Preliminary Analysis and Consideration on Replacement of Vehicle Fleets

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1. Background and Awareness of Problems

Countries around the world are promoting the adoption of electrified vehicles and zero-emission vehicles (ZEVs) to decarbonize the transportation sector. At the Group of Seven's (G7) Climate, Energy, and Environment Ministers' Meeting in Sapporo in April 2023, the G7 countries shared not only the traditional goal of electrifying new vehicles but also the recognition of efforts to reduce greenhouse gas emissions from their vehicle fleets.[1] Conceivable measures to reduce emissions from vehicle fleets include promoting synthetic and other carbon-neutral fuels and switching to electrified vehicles.

Table 1 shows some country-specific goals for adopting electrified vehicles and ZEVs as published in the International Energy Agency's Global EV Policy. [2] The table indicates that vehicles subject to adoption goals are varied. Some countries fall short of setting adoption goals. The composition of vehicle fleets must be considered for analyzing CO_2 emissions in the transportation sector. The promotion of electrified vehicles and ZEVs in new vehicle sales must be assured, along with the time it takes to replace fleets. Therefore, I would like to estimate country-specific vehicle retention rates in a preliminary analysis of the replacement of vehicle fleets and consider the estimates.

Table 1 Country-specific electrification goals for new car sales and fleets

	New vehicle sales		Fleets	
	Light-duty vehicles (Passenger cars, vans)	Medium- and heavy-duty vehicles (Cargo and commercial vehicles)	Light-duty vehicles (Passenger cars, vans)	Medium- and heavy-duty vehicles (Cargo and commercial vehicles)
Canada	The ZEV share will be raised to 20% by 2026, to 60% by 2030, and to 100% by 2035.	The ZEV share will be raised to 35% (100% for some types) by 2030.		
China	The NEV share will be raised to about 20% by 2025.	The NEV share of buses, postal vehicles, and logistics vehicles will be raised to 80% by 2025.		
China	The NEV share of all types of new vehicle sales (including buses) will be raised to 45% by 2027.			
Germany			15 million EVs will be introduced by 2030.	
Spain			The number of EVs will be increased to 5 million (including buses) by 2030.	

	New vehicle sales		Fleets	
	Light-duty vehicles (Passenger cars, vans)	Medium- and heavy-duty vehicles (Cargo and commercial vehicles)	Light-duty vehicles (Passenger cars, vans)	Medium- and heavy-duty vehicles (Cargo and commercial vehicles)
France			The respective numbers of BEV (including FCEV) and PHEV will be increased to 660,000 and 500,000 by 2030 and to 3 million and 1.8 million by 2028. (The number of FCEV will be increased to 5,000 by 2023 and to 20,000-50,000 by 2028).	The number of low-emission large vehicles will be increased to 21,000 by 2023 and to 65,000 by 2028. The number of heavy commercial FCEV will be increased to 200 by 2023 and to 800-2,000 by 2028.
U.K.	The ZEV share will be increased to 80% for passenger cars and 70% for vans by 2030, and to 100% for both by 2030.			
Italy	The EVs and HEV share will be raised to 30% by 2022, to 50% (including methane and hydrogen in some cases) by 2025, and to 85% by 2030.	The EVs and HEV share of large vehicles will be increased to 30% by 2022, to 50% (including methane and hydrogen in some cases) by 2025, and to 85% by 2030.	The number of EVs will be increased to 6 million (including 4 million BEVs) by 2030.	
Japan	Electrified vehicles will account for 20-30% of new vehicle sales by 2030 and for 100% by 2035. Electrified and decarbonized fuel vehicles will account for 100% of new vehicle sales by 2040.	Aiming for an advanced introduction of 5,000 electrified vehicles in the 2020s.		

	New vehicle sales		Fleets	
	Light-duty vehicles (Passenger cars, vans)	Medium- and heavy-duty vehicles (Cargo and commercial vehicles)	Light-duty vehicles (Passenger cars, vans)	Medium- and heavy-duty vehicles (Cargo and commercial vehicles)
Korea	Electrified vehicles will account for 50% of new vehicle sales by 2025 and for 83% by 2030.		By 2025, the number of BEV will be increased to 1.13 million and the number of FCEV to 200,000. By 2030, the number of BEV will be increased to 3.62 million, the number of FCEV to 880,000, and the combined number of PHEV and HEV to 4 million.	
U.S.	ZEV will account for 50% of new vehicle sales by 2030.			

Note: Electrified vehicles cover hybrid electric vehicles (HEV), battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV), and fuel cell electric vehicles (FCEV). While EVs, zero-emission vehicles (ZEVs), and new energy vehicles (NEVs) include BEV, PHEV, and FCEV, notations in the table fail to be unified and are according to each country's notations or source notations.

2. Analysis

The vehicle retention rate is estimated as an indicator for analyzing the replacement of vehicle fleets. The retention rate is defined as the percentage of vehicles that are retained from the previous year to the current year among those on the road in the previous year, excluding scrapped ones. It is estimated based on Equation (1).

$$\text{Vehicles owned}_t - \text{New vehicle sales}_t = \beta \text{ Vehicles owned}_{t-1} \qquad \text{Equation (1)}$$
$$t: \text{Year} \quad \beta: \text{Retention rate} \quad \beta > 0$$

The retention rate is thought to move between 0 and 1. The closer it is to 1 means that the smaller the decrease through scrapping, etc., and the less vehicle replacement per year.[1]

This analysis covers 12 countries: Brazil, Canada, China, Germany, Spain, France, the United Kingdom, India, Italy, Japan, Korea, and the United States, compiling country-specific data from the Japan Automobile Manufacturers Association, the International Organization of Motor Vehicle Manufacturers, and the EDMC Handbook of Japan's & World Energy & Economic Statistics.[4][5][6] First, an estimation result for Japan is shown by Equation (2).

$$\text{Vehicles owned}_t - \text{New vehicle sales}_t = 0.9348 \text{ Vehicles owned}_{t-1} \qquad \text{Equation (2)}$$
$$(t: 665.19)$$

Estimation period: 2000-2022   Determination coefficient = 0.9579

Standard error = 510,262.314   Durbin-Watson ratio = 0.822

According to the estimation, Japan's retention rate is 0.9348, meaning that 93.48% of vehicles owned in a year were retained in the next year. In fact, there are cases where vehicles are suddenly scrapped due to accidents, etc. If 6.52% of vehicles owned are considered to be replaced in order of old vehicles every year, all vehicles owned in a year may be considered to be replaced in about 15 years. This estimate may be a roughly reasonable result because the average age of use published by the Automobile Inspection and Registration Information Association is 13.32 years for passenger cars and 16.08 years for cargo vehicles.[3]

Next, the estimation results for all 12 countries, including Japan, are shown in Table 2. It suggests that the vehicle retention rate varies from country to country, meaning that the time for the replacement of vehicle fleets differs by country. Japan recorded the lowest rate, at 93.48%, while India posted the highest rate, at 98.63%.

**Table 2** Country-specific estimation results

	Estimation period	Determination coefficient	Durbin-Watson ratio	Coefficient β	(Retention rate)	t value for Coefficient β
Brazil	2001-2022	0.9981	1.976	0.9654	(96.54%)	348.45
Canada	2004-2022	0.9914	1.531	0.9373	(93.73%)	446.54
China	2010-2022	0.9997	1.078	0.9725	(97.25%)	391.73

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[1] If the influence of variables (such as the number of used vehicle sales) that are not considered for Equation (1) is large, β may exceed 1.

Germany	2000-2022	0.9259	0.597	0.9352	(93.52%)	506.78
Spain	2000-2022	0.9946	1.250	0.9660	(96.60%)	450.76
France	2000-2022	0.9865	0.763	0.9423	(94.23%)	720.50
U.K.	2000-2022	0.9797	1.017	0.9441	(94.41%)	259.36
India	2008-2022	0.9897	2.202	0.9863	(98.63%)	113.98
Italy	2000-2022	0.9913	0.839	0.9596	(95.96%)	436.18
Japan	2000-2022	0.9579	0.822	0.9348	(93.48%)	665.19
Korea	2000-2022	0.9990	0.930	0.9540	(95.40%)	723.73
U.S.	2004-2022	0.9632	2.002	0.9464	(94.64%)	549.34

3. Consideration

The reason for the difference in country-specific retention rates may be that the spread of vehicles differs from country to country. Relations between the number of vehicles owned per 1,000 people (in 2022), a vehicle penetration indicator, and the retention rate indicate that retention rates are higher for India, China, and other countries with lower vehicle penetration indicators and lower for those with higher vehicle penetration indicators (Figure 1). This may be because countries where the vehicle penetration indicator is rising have relatively fewer old vehicles being scrapped, resulting in higher retention rates.
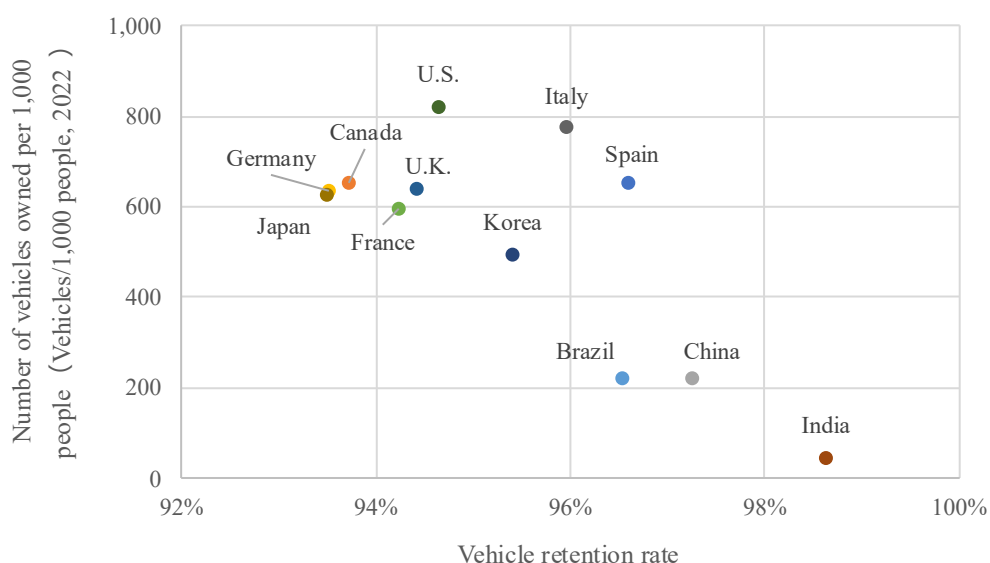
Figure 1 Relations between the vehicle retention rate and the number of vehicles owned per 1,000 people

Some countries with similar vehicle penetration indicator levels post lower retention rates than others. For example, Spain, while having a number of vehicles owned per 1,000 people that is similar to that of Japan, Germany, and Canada, posts a higher retention rate than the other three countries. This gap may be due to differences in the national environment surrounding vehicles. In countries that have tougher vehicle safety and inspection standards than others, for example, vehicles may become unable to meet such standards and be scrapped faster than others. In addition, the vehicle retention rate may be affected by the introduction of scrap incentives and other systems to promote the replacement of vehicles by increasing taxes on old vehicles and providing subsidies. For example, Japan's special

green taxation system increases the automobile tax on vehicles beyond a certain age. In Germany and France, the vehicle tax is determined in proportion to emissions, subjecting older and poorer performing vehicles to higher tax amounts. Scrap incentives include Japan's eco-car tax reduction and Germany's environmental tax premium.

Since the times for the replacement of vehicle fleets differ from country to country, as shown above, it is essential to take this point into account when assuming the composition of future fleets in conjunction with a goal for promoting the spread of electrified vehicles and ZEVs among new vehicle sales. Japan and Canada have low vehicle retention rates and are expected to take about 15 years to replace their vehicle fleets, according to a simple computation. If they achieve their target shares for electrified vehicles or ZEVs in new car sales by 2035, as shown in Table 1, they may realize their assumed vehicle fleet compositions in time to accomplish the goal of carbon neutrality by 2050. In contrast, the United Kingdom posts a higher vehicle retention rate than Japan and Canada while having set a similar target share for ZEVs among new vehicle sales for 2035. For this reason, it may have to try to achieve the target share a few years earlier, considering that it would take a longer time to replace its vehicle fleet than Japan and Canada.

4. Future Challenges and Prospects

In this paper, I estimated the vehicle retention rate for a preliminary analysis of the replacement of vehicle fleets. I used a uniform equation for the estimation, limiting variables to the number of vehicles owned and the number of new vehicle sales. As the abovementioned impact of used vehicle markets, vehicle inspection and tax systems, and other factors are expected to affect the retention rate, this analysis is considered to fall short of taking these factors into account. A future challenge is to further increase the accuracy of estimates by looking into each country's vehicle uses, relevant systems, and vehicle markets, including these factors, by considering factors to be taken into account, and by improving the resolution of the interpretation of analysis results.

In the future, I would like to conduct a simulation analysis on future vehicle fleet compositions and assess country-specific greenhouse gas emission goals for the road sector from a long-term perspective, considering that the times to replace vehicle fleets differ from country to country.

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