public transport infrastructure with funds earmarked for roads Making it popular to care for the environment
Large Differences in Opinion	Accepting immigrants Rise of China & India, Decision-making, Crude oil prices	Housing trends, Changes in basic mobility needs, Changes in the need for speed, Resource recycling, Fuel cell vehicles	※Varied measures

who were able to participate in a 2 hour meeting on one of three days in mid-March, 2005 served as the respondents. The topic of discussion was "Future Prospects of Mobility Modes in 2050"; respondents were asked "what modes and forms of transportation of people and things could be expected in 2050 if no thought is given to realizing a low-carbon society" and "what modes of transportation and social circumstances could be expected if Japan is to reduce its CO_2 emissions 60% below 1990 levels (64% below 2002 levels) by 2050 in order to achieve a low-carbon society."

The following keywords were mentioned by experts as they discussed their visions for 2050 in the interviews.

Catastrophe in the period of transition to 2050, mistrust in science and technology, decentralized decision-making systems, globalization, slow life, natural energy, local production for local consumption, IT, hydrogen society, efficiency, time, speed of mobility, redundancy of infrastructure, IT to compensate for mobility, solar energy, an energy hunting / energy cultivating civilization.

Many expressed the view that it is difficult to make projections as 2050 is too far in the future.

Social factors (driving forces) with a large impact on transportation scenarios were grouped according to the extent of differences in opinion in Table 1 with consideration of these views and scenario adoption methodologies.[6] Concepts and policies concerning cities and transportation were also summarized in the table. Factors subject to large differences of opinion have been listed in the lower row, and are thought to be useful when incorporating measures geared to local characteristics into scenarios. Factors considered as relevant to a low-carbon society include accepting immigrants, rising economic levels of China and India, decision-making schemes, and crude oil prices. These should be priority topics for research. Factors considered relevant to transportation in particular include housing trends, fundamental mobility needs, the need for speed, the scale of resource recycling, and the feasibility of promoting fuel cell vehicles. Future scenarios need to be interpreted with attention to the fact that they will vary greatly depending on these factors.

References

1) OECD (2002): “OECD Guidelines towards Environmentally Sustainable Transport”

2) World Business Council for Sustainable Development (WBCSD) (2004): “Mobility 2030”

3) J. Whitelegg et.al.(2003): “Selected international transport investment and funding frameworks and outcomes”, A report for the Australian National Transport Secretariat, Eco-Logica reports

4) P. Steen, K.H. Dreborg, J.Åkerman (1998): “Policy Scenarios for Sustainable Mobility in Europe – the POSSUM Project”, Environmental Strategies Research Group/FOA

5) A. Tuominen (2001): “Strategic Impact Assessment Methods for future transport in Europe”, NECTAR Conference 6 (Espoo, Finland)

6) Scenarios for Sustainability (2005.12.15): http://www.scenariosforsustainability.org/howto_recipes.php

(K.Matsuhashi, Y.Moriguchi: NIES)

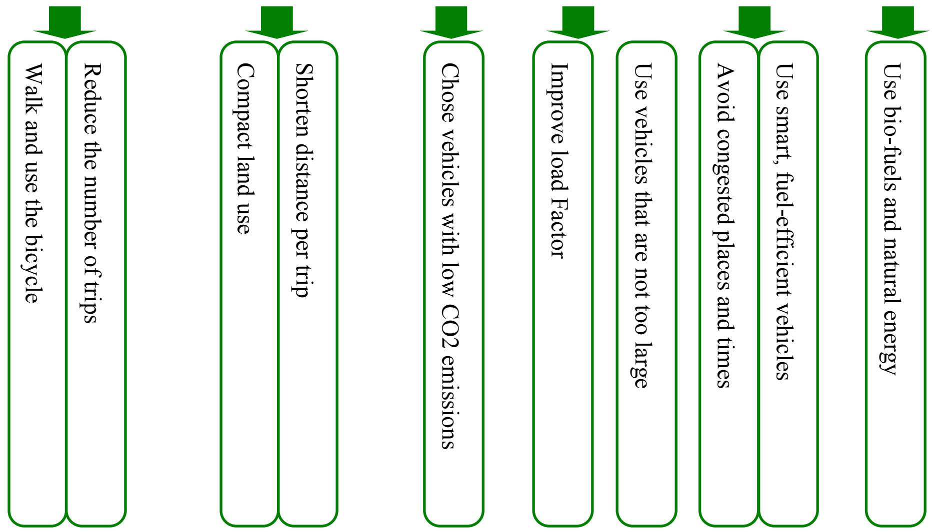
AN EQUATION SHOWING THE COMPOSITION OF TRANSPORTATION SECTOR CO_2 EMISSIONS

An equation showing the composition of traffic sector CO_2 emissions was proposed, and it was argued that a reduction of 74% could be achieved by reducing 6 terms by 20% each. It was argued that combining various measures is not only effective in preventing the reduction effect of one factor from being cancelled out by increase of another factor, but also makes reductions relatively easier.

Equation (1) was developed to show the composition of CO_2 emissions due to transportation in terms of the factors of transportation service volume, travel distance per access, means of transportation, transport efficiency, fuel efficiency and CO_2 emission intensity of fuel. As in the case of the OECD/EST project, which presented scenarios combining technology with behavior change, it is thought to be more feasible to achieve drastic reductions by combining multiple reduction measures than by relying on just one factor. For instance, it was estimated that by adopting measures to reduce each factor by 20%, a total reduction of 0.8 times to the sixth power, namely, 74%, would be possible.

Transportation Sector CO_2 Equation (1)

$$\frac{CO_2}{capita} = \frac{TransServ}{capita} \times \frac{Pkm\ (Tkm)}{TransServ} \times \sum_{Mode}\left(\frac{Vkm}{Pkm\ (Tkm)} \times \frac{Fuel}{Vkm} \times \frac{CO_2EF}{Fuel}\right)$$



Measures relevant to each factor in Equation (1) are explained in sequence, starting with the rightmost term. The first term concerns measures to decrease the CO_2 content per unit of consumed fuel. This includes, for instance, use of natural energy such as electricity from photovoltaic power generation and wind power generation and use of biomass fuels, as well as relying on technology for nuclear power generation, coal power generation, or use of coal gasification and liquefaction technology, combines with carbon capture and storage and the like.

The second term concerns measures to reduce the fuel consumption per traveled distance. It includes developing, promoting and using fuel-efficient vehicles, as well as operations that avoid locations and time periods with traffic congestion, which tends to worsen fuel efficiency.

The third term concerns measures to increase the transport volume per traveled distance. It includes reducing the distance traveled per transport volume by increasing the average number of passengers or average loadage per vehicle. Use of a vehicle that is not too large and matches with the number of passengers or loadage leads to improved fuel efficiency.

The fourth term concerns measures to increase the mode choice rate of transportation modes with high loading ratio, good fuel efficiency and low carbon intensity. It includes conversion from automobiles, airplanes, etc., to railway, buses, freight ships, and the like.

The fifth term concerns shortening the distance of each trip. It includes making more compact use of land and promoting use of nearby facilities.

The sixth term concerns measures to reduce the frequency of travel using energy. It includes conversion to bicycles, walking, hand-cart, and other means not requiring energy use, as well as reducing the number of trips by completing multiple errands in one place or using ICT (information and communications technology).

Measures to develop roads in order to increase travel speeds and thereby improve fuel efficiency are known to induce traffic, leading to shifts in transportation mode and increased transport distances; attention should be paid to the fact that such measures may not necessarily reduce CO_2 emission on the medium- and long-term.

The further to the left in the equation, the more implementable measures depend on local circumstances. Thus, the reduction potential is expected to increase if transportation measures geared to local characteristics are given due consideration.

References

1) Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism (2005): "Report of the Road Policy Council for the Prevention of Global Warming"

(Y.Moriguchi, K.Matsuhashi: NIES)

AUTOMOTIVE CO_2 EMISSIONS ACCORDING TO REGION TYPE

The current status of automotive CO_2 emissions nationwide was made known. Whereas metropolitan areas had per capita CO_2 emissions of approximately 1.0 t/person/year, the small and medium cities and rural counties of other regions had levels about twice as high of approximately 2.0 t/person/year.

In order to drastically reduce transportation sector CO_2 emissions in Japan, it is important to curb CO_2 emissions from automobiles, which account for about 90%. The results of estimation of CO_2 emissions from automobiles according to municipality in FY 1999[1)] and estimates of emissions in FY 2005 were used to calculate automotive CO_2 emissions by region type, as shown in Figures 1 and 2.

Though the three metropolitan regions account for 50% of population, their share of emissions was less, accounting for only 42%. Whereas the wards and urban districts of the Tokyo and Kyoto-Osaka-Kobe metropolitan areas had CO_2 emissions of approximately 1.0 t/person/year, the small and medium cities and rural counties of other regions had levels about twice as high of approximately 2.0 t/person/year. In the Tokyo metropolitan area, the levels were highest in the small satellite cities and rural counties, whereas in other regions they were lowest in ordinance-designated cities; in both of these cases, the levels were approximately 1.5 t/person/year. In light of the contributions by region type to Japan's overall emissions, and the potential to substitute transportation modes, reduction in regions with intermediate levels is thought to be most important. Specifically, it is important to introduce transportation measures leading to reduced CO_2 emissions from automobiles especially in small satellite cities and rural counties in the Tokyo metropolitan area, throughout the Nagoya metropolitan area, and in medium and large cities in other regions.

It should be noted that the figures for kilometrage driven based on survey data of the origin to destination of automobile trips used for these estimations are less than the kilometrage figures of the Statistics on Motor Vehicle Transport.
For this reason, the nationwide average per capita CO_2 emissions in 2005 were estimated to be 1.53 t/person/year, which is slightly less than the figure of 1.76 t/person/year given in the National Greenhouse Gas Inventory Report of Japan.

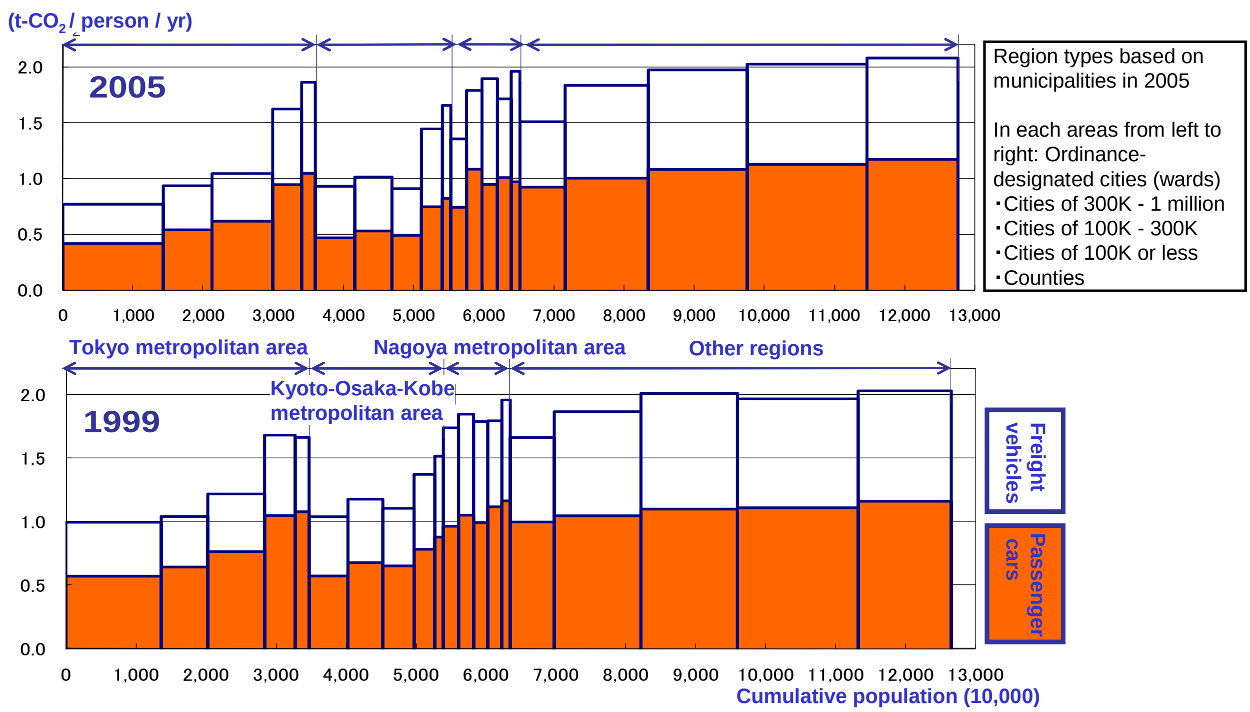
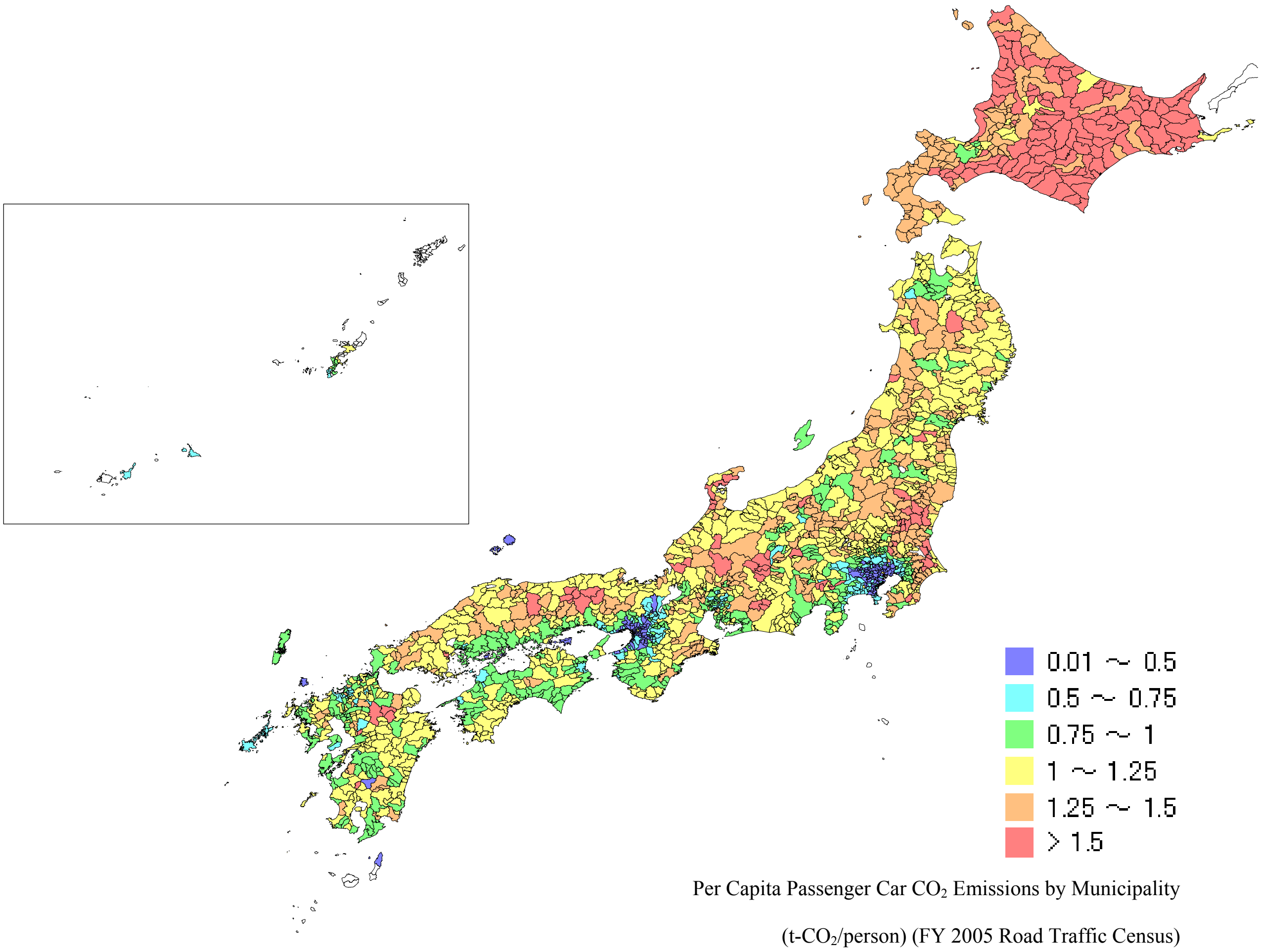


Figure 1: Per Capita Automotive CO_2 Emissions by Region Type



Per Capita Passenger Car CO_2 Emissions by Municipality

(t-CO_2/person) (FY 2005 Road Traffic Census)

Figure 2: Regional Characteristics of Automotive CO_2 Emissions [2)]

References

1) K. Matsuhashi, Y. Kudoh, N. Kamioka, Y. Moriguchi (2004): "A Comparative Study of Estimation Methodologies regarding Transport Sector CO_2 Emissions of Municipalities," Proceedings of the Annual Meeting of Environmental Systems Research, 32, pp. 235-242

2) Environmental Information Center of the National Institute for Environmental Studies (2009): "Environmental GIS," http://www-gis.nies.go.jp/

(K.Matsuhashi, Y.Moriguchi: NIES)

(Y.Kudoh: AIST)

A VISION FOR LOW-CARBON TRANSPORTATION IN 2050 THROUGH A COMBINATION OF MEASURES

In light of the current situation of automotive CO_2 emissions according to municipality nationwide, a vision for low-carbon transportation was developed using a combination of various region-specific measures; it was projected that CO_2 emissions could be reduced approximately 70% thereby. It should be kept in mind that there is room for variation in the balance between technological and traffic demand adjustment measures that are combined.

In light of the current situation of automotive CO_2 emissions according to municipality nationwide, transportation measures relevant to factors affecting transportation sector CO_2 emissions were considered, and a draft vision to achieve a 70% reduction through a combination of region-specific transportation measures was developed as shown in Figure 1. With regard to intra-city passenger transport, four regional categories were indicated column-wise, namely, the metropolitan urban areas, metropolitan suburbs, provincial urban areas and provincial rurals. Measures affecting terms in the transportation sector CO_2 equation (1) were indicated in the rows. Examples of measures applicable to each regional category and reductions achievable with them were shown in the columns.

Metropolitan urban areas were thought to have already achieved high densities conducive to pedestrian mobility, leaving little room for further reductions. Suburban areas were considered to have relatively more potential to shift to walking and bicycle use through consolidation of neighborhoods. In the urban areas , it was assumed that an increase in population density due to redevelopment and reappraisal of the urban areas combined with reduced support for development of regions distant from the urban areas could reduce travel distances approximately 10%. With regard to a modal shift, there was considered to be large potential for reductions due to introduction of LRT (Light Rail Transit) and BRT (Bus Rapid Transit) in regional cities. This is because they are thought to be economically viable in many regions, if infrastructure development costs are excluded. It was estimated that improved fuel efficiency through use of hybrid vehicles that are most effective in metropolitan areas as well as improved efficiency of railroads, could achieve a 20% reduction in fuel consumption. It was felt that increasing population density in suburban areas would not be possible to the extent feasible in cities. Such figures were added up to estimate the per capita reductions in CO_2 emissions by regional category.

The estimates were revised repeatedly with the aim to develop a vision for CO_2 emission reductions with high feasibility using a well-balanced combination of technical and

Table 1: 2050 Passenger Transport Vision Draft[1)]

	Metro Urban	Metro - Suburbs	Provincial Urban	Provincial Rurals	Total
Compact neighborhood	△ Rehabilitation	○ Rehabilitation	△ Rehabilitation	○ Compact settlement	112->33Mt Compared to 1990 -70% (incl. inter-city passenger transport 30 km-) Legend: ◎: -30% ○: -20% △: -10% ×: no reduction
Compact city	△ City center renewal	△Withdrawal	△ City center renewal	×	
Enhance transit	△ Pricing	△ Park & ride, etc.	○ LRT	△ Shared taxis	
Improve loading efficiency	△ Use small vehicles		△Enhance ride-sharing	×	
Improve fuel efficiency	◎Urban mode	○ Suburban mode			
Low-carbon energy	△	○ Bio-fuels and low-carbon electricity for electric vehicles etc.			
Population (1 mill.)	46→40	15→12	27→20	35→23	124→94
t-CO_2 / person	0.66→0.27	0.94→0.35	1.03→0.38	1.11→0.51	0.90→0.35

Table 2: 2050 Freight, etc., Transport Vision Draft

	Inter-region freight: 300 km-	Inter-city freight: 30-300 km	Intra-city freight: -30km	(Inter-city passenger transport: 30 km-)	Total
Supply chain management	○ SCM		△ SCM		106->32Mt Compared to 1990 -70% (excl. inter-city passenger transport 30 km-) Legend: ◎: -30% ○: -20% △: -10% ×: no reduction
Compact city			○ Shorten route	△-X Modal shift promotion	
Modal shift	○ Ship, railway	△ railway	△ Hand cart	◎Railway, express bus	
Improve loading efficiency	△ Reduce delivery frequency	△ Corporative delivery	△ Corporative delivery	○ Ride-sharing	
Improve fuel efficiency	○ ITS, fuel-efficient trucks	◎ITS, Fuel-efficient trucks	○ ITS, fuel-efficient trucks	◎ITS, Fuel-efficient trucks	
Low-carbon energy	△ Bio-fuel			○ Bio-fuel, low-carbon electricity	
t-CO_2 / person	33→10	49→15	24→7	(35→10)	

traffic demand adjustment measures and varying projected reductions according to regional characteristics. Regarding changes in demographic composition by region, the assumptions of the scenario team of the Developing Visions for a Low-Carbon Society Project 2050 (scenario A) were used together with projections by the National Institute of Population and Social Security Research up to 2030 extrapolated further into the future.

A vision for CO_2 emission reductions in freight transport and inter-city passenger transport is also shown in Tables 1 and 2 with consideration of measures applicable to different travel distance ranges indicated in the columns. Relatively large reductions of freight transport volumes accompanying changes in production and business transaction schemes were also envisioned. It was rather difficult to develop a highly feasible vision as compared to passenger transport; there is thought to be room for further improvement.

It should be kept in mind that there is room for variation regarding region types, examples of measures (and their feasibility), reduction amounts, population projections, etc. It should also be noted that the relative weight of the measures for the future vision may vary greatly according to the direction taken with regard to Table 1.

Study sessions of experts were organized with contents as shown in Table 3 in order to brush up and increase the persuasiveness of the vision and scenarios for transportation and logistics in a low carbon society in 2050.

With reference to the many suggestions from the debates, two packages of measures to contribute to achieving a low carbon society in the field of transportation, namely "intensified land use around focal points and collaboration among transportation modes" and "promotion of light electric-powered passenger vehicles" were developed, and provided to the scenario team. They were applied to one of the twelve strategies to achieve a low-carbon society, namely, "Developing Towns For a Pedestrian Lifestyle."

Table 3: Overview of Study Sessions

Study theme	Date of meeting	Theme	Partial memo
Inter-regional logistics	1st 2007.10.15	Freight transport in 2050	Freight railway: monorail, Shinkansen, New Tomei Expressway. Structural change in business transactions: next day delivery, delivery fee included, ~ local brand label
	2st 2008.1.18	Environmental management of freight companies	Hub loading ratio 80%. Dollies used at 177 locations. Truck free delivery. Absence rate 60-70%. Railway 10% between Osaka-Tokyo, lack of freight rail capacity.
Land & transport in a low-carbon society	1st 2007.10.15	Transportation in 2050	Need to be realistic. Differentiate road use per segment and per means. Consolidation on long-term. Motivate citizens. Overseas collaboration.
	2st 2007.11.14	A renaissance in transport & logistics	Industrial competitiveness discussion group. Model projects. Improved transport efficiency + technology: personal commuter, automated parking
		Sustainable mobility project (WBCSD)	Mobility 2030 Fast technological change: fuel cell vehicle → electric vehicle. Bio-fuel vehicle →?
	3st 2008.2.18	Future prospects of automotive fuels	Reserves exist but are not being newly developed. Transport oil dependency to 80%. Recharging stands. GtL for heavy vehicles. Ensure quality with ETBE. Produce & consume domestically.

References

1) K. Matsuhashi (2011): " Reducing Carbon Dioxide Emissions in the Transport Sector," T. Onishi, H. Kobayashi, 'Low-Carbon Cities,' , Gakugei Shuppan-Sha CO., Ltd., pp. 84-104

(K. Matsuhashi: NIES)

PASSENGER CAR CO_2 EMISSION REDUCTION TARGET ACHIEVEMENT SCENARIOS BY REGION

It was demonstrated quantitatively that transportation measures combining nationwide promotion of fuel efficiency and vehicular technology with measures to downsize urban areas as populations decrease would be required to achieve low carbon intra-city passenger transport systems. The cost of implementation of such transportation measures was also estimated.

Transportation systems with low environmental burden that are feasible and suited to regional characteristics, as well as medium- and long-term policy packages towards their realization were proposed, focusing on passenger transport, as basic information necessary to realize low-carbon transportation systems (EST: Environmentally Sustainable Transport) in urban and outlying regions.

When preparing scenarios, the long-term (2050) reductions due to nationwide implementation of measures concerning fuel and vehicle technologies were first estimated, after which reductions due to transportation measures in each region required to compensate for the shortfall from the reduction target were calculated.

First, the private vehicle ownership rate and the driving distance per vehicle were estimated, and then a model was constructed to derive the private vehicle CO_2 emissions from multiplication of these estimates. The private vehicle ownership rate can be explained using parameters such as population density, working age population ratio, road length per population, availability of railway stations, etc. Driving distance per vehicle can be explained using parameters such as population density, availability of railway stations, etc.

Table 1: Vehicle Adoption Rates and CO2 Emission Intensities due to Driving in the Technology Innovation Scenario (EST1) (2050)

Vehicle	Vehicle type / segment	Fuel Consumption Reduction (relative to 2000)	Driving CO_2 Emission Intensity [g-CO_2/台 km]	Adoption Rate
Automobile	Hybrid	33.2%	114	60%
	Electric Vehicle	70.6%	55.5	40%
Bus	Hybrid	14.3%	647	100%
Railroad	Electrified	10%	—	
	Non-electrified	30%	—	

The model was used to estimate emissions in 2050 under a business-as-usual scenario (BAU) and a technological innovation scenario (EST1). Future demographics, which largely determine traffic volume, were estimated using the cohort method with age groups at 5 year intervals, assuming that current trends of birth rates, survival rates, and net migration rates would continue in the targeted municipalities. The habitable land area was assumed to increase in proportion to any population increases, but to remain constant with population decrease (a. the BAU scenario explained below). Assumptions regarding adoption of technology in EST1 used the adoption rates and emission intensities indicated in Table 1, drawing upon the "Energy Technology Vision 2100."

In the BAU scenario, a reduction (10.9%) in private vehicle traffic volume due to a decrease in population (21.8%) resulted in a 9% reduction in CO_2 emissions nationwide compared to 2000 levels, but the per capita emissions increased 16%. Meanwhile, in the EST1 scenario, the nationwide CO_2 emissions were reduced 65% and the per capita emissions were also reduced 56% compared to 2000 levels. However, the target of an 80% reduction nationwide could not be achieved, indicating the need to implement traffic demand management (EST2). In order to increase the reduction level from 65% to the target of 80%, emissions need to be further reduced (100-80) / (100-65) = 0.57 times; it is a difficult target indeed. The above relationships are summarized in Figure 1.

Therefore, the EST2 scenario was developed assuming a combination of measures such as introduction of new transportation systems capable of CO_2 emission reductions through large scale conveyance, and the development of access and egress facilities to support them (regarding selection of the transportation systems, please refer to the section on "System-wide Lifecycle CO_2 Emissions of Transportation"). Furthermore, in order for the large volume transportation

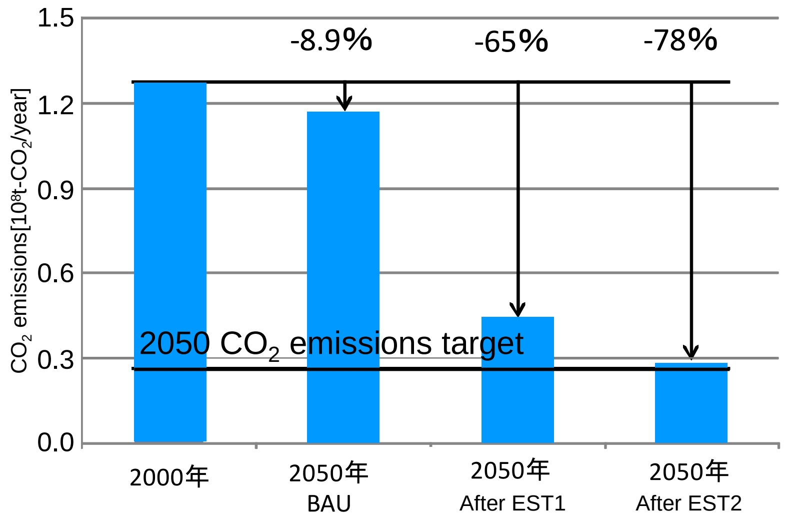


Figure 1: Personal Vehicle CO_2 Emission Reductions Achievable in the EST Scenario

systems to achieve their full potential for reducing CO_2 emissions, there is a need for substantial transport demand and thus for concentration of population along routes. However, if the decline in population continues it is likely that the concentration of population in urban areas will also decrease, so measures to downsize urban areas are needed to counteract this trend.

Therefore, the following three scenarios of urban area downsizing were posited in combination with the measures of EST2.

a) Business-as-usual scenario: The habitable land area was assumed to increase in proportion to any population increases, but to remain constant with population decrease.

b) Constant population density scenario: population density was assumed to be constant, such that habitable land area and DID (Densely Inhabited District) areas were made proportionate to population. Thus, urban areas decreased in area in accordance with population decline.

c) Urban area downsizing scenario: the habitable land area and DID area were assumed to be reduced to half of current (2000) levels. Though both values cancel each other out to the extent population decreases, the population density of both habitable areas and DIDs is increased in each transportation region.

The impacts of each of these scenarios on EST2 as well as estimates of the required level of introduction of new transportation systems to achieve the target, and the cost of their introduction are summarized in Table 2. It was found that the cost-effectiveness of CO_2 reduction measures was highest when urban areas are reduced in size; that of the urban area downsizing scenario in particular was about three times that of the business-as-usual scenario.

Figure 2: The Impact of Downsizing Urban Areas on Feasibility of Introducing Transportation Systems

Scenario	a) BAU	b) Fixed Pop. Density	c) Urban Downsizing
Reductions required in EST2 (post EST1)[Mt-CO_2/yr]	11.3	8.44	6.11
Areas Achieving Reduction Target with EST1 Alone	8(2.9%)	50(18.3%)	70(25.6%)
Areas Suitable for Introducing Core Transportation Systems	108(39.6%)	207(75.8%)	198(72.5%)
Average Required Route Length [km/region]	329	136	33.7
Reductions [Mt-CO2/year] Needed after Intro. of Core Transport Systems (EST2)	2.21	-0.04	-0.26
Core Transportation System Introduction Cost [Trillion Yen]	22.9	15.7	5.07
Cost-Effectiveness of CO2 Reductions [t-CO_2/ 1 million yen]	0.40	0.54	1.3

References

1) K. Itoh, N. Shibahara, H. Kato (2009): "Estimating the Needed Amount of Measure to Introduce Low Carbon Passenger Transport System for Each Region in Japan," Proceedings of the Symposium of Global Environment 17, Japan Society of Civil Engineers

(H.Kato: Nagoya Univ.)

TRANSPORTATION SYSTEM-WIDE LIFECYCLE CO_2 EMISSIONS

A methodology to evaluate the lifecycle CO_2 emission reduction effect and economic viability of developing and enhancing core public transportation routes was developed to assist selection of policy packages to achieve low-carbon transportation systems suited to local circumstances. It was found that LRT would be selected as the core public transportation mode in many cases, including in metropolitan areas.

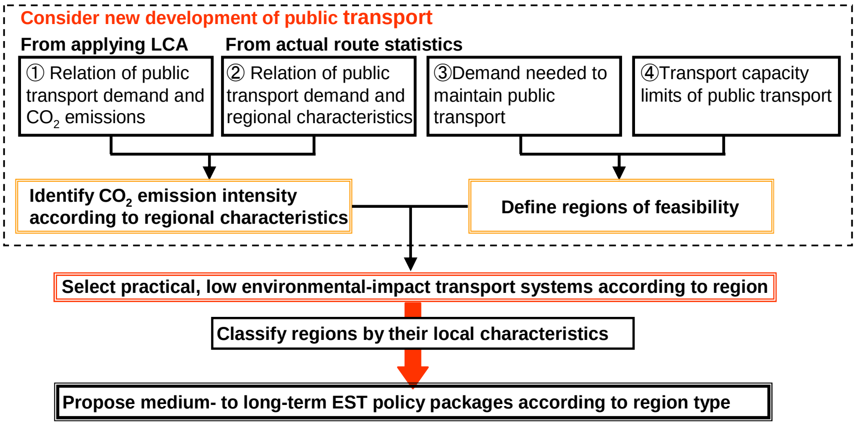


Figure 1: Core Public Transport Systems and EST Packages

A methodology for selection of transportation systems considering their CO_2 emission reduction effect and economic viability was constructed as shown in the flowchart of Figure 1, targeting development and enhancement of core transportation systems that can serve as a hub for regional transportation and be highly effective in reducing CO_2 emissions by facilitating consolidated transport and a shift away from automotive transport.

The CO_2 emissions per passenger kilometer using existing railways, buses and cars were compared with that of LRT(Light Rail Transit),BRT(Bus Rapid Transit), a new transport system (AGT; Auto mated GuideWay Transit),monorail, and GWB(GuideWay Bus), to consider the feasibility of new infrastructure development. LCA(Life Cycle Analysis) was used to estimate the CO_2 emissions of transportation including infrastructure development and vehicle manufacture, etc.

The results of estimation of SyLC-CO_2 (system-wide lifecycle CO_2 emissions of the transportation system) assuming round-trip demand of 10,000 people / day are shown in Figure 2. LRT was found to have the lowest SyLC-CO_2 through all stages of its life cycle. This is because only minimal infrastructure is required, and CO_2 emissions for manufacture of the rolling stock are low because they are lightweight relative to their passenger capacity. Furthermore, assuming that transport density affects the number of trips, the sensitivity of SyLC-CO_2 per person per kilometer traveled to transport density was analyzed. It was found that the transportation mode with lowest SyLC-CO_2 per person per kilometer traveled was BRT requiring the least infrastructure development when demand was less than 2000 people / day, whereas at higher demand levels it was LRT with low CO_2 emissions for both infrastructure development and operations.

Next, the results of estimation of SyLC-CO_2 per person per kilometer traveled by each means of transportation according to the DID population density along the routes is shown in Figure 3. Here, a distinction was made between LRT and BRT with low scheduled speed such as is common for streetcars in Japan and that with high scheduled speed using dedicated tracks or the centerlines of roads, and the trends for each of these categories were estimated. The CO_2 emission intensity of automobile driving (only) is also indicated for reference's sake (from FY2006 Transportation-related Energy Statistics Handbook). This value in the figure does not reflect any future technological innovation. Though the CO_2 emission intensity of driving private vehicles is likely to decline with the adoption of hybrid and electric vehicles, if similar fuel efficiency improvements occur for BRT and GWB, the net impact on these study results is not expected to be very large. At almost all levels of DID population density, LRT was found to be the transportation mode with the lowest SyLC-CO_2 per person per kilometer traveled. However, in regions with low DID population density, there are cases in which the environmental burden is lower using existing railways, bus routes or automobiles, than introducing new public transport such as LRT, BRT and the like. Furthermore, it is apparent that the range of DID population densities at which introduction of LRT or BRT would be effective in reducing CO_2 emissions is reduced if their scheduled speeds are at low levels (20 km/h or less) similar to that of many streetcars currently in operation.

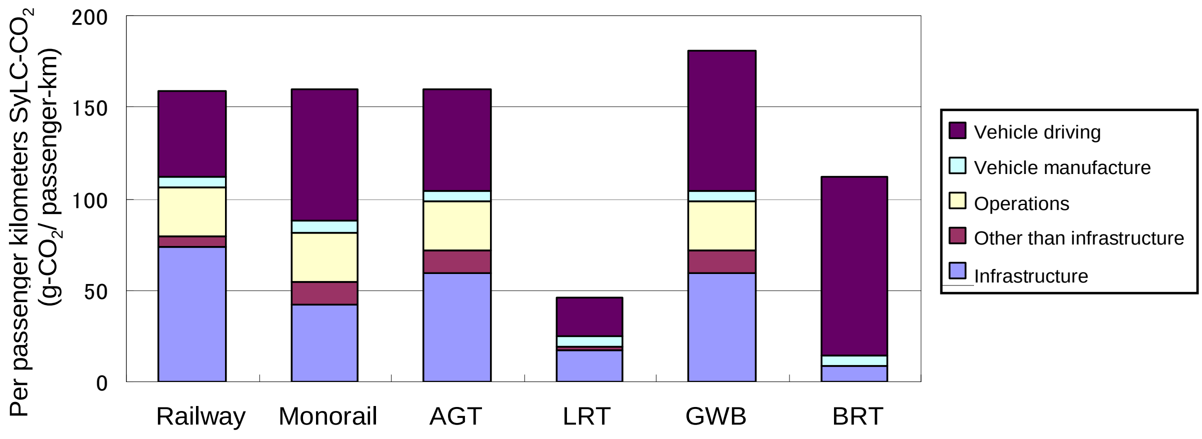


Figure 2: SyLC-CO_2 per person per kilometer traveled (demand: 10,000 people/day)

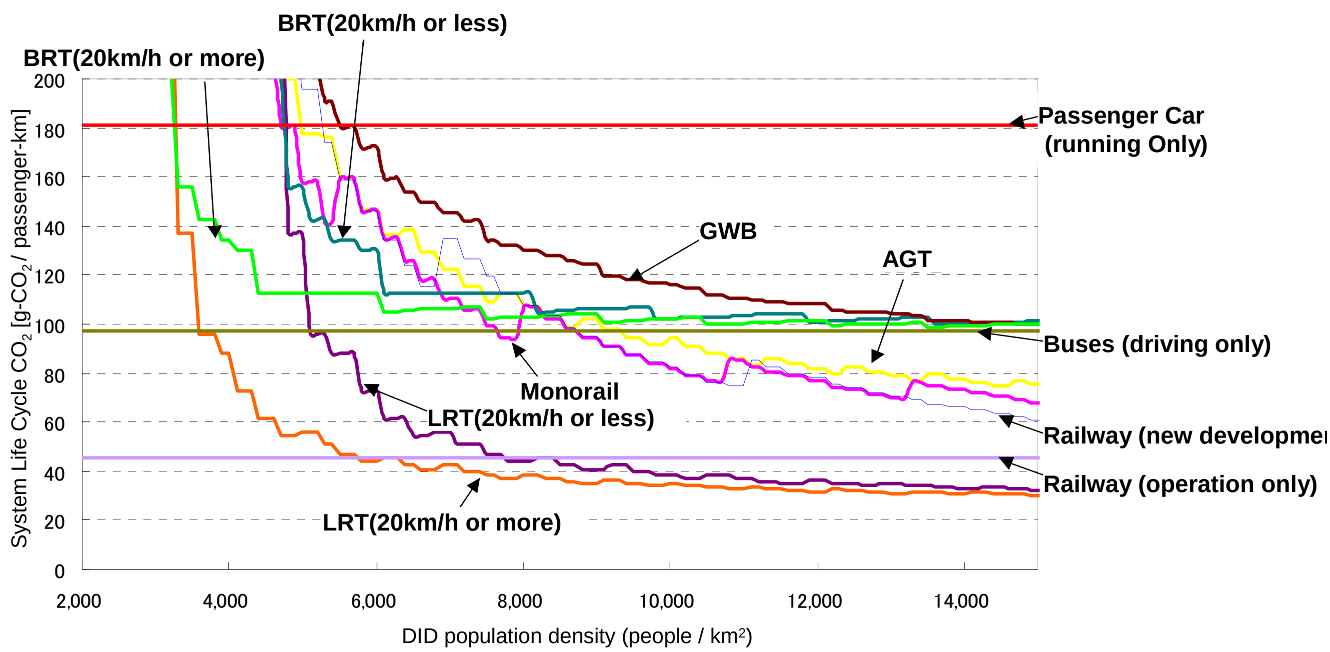


Figure 3: SyLC-CO_2 per person per kilometer traveled according to Variations in DID Population Density

It is possible to estimate the route lengths necessary to achieve the reduction targets, assuming that a modal shift away from private vehicles will occur in proportion to length of the new routes introduced. Estimations of the required route lengths in regions where LRT would be the new transportation mode of choice showed that the largest CO_2 emission reductions could be achieved in metropolitan areas and urban districts in outlying regions of Japan, suggesting that infrastructure development should focus on these regions.

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(H.Kato: Nagoya Univ.)

DEVELOPING ROADMAPS FOR REGION-SPECIFIC MEASURES SUITED TO TO CHARACTERISTICS OF TRANSPORTATION AND LAND USE

Urban areas nationwide were divided into 273 regional transportation areas, which were classified into 7 types according to characteristics of transportation and land use; roadmaps of long-term measures to develop low-carbon transportation systems were developed for each type.

Regional transportation systems have developed to link central cities with their suburbs in spheres of daily activity with close economic and social interactions. Urban areas nationwide were divided into 273 "regional transportation areas," and the characteristics of transportation and land use in their central cities were identified using principal component analysis as shown in Table 1, to examine measures to achieve low-carbon transportation systems at such a level.

Table 1: Results of Principal Component Analysis of Macro Indices for Classifying Regions

First Principal Component		Second Principal Component		Third Principal Component	
Dependency on automobile		Preference for walking and bicycles		Spaciousness of City	
Variable	Loading	Variable	Loading	Variable	Loading
Automobile	0.935	Walking/Bicycle	0.862	Habitable area	0.746
Walking/Bicycle	- 0.376	DID Population Concentration	0.347	Automobile	0.128
Habitable area	- 0.600	Habitable area	0.045	DID Population Concentration	0.113
Station Service Area / Land Area	- 0.672	Automobile	- 0.094	Public Transport	0.001
DID Population Concentration	- 0.746	DID Population Density	- 0.108	DID Population Density	- 0.092
DID Population Density	- 0.823	Station Service Area / Land Area	- 0.397	Walking/Bicycle	- 0.248
Public Transport	- 0.843	Public Transport	- 0.406	Station Service Area / Land Area	- 0.364
Eigenvalue	3.773	Eigenvalue	1.209	Eigenvalue	0.789
Proportion of Variance	53.90%	Proportion of Variance	17.27%	Proportion of Variance	11.27%
Cumulative Proportion of Variance	53.90%	Cumulative Proportion of Variance	71.17%	Cumulative Proportion of Variance	82.44%

The regional transportation areas were classified into one of 7 segments on the basis of the 3 principal components identified. The segments have the following characteristics.

1) Strongly dependent on automobiles: low concentration of population, and severe decline in public transport
2) Somewhat dependent on automobiles: low concentration of population with tendency to commute to work or school by automobile
3) Living close to work: compact cities suitable for commuting to work or school by foot or bicycle
4) Mixed: no distinct characteristics regarding concentration of population and use of transportation
5) Focal TOD: The city area is spread out but the population and facilities are concentrated so that public transport is highly convenient.
6) Concentrated TOD: The population and facilities are concentrated so that public transport is highly convenient.
7) Weak orientation toward public transit: the population is relatively highly concentrated, but public transport is not used so much

Table 2: Segment Classification Results

Segment	Central City of Regional Transportation Area
(1) Strongly car dependent	Nagai, Kitakata, Saku, Ootawara, Masuda, Kanoya, Yomitanson, etc. (13 regions)
(2) Somewhat car dependent	Abashiri, Kitakami, Tsukuba, Itoigawa, Gotemba, Fukuchiyama, Imari, Okinawa-shi, etc. (150 regions)
(3) Living close to work	Hakodate, Aomori, Akita, Matsumoto, Shizuoka, Tottori, Takamatsu, Saga, Naze, etc. (25 regions)
(4)Mixed	Chitose, Hachinohe, Kanazawa, Fuji, Nagano, Gifu, Fukuyama, Shimonoseki, Oita, etc. (63 regions)
(5) Focal TOD	23 Wards of Tokyo, Kobe (2 regions)
(6) Concentrated TOD	Odawara, Atami, Nosu-cho, Osaka-shi, Kurume, Naha (6 regions)
(7) Weak orientation toward public transit	Sapporo, Sendai, Niigata, Nagoya, Kyoto, Hiroshima, Fukuoka, Kumamoto, etc. (14 regions)

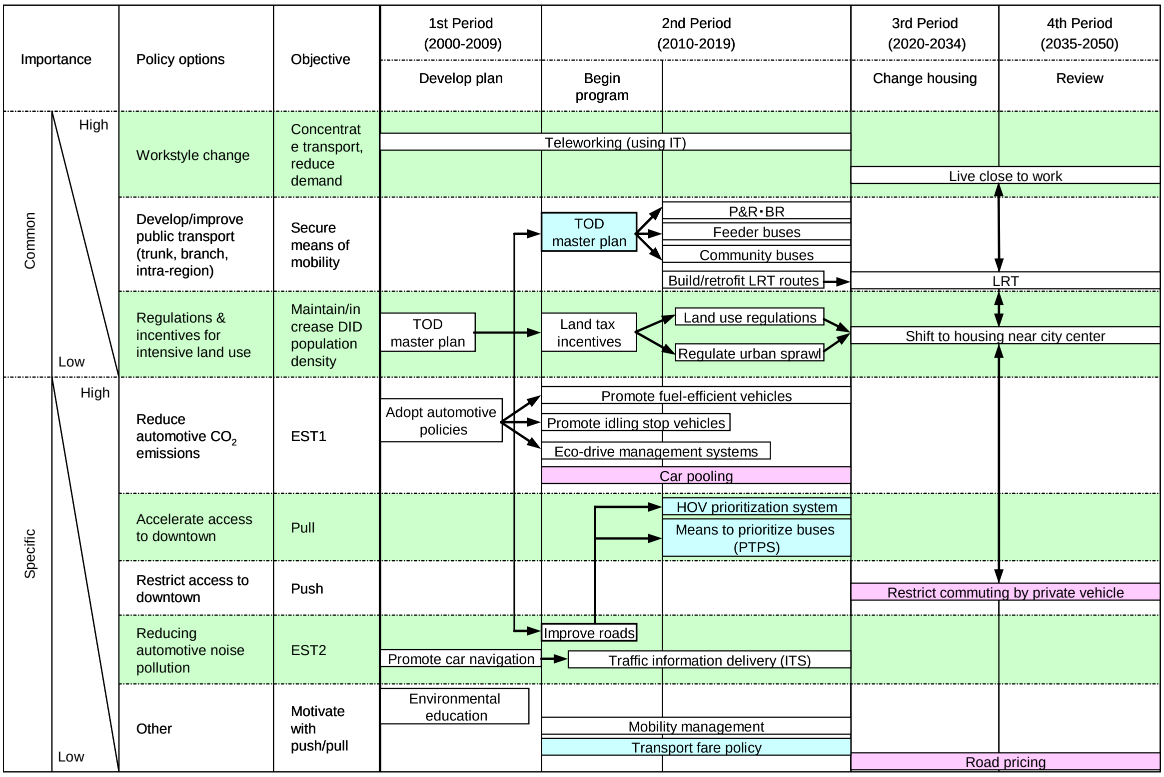

Figure 1: Draft Roadmap of EST Measures in a Regional Transportation Area Somewhat Dependent on Automobiles

Next, for each segment, roadmaps indicating time schedules for implementation of long-term transportation plans to achieve the CO_2 emission reduction targets were developed. The roadmap for cities that are somewhat dependent on automobiles, the type with the largest number of corresponding transportation areas, is shown in Figure 1 as an example.

Cities that are somewhat dependent on automobiles are unable to reduce CO_2 emissions by introducing mass transport such as LRT or BRT if they remain unchanged in size without downsizing. Therefore, their urban areas need to be downsized as population decreases. Urban downsizing was set forth as a clear objective in the master plan; measures regarding land use, transportation, etc., were planned and elaborated accordingly. When introducing core transportation systems, downsizing measures are emphasized at the initial phase to restrain urban sprawl. Downsizing is expected to progress as existing buildings reach their end of life en masse. Core transportation systems are built once there is sufficient demand for their introduction.

Characteristics and Goals of Roadmaps for Regional Transportation Area-Specific Measures

a) Package of measures to end dependency on automobiles
Region: 1) strongly dependent on automobiles, 2) somewhat dependent on automobiles
Characteristics: dependent on automobiles, lack of public transit, low population concentration
Goals: 1) reduce need to travel using IT, 2) make cities compact to increase effectiveness of developing public transport, 3) reducing direct CO_2 emissions from personal vehicles

b) Package of measures to build cities enabling living close to work
Region: 3) Living close to work
Characteristics: a relatively high mode choice rate for walking and bicycling = a compact urban area
Goals: 1) promoting walking and bicycle transport, 2) enhancing local public transport, 3) creating lively towns

c) Package of measures to maintain and reinforce the tendency to use public transport
Regions: 5) Focal TOD, 6) Concentrated TOD, 7) Weak orientation toward public transit
Characteristics: High public transport coverage and population concentration
Goals: 1) curbing private vehicle transport (push measures), 2) accelerating access to city center with public transport (pull measures), 3) introducing staggered commuting and flex time (avoid congestion)

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(H.Kato: Nagoya Univ.)

LONG-TERM SCENARIOS OF CO_2 EMISSIONS DUE TO INTER-REGIONAL PASSENGER TRANSPORTATION, DERIVED FROM AN AIR TRANSPORT DEMAND FORECAST MODEL

A simplified model to forecast long-term demand for inter-regional passenger transport was developed. It was projected that CO_2 emissions due to inter-city passenger transport could be reduced 40% below BAU by improving the fuel efficiency of automobiles, etc., and promoting the use of railways. Measures to promote a modal shift reducing CO_2 emissions from air travel in half are required for a 70% reduction.

The air transport demand forecast model announced by the Civil Aviation Bureau of the Ministry of Land, Infrastructure, Transport and Tourism was simplified for study of long-term scenarios regarding CO_2 emissions due to inter-regional passenger transport. The total number of passengers nationwide was forecast on the basis of population, GDP, etc., using a nationwide travel occurrence model, the number of passengers per transportation mode between 223 zones was forecast on the basis of travel time and cost per transportation mode using a transportation mode choice model, and the number of passengers per route was forecast on the basis of the travel time and number of flights per airport route using an air route choice model. Next, the number of passengers per flight was forecast on the basis of the number of passengers and route distances per air route using a per-flight passenger number estimation model. This was used to derive the number of flights per route, after which adjustments were made between the capacity limitations of airports and the number of flights, and again the number of passengers per route was calculated. This process was repeated until convergence. The result was multiplied with the CO_2 emission intensity to derive the CO_2 emissions.

The transportation mode choice and air route choice models of the National Institute for Land and Infrastructure Management were used without modification. A model based on GDP, which serves as an intermediate value between patterns of proportional population, was used as the nationwide travel occurrence model.

When making estimations for 2050, the following CO_2 emission intensities were assumed: maximum 50% for automobiles, maximum 80% for aircraft, and 90% for other transportation modes, compared to 2005 levels. The Ministry of Land, Infrastructure, Transport and Tourism forecasts that the fuel efficiency of automobiles will improve 23.5% in the eleven years from 2004; at that pace, the CO_2 emission intensity in 2048 would be 47.6% of 2004 levels. Furthermore, if all automobiles are converted to existing fuel-efficient models, the CO_2 emission intensity would be 42.5% even without technological innovation. A level of 50% is thus thought to be feasible. It was assumed that the average levels for aircraft in 2050 would be the same as the levels of new aircraft currently under development. It was supposed

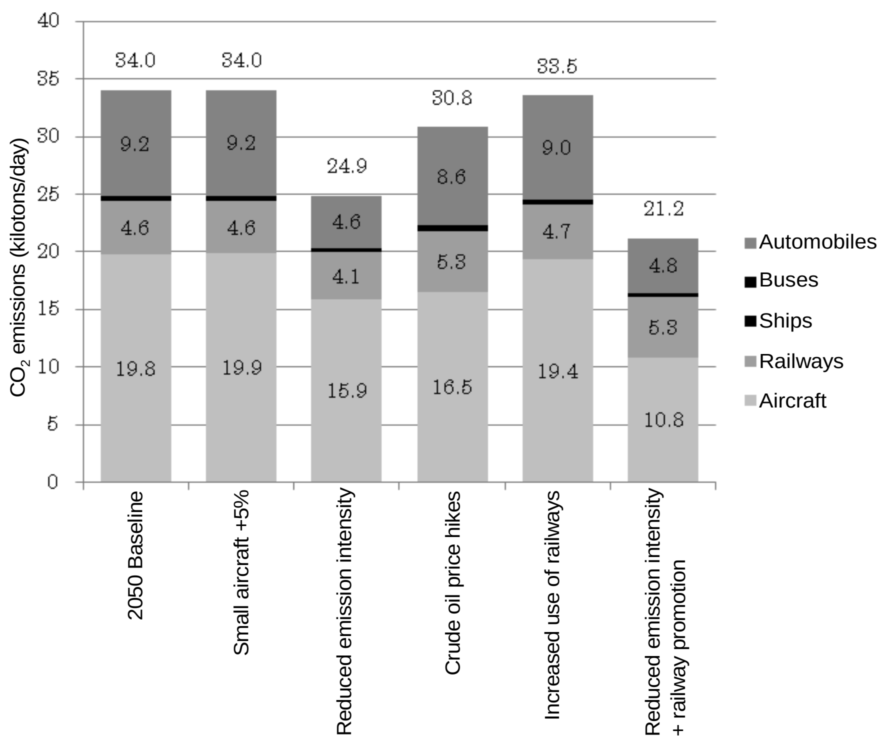

Figure 1: CO2 Emissions in 2050

that transportation networks would be enhanced with the opening of new airports, extension of Shinkansen lines, etc., by 2050. The proportion of large aircraft was assumed to be 35% in 2005 and 25% in 2050.

The "baseline case" in Figure 1 was estimated applying only the 2050 assumptions regarding transportation networks and the proportion of large aircraft. The nationwide travel occurrence model estimated that travel occurrences in 2050 would only be slightly less than in 2005, but that CO_2 emissions would decline as railroad use increases due to extension of Shinkansen lines, etc. The "small aircraft +5% case" assumes that the proportion of large aircraft is 5% less than in the "baseline case"; it is set such that there would be more frequent flights of smaller aircraft, but the CO_2 emissions are almost the same as in the "baseline case." The "reduced CO_2 emission intensity case" adds the assumption that CO_2 emission intensities for automobiles, aircraft and other would be 50%, 80%, and 90%, respectively, to the "baseline case." The "crude oil price hike case" assumes that non-railway transportation fares increase 20% and railway fares increase 10% due to higher crude oil prices. The "increased railway use case" has 10% more scheduled train trips than the "baseline case." The "reduced CO_2 emission intensity + railway promotion case" adds to the "reduced CO_2 emission intensity case" the assumption that railway fares are discounted 10% whereas automobile driving costs and airfares are increased 20%. The extent of reduction in CO_2 emissions is greater when the CO_2 emission intensity is reduced than when the number of scheduled train trips is increased. This shows that a crude oil price hike would be a factor for reducing CO_2 emissions.

Table 1 shows the variation in CO_2 emissions when fares, frequency, emission intensity and other indices are increased as well as decreased 20%. The sensitivity to changes in indices regarding air travel can be seen to be highest. This is thought to be because air travel accounts for a high proportion of inter-city travel. Sensitivity to train fares is also relatively high; this is thought to be because railways compete with automobiles for relatively short distance travel, and with airplanes for relatively long distance travel. The low sensitivity to automobile-related factors is thought to be due to factors such as the fact that the automobile is the only available transportation in some cases.

In order to intensify measures to achieve a 70% reduction by 2050 rather than the 40% reduction of this scenario, it is thought to be necessary to further halve CO_2 emissions from aircraft, which account for the highest proportion of emissions in inter-regional passenger transport. Use of bio-fuels in

aircraft is an option, but development of linear motor Shinkansen trains, or other high-speed transport systems can also be considered. Basically, it is thought to be most important to promote a modal shift by reducing train fares relative to airfares and driving costs.

Table 1: Indices' Impact on CO2 Emissions

	+20%	-20%
Car charges	-2.8%	3.1%
Car Intensity	4.0%	-4.5%
Train fares	7.5%	-7.6%
Train frequency	-2.7%	3.3%
Airfares	-10.0%	10.1%
Aircraft Intensity	11.7%	-11.7%

(T.Hyodo: Tokyo University of Marine Science And Technology)

DIFFERENCES IN EFFECTIVENESS OF MEASURES TO REDUCE CO_2 EMISSIONS FROM INTER-REGIONAL PASSENGER TRANSPORTATION, DEPENDING UPON THE ORDER OF IMPLEMENTATION

A combination of reduction measures was broken down into two components, namely, measures to "promote fuel efficient vehicles" and to "promote railways," and it was investigated whether the order in which the measures are implemented affects their effectiveness. Promotion of railways was found to have more immediate effect than promoting fuel efficient vehicles, and also to be preferable in terms of limiting cumulative emissions over a forty year period.

Setting a target of a 40% reduction in CO_2 emissions in 2050 compared to 2050 baseline levels, a combination of target-achieving reduction measures referred to as the "reduced CO_2 emission intensity + railway promotion case" was considered. The case was broken down into two components, namely "promotion of fuel efficiency" by encouraging purchases of fuel-efficient vehicles and reducing the CO_2 emission intensities of automobiles, aircraft and other transport to 50%, 80% and 90%, respectively, and "railway promotion" to encourage use of railways by discounting railway fares 10% while increasing automotive costs and airfares 20%. The difference in effectiveness due to the order of implementation was investigated.

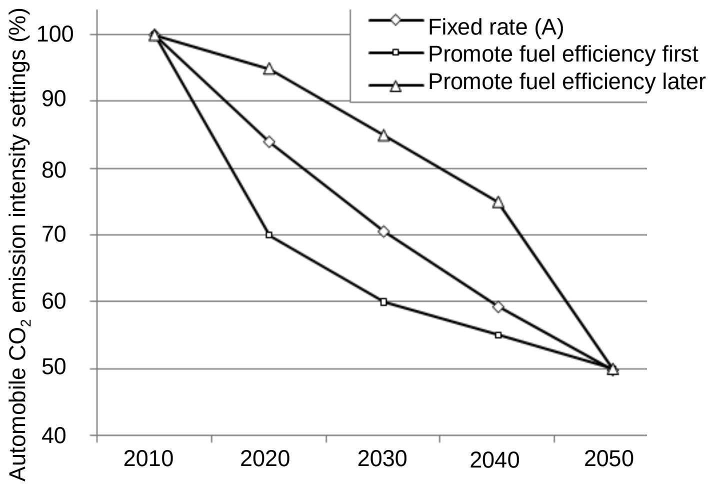

Figure 1: CO2 Emission Intensity during Implementation of Measures to Promote Fuel Efficient Vehicles

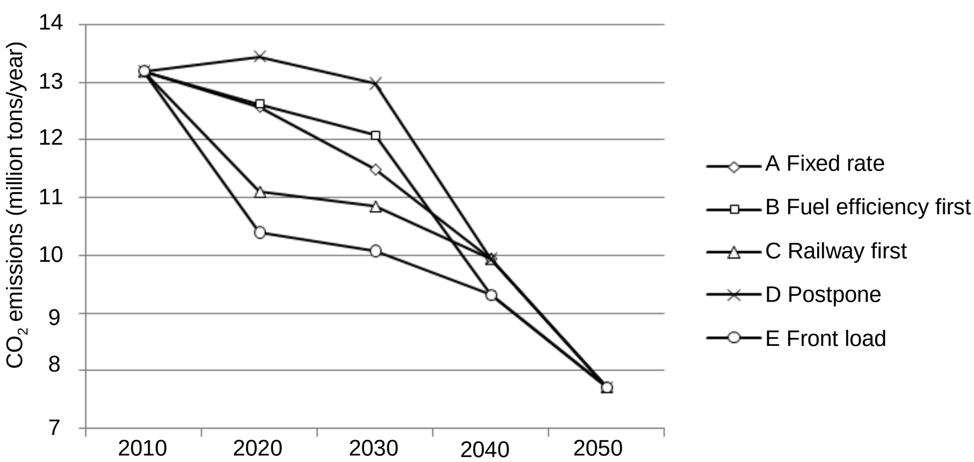

Figure 2: Variations in CO2 Emission Trends due to the Order of Implementing Measures

The cumulative CO_2 emissions for forty years from 2010 to 2050 were estimated for five patterns, namely, the "fixed rate" pattern A in which both measures are implemented at a fixed rate each year, the "fuel efficiency first" pattern B in which fuel efficient vehicles are promoted first (2010-2020) followed by promotion of railways (2030-2040), the "railway first" pattern C in which railways are promoted first followed by promotion of fuel efficiency, the "postponement" pattern D in which both are delayed, and the "proactive" pattern E in which both are front loaded. The variations in set values of CO_2 emission intensity during implementation of measures to promote fuel efficient vehicles are as shown in Figure 1.

In Figure 2, when comparing the CO_2 emissions over time between the "fuel efficiency first" pattern B and the "railways first" pattern C, one can see that until 2030 the emissions are less for pattern C in which railways are promoted first, but that the situation is reversed in 2040, indicating that promoting railways has more immediate effect than promoting fuel efficient vehicles.

Forty year cumulative emissions are shown in Figure 3. The difference between pattern E with lowest emissions due to front-loading of both measures, and pattern D with highest emissions due to delayed implementation of both measures, was as high as 66 million tons (equal to 5.0 years' worth of emissions in 2010 or 8.5 years' worth in 2050), whereas the CO_2 emissions of pattern C were 21 million tons less than those of pattern B. It was demonstrated that implementing measures to promote railroads first was more effective with this combination of reduction measures. However, it is thought that a greater CO_2 emission reduction effect would have been expected from measures to promote fuel efficient vehicles if the analysis had also covered intra-city short-distance transport, which relies more heavily on automobiles.

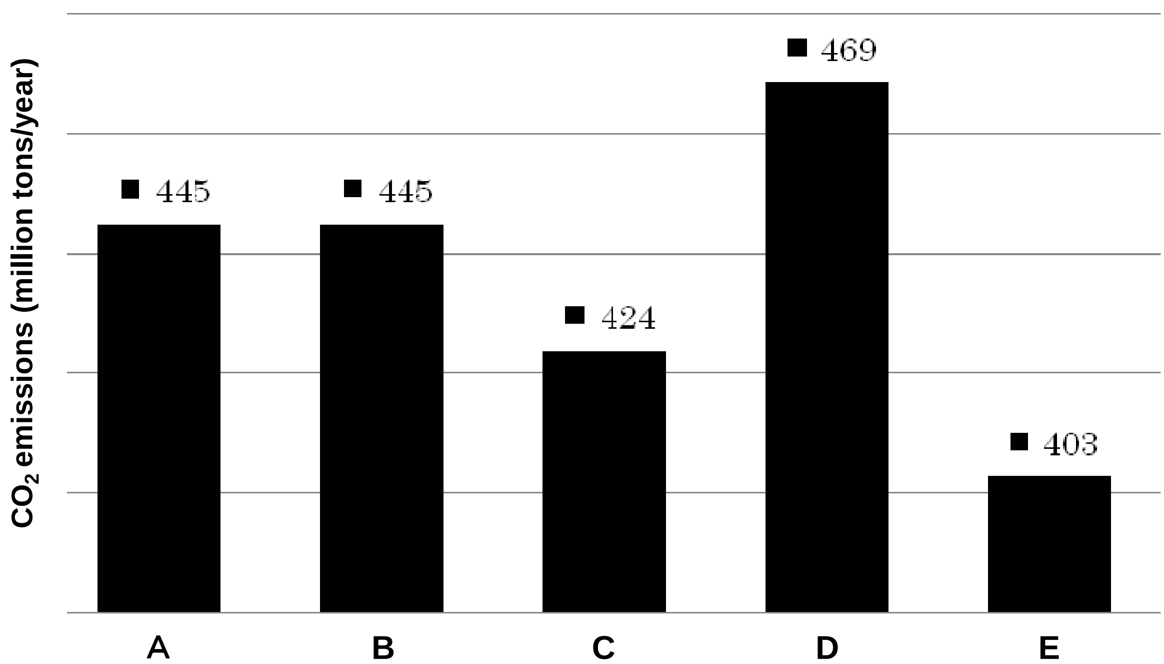

Figure 3: 40 Year Cumulative CO2 Emissions according to the Order of Implementing Measures

(T.Hyodo: Tokyo University of Marine Science And Technology)

FORECASTS OF FUTURE INTER-REGIONAL LOGISTICES AND EMISSION REDUCTION SCENARIOS

A simplified model to forecast long-term demand for inter-regional logistics was developed; it was used to show that it would be possible to achieve a 70% reduction in CO_2 emissions with a combination of measures.

One example of a study on forecasting of long-term demand for domestic freight transport is the "Long-Term Transport Demand Forecast Study" (Institution for Transport Policy Studies) (March 2000). [1] It presents a method for forecasting net flows per transport mode on the basis of the four step method. According to the 2005 Logistics Census, approximately 70% (in tons) of freight transport in Japan was by commercial trucks and other forms of automotive transport, and about 25% was by marine transport. Transport volumes in tons by item were highest for products from the chemical industry, followed by those from metallic and machinery industries and light industry. Region-wise, flows between prefectures in the Tokyo metropolitan area and between Aichi prefecture and surrounding prefectures were greatest.

The present study adopted the model structure shown in Figure 1 on the basis of the results of "Long-Term Transport Demand Forecast Study," provided that the demand forecast model was completed by integrating some variables and simplifying the model structure in light of constraints regarding usable data and the usability of the model, as well as to allow inclusion of future scenarios into the structure. A cross-section multiple regression model with the 2005 region-specific socioeconomic framework as an explanatory variable was used as the model to forecast occurrence and concentration of freight. In principle, the occurrence forecast model was developed considering supply factors whereas the concentration forecast model was developed considering demand factors. As for the ability of the model to reproduce the present situation, it was found to be possible to build a highly explanatory model with a coefficient of determination of 0.6 or more for most items. However, the coefficient of determination for forest and mineral products in the occurrence model was only around 0.5. The transport mode choice model was constructed as an aggregation type logit model of choice from among the three transport modes of railway, automobile and ship, targeting inter-prefecture OD transport volumes based on 2005 Logistics Census data. Total flows (tonne-kilometres) per transport mode in Figure 2, calculated by the mode choice model were multiplied with the CO_2 emission intensity per transport mode to obtain the CO_2 emissions in Figure 3 for each of the scenarios in Table 1.

A number of long-term reduction scenarios were posited, such as fuel improvement due to technological innovation, reduced emissions per transported tonne-kilometre due to improved loading ratios and other measures to improve the

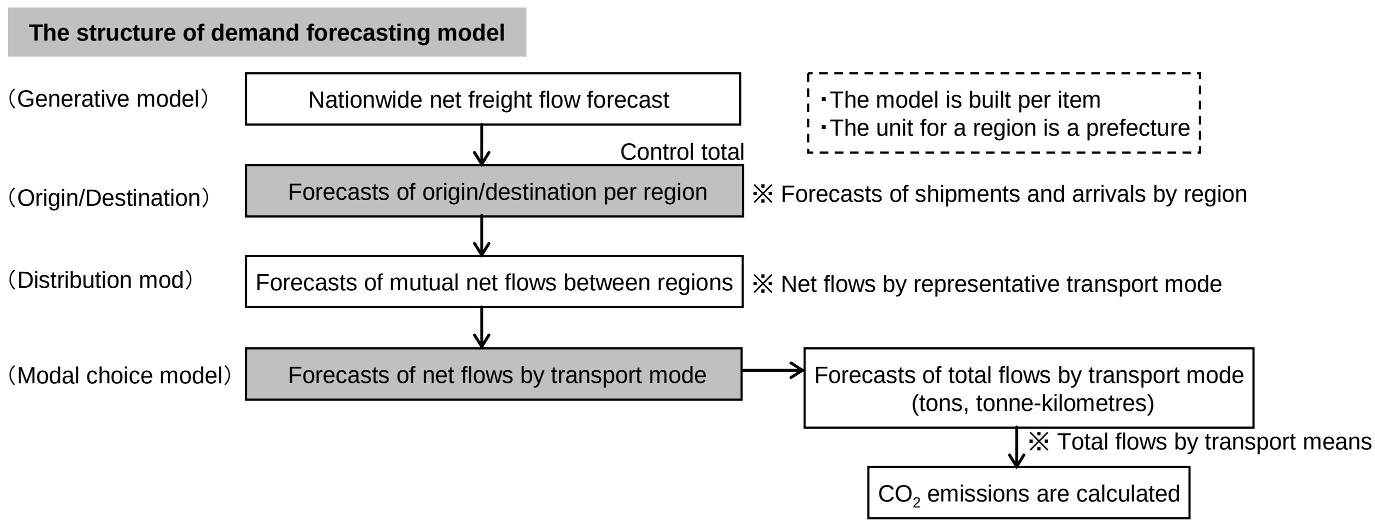

Figure 1: Inter-Regional Freight Transport Model Structure

efficiency of logistics, facilitation of intra-city traffic flows using ICT, and a modal shift due to reduced fares and travel times, etc. It was possible to posit a scenario enabling a 70% reduction by converting 50% of truck freight to rail freight in the prefectures in the Tokaido area (Saitama, Chiba, Tokyo, Kanagawa, Gifu, Shizuoka, Aichi, Mie, Shiga, Kyoto, Osaka, Hyogo and Nara prefectures) through such measures as construction of the New Tomei Expressway and the Chuo (Linear Motor Car) Shinkansen, etc.

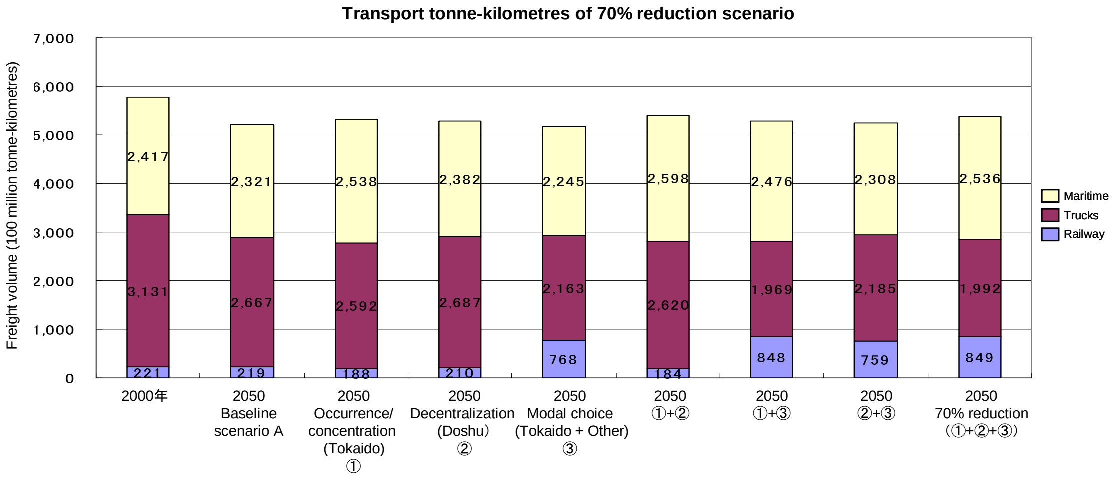

Figure 2: Transport Tonne-Kilometres per Scenario

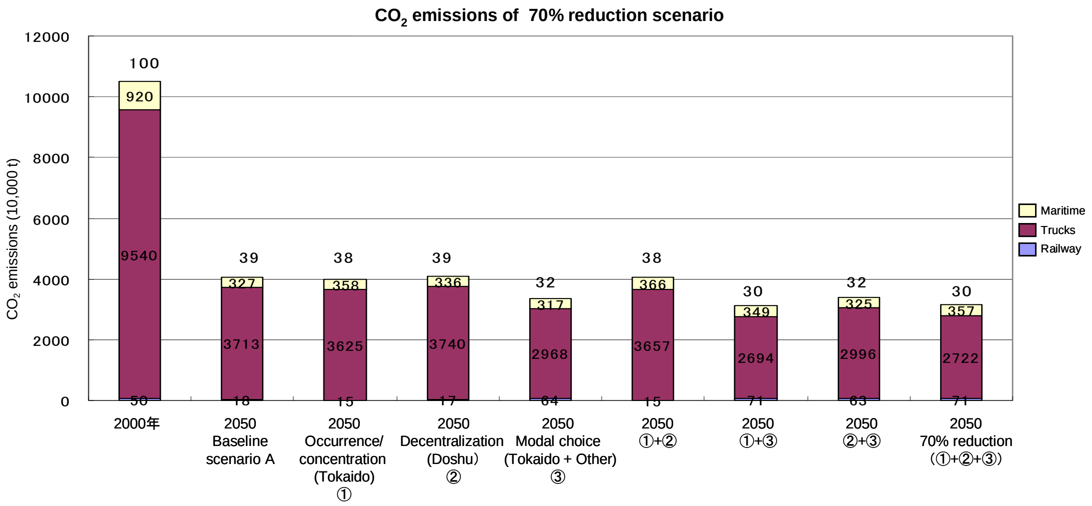

Figure 3: CO_2 Emissions per Scenario

Table 1: Baseline Scenario and Additional Scenarios

Model	Scenario
Baseline Scenario A	Economic development / technology-oriented society (improved energy efficiency, increased efficiency of logistics and reduced urban congestion through technological innovation)
Additional Scenario ①	Move industry to a region (Tokaido) facilitating use of transportation modes with low environmental burden (①)
Additional Scenario ②	Reducing distances between places of production and consumption (②)
Additional Scenario ③	Modal shift measures (development of new freight railway along Tokaido) (③)

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(T.Komeiji: Mitsubishi Research Institute, Inc.)

IMAGE OF A LOW CARBON CITY DEVELOPING TOWNS FOR A PENDESRIAN LIFESTYLE

It may be possible to start by promoting electric-powered vehicles that go beyond the conventional concept of automobiles. It is possible that such mobility modes will change the town landscape. An image was presented of highly convenient, low-carbon cities with walking as the basic means of mobility interlinked with various electric-powered vehicles according to the population density and other local characteristics

It was shown that widescale popularization of hybrid vehicles is a realistic and effective CO_2 emission reduction measure until 2020. Subsequently, a slow but steady transition is expected to occur from hybrids to plug-in hybrids and eventually to battery electric vehicles until 2030. However, due to their relatively low energy density, batteries to achieve long cruising distances tend to be heavy and expensive. Such disadvantages may not be overcome even by 2030. If a wide range of possibilities are considered with regard to energy and power-train characteristics, it may be possible to start by promoting electric-powered vehicles that do not fit the conventional concept of automobiles. It is even possible that such mobility modes will change the city landscape.

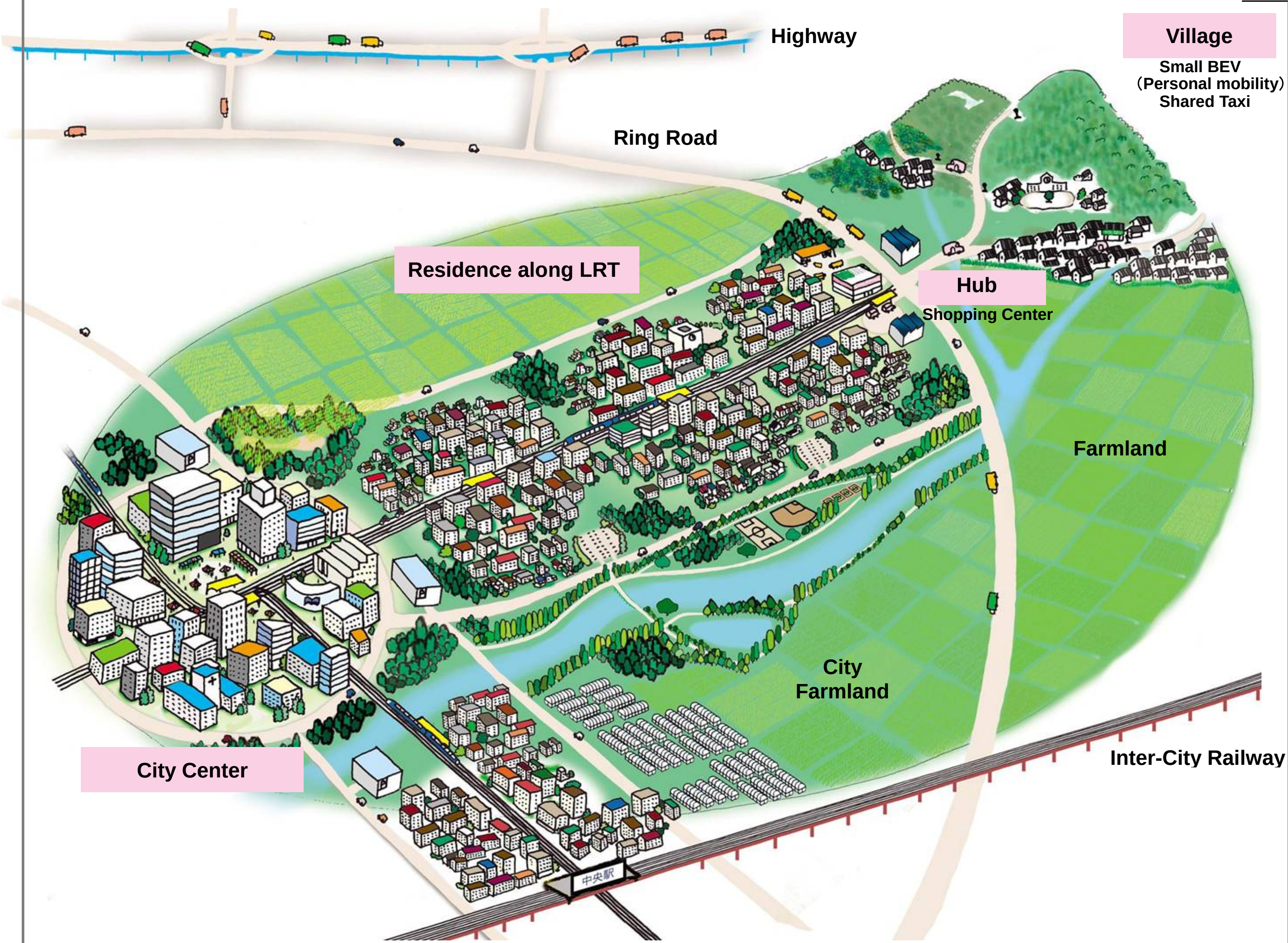

Figure 1: Image of a Low carbon city

Table 1: Overview of Measures to Develop Towns For a Pedestrian Lifestyle

Public Transportation Linking to the City Center	Frequently used facilities are placed near dwellings and facilities attracting many visitors are located in the city center to form a highly convenient urban structure. Regional hubs are interlinked with tiered networks of public transportation for ease of use.
Communities Safe to Walk in	Streets closed to car traffic and bikeways are established in each locality, and large areas are also reserved for safe, mobility with wheelchairs, mobility scooters (electric-powered vehicles for the elderly or disabled), etc.
Automobiles become electric-powered and lightweight	Automobiles are used mainly for mobility between areas with low density land use, which is coordinated with public transit using park-and-ride, car sharing and other schemes. Battery electric vehicles and other electric-powered vehicles are widely used. These electric-powered vehicles have vastly improved energy efficiency when being driven, due to higher performance of energy storage devices and lightweight car bodies made possible through development of materials with high tensile strength. Most users of battery electric vehicles recharge the batteries at home, but some users frequently use charged battery pack exchange services for convenience's sake.

"A Dozen Actions towards Low-Carbon Societies" (Global Environment Research Fund Strategic Research "Developing Visions for a Low-Carbon Society Project 2050" 2008.5) partially modified.

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