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Life cycle optimization of ownership costs and emissions reduction in US vehicle retirement decisions

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Abstract

Vehicle scrappage programs have emerged in the US to address the challenge of regional fleets that contain older, often inefficient vehicles with higher emissions and lower fuel economy. These programs provide an incentive for removal of old vehicles from the road before their economic lifetimes have been exhausted. Scrappage programs operate on the assumption that newer vehicles will offer more efficient, less polluting alternatives to older vehicles. Little attention, however, has been given to the additional energy and emissions burdens associated with the manufacture of the replacement vehicles. This paper considers the optimal intervals for vehicle replacement over a 36-year period that minimize life cycle economic and emissions burdens. Comparisons are made between the optimal product replacement intervals based on explicit private costs, estimated pollution damage costs, carbon dioxide emissions, energy use, and criteria air pollutant emissions. The results show that private costs of vehicle ownership favor long replacement intervals (in the range of 17–19 years), while short replacement intervals support minimization of criteria air pollutants such as CO (3–6 year intervals), NO_x (5–7 year intervals), and NMHC (6–9 year intervals). Longer ownership periods (18 year intervals), however, provide minimum life cycle CO_2 emissions and energy use. When damage cost factors are used to estimate the external costs of pollution to society, intermediate replacement intervals (10–14 year) are favored.

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1. Introduction

In the US, the predominant mode of personal transportation is the automobile that accounts for over 90% of all passenger miles traveled and 14% of national energy use. Since the passage of the corporate average fuel economy regulations in 1975, however, new vehicle fuel economy has improved more than 82%. Simultaneously, the average cost of a new vehicle has been relatively constant, growing by less than 1% per year in constant dollars (Davis and Diegel, 2003). Despite the relative affordability of new cars, both the average age of vehicles on the road and expected vehicle life are increasing. This, in combination with the fact that annual passenger miles traveled have grown at nearly three times the rate of population over the past two decades, explains why energy use and emissions associated with automobile use continue to increase.

Increasing vehicle age poses a twofold challenge to development of more sustainable mobility systems: extending the life of older vehicles can slow the rate of introduction of more efficient technologies, and emission control systems typically deteriorate with vehicle age and are more likely to fail in older vehicles leading to what are known as ‘high-emitters’ (Austin and Ross, 2001). Studies by the California Air Resources Board (CARB) and Pokharel et al. (2002) have shown that while high-emitters represent a relatively small fraction of total on road vehicles, they contribute a disproportionate share of total emissions. CARB found that just 3% of all vehicles contributed 23–27% of roadside emissions (California Air Resources Board, 1994). Pokharel studied vehicles in the Phoenix area and determined that 10% of vehicles contributed between 49% and 78% of emissions depending on the pollutant studies.

Scrappage programs (also known as accelerated vehicle retirement programs) represent an attempt by government and industry to address the challenges of aging vehicles. These programs are designed to accelerate the removal of older, less efficient vehicles by creating a market-based incentive for retiring and scrapping vehicles meeting specific criteria. Eligibility criteria include vehicle age (or model year), operating tests, and location/duration of ownership. Economic incentives are generally in the form of payment for a vehicle meeting the criteria, with payment ranging from $400 to $1000 in the US (Dill, 2004).

Several criticisms of scrappage programs exist; these include the possibility of fraud by vehicle owners, fewer assets available for the used part/vehicle markets, migration of older vehicles to regions with programs, and uncertain emissions benefits (Kim, 2003). Much of the research on scrappage programs to date has focused on reductions in vehicle tailpipe emissions and the challenges of accurately estimating vehicle mileage replaced, emissions from vehicles to be scrapped, substitute vehicle emissions, and potential for vehicle scrappage with no program (Dill, 2004). However, few researchers have examined scrappage programs from a holistic environmental perspective. The potential environmental impacts of retirement operations (e.g., dismantling, shredding, etc.) and new vehicle production must also be considered when examining the potential environmental benefits of scrappage. In addition, the development of meaningful understanding of the vehicle system as it relates to scrappage decisions requires consideration of the economics of vehicle acquisition, operation, and retirement.