Vehicle Life Cycle Analysis Considering Uncertain Driving Distance

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論　文　内　容　の　要　旨

The Organization for Economic Co-operation and Development (OECD) Environmental Outlook shows that “greenhouse gas emissions from the transportation sector are projected to double by 2050 due to a strong increase in demand for cars in developing countries, and OECD economies have been responsible for most of the emissions.” The International Energy Agency (IEA) shows that “Reducing CO2 emissions in the transport sector over the next half-century will be a formidable task” in Energy Technology Perspective 2022. And they estimated that “passenger-kilometers travelled doubles between 2019 and 2070.” In particular, it is extremely important to reduce the emissions of motor vehicles by improving their fuel efficiency. The Corporate Average Fuel Economy (CAFE) standard is one example of policies aimed at improving fuel efficiency. This standard was adopted by the United States in 1975 and it is aimed at improving vehicle fuel efficiency, whereby the average vehicle fuel efficiency (miles per gallon) calculated from the weighted average of sold vehicles must not fall below the “fuel efficiency target standard (miles per gallon) established by the government.” Japan has also introduced company-specific fuel efficiency standards from 2020, in line with its twofold goal of reducing the CO_2 emissions of the transport sector and realizing more flexible promotion of vehicle sales. An important research question is how to estimate the life cycle CO_2 emissions from passenger cars more accurately. With the background, the objective of this doctoral thesis is to quantitatively evaluate not only corporate average fuel economy of Japan’s seven automobile manufacturers but also life cycle CO_2 emissions from a wide variety of passenger cars sold by the manufacturers, and to propose an uncertainty analysis framework for life cycle CO_2 emissions of a specific vehicle model.

This doctoral thesis consists of five chapters. In Chapter 1, the current status of CO_2 emissions from transport sector and its contribution of passenger cars are highlighted and the main objectives of this doctoral thesis are clarified. Chapter 2 gives an overview of previous studies about environmental impacts of introducing CAFE standard and life cycle assessments of passenger cars and clarifies novelties of this thesis.

Chapter 3 uses data on new car sales in Japan provided by the Japan Automobile Dealers Association, estimates the corporate average fuel economy (CAFE) and CAFE targets of Japan’s domestic seven automobile manufacturers (Toyota, Nissan, Honda, Mitsubishi, Mazda, Suzuki, and Subaru) and evaluates whether manufactures have achieved these estimated CAFE targets. Furthermore, an analysis framework is proposed for estimating what impact the introduction of the CAFE standards in Japan will have on motor

vehicle-derived lifecycle CO_2 emissions. The results show that in 2015 the CAFEs of Toyota and Honda exceeded their CAFE targets while those of Nissan, Mitsubishi, Mazda, Subaru, and Suzuki fell below their CAFE targets. Toyota sells a large number of hybrid vehicles than the other six automobile manufacturers, whereas Honda sells fewer vehicle models with poor fuel economies. Thus, differences in sales patterns and fuel economy technology between companies account for the gaps in their ability to achieve their targets. This study also demonstrates that based on the estimated optimal sales patterns for each company in a scenario, where fuel economy for the vehicle models sold is improved 20%, the overall carbon footprint for all seven companies would be approximately 53 million tons, a 1.2-fold increase over their 2015 carbon footprint. This result implies that economically optimal automobile manufacturer behavior—striving to achieve CAFE standards while maximizing sales—will increase the manufacturers' overall carbon footprint and worsen the environment.

Chapter 4 uses data on vehicles advertised for sale on the used car sales website: Goonet Exchange. The data includes 3618 Prius models from 2002 to 2017 (1800 cc displacement, new retail price JP¥2.5 million, Toyota Motor Corporation) and 239 Premio models from 2000 to 2017 (1500–2000 cc displacement, new retail price JP¥2 million, Toyota Motor Corporation). The Prius is a hybrid vehicle, while the Premio is a gasoline vehicle. Based on the data, this study specifies the relationship between motor vehicle lifetime and lifetime mileage by using a quantile regression approach. The results show that, for drivers who drive longer distances, the rate of decrease in average mileage grows as the vehicle age increases. Specifically, average annual mileages for Prius model vehicles decline from between 5% and 11% for each one-year increase in vehicle age. Premio model shows a rate of decrease in average annual mileages in the range of 4%–6% for every one-year increase in vehicle age. This study further estimates the difference arrived at by subtracting "cumulative emissions calculated using a -7.7% rate of decrease in average annual mileage within the 0.5 quantile, as estimated in this study" from "cumulative emissions calculated over a 13-year lifespan under uniform average annual mileage of 10,000 km and 'average' fuel efficiency, as per Toyota modeling." From the result, this study finds that cumulative CO_2 emissions calculated with the assumption of "uniform" average annual mileage (i.e., as per Toyota modeling) have been overestimated at the quantile of 0.5. Similarly, the estimated cumulative CO_2 emissions from driving a Premio during a 13-year lifespan, as estimated using Toyota modeling, overestimated around 5 tons-CO_2 at the quantile of 0.5. Finally, this chapter suggests that vehicle lifecycle assessments should take into account the annual decrease in mileage demonstrated in this study.

Finally, the summary, limitations, and conclusions of this entire doctoral thesis are provided in Chapter 5.