Fostering the transition to new technologies with car organ transplant

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Abstract

The transport and energy sectors face multiple challenges including the accommodation of increasing fuel prices, energy security and environmental pressures. These hurdles become more important in road transport where cars hold a larger share of final energy consumption and emissions. While transportation demand management is mandatory to reduce pressure on the system, especially in urban areas, governments are implementing regulation for pollution control (e.g. EURO standards in the EU) and making voluntary agreement with car manufacturers (EU with ACEA, JAMA and KAMA) to reduce carbon emissions by means of increased fuel economy of cars. For that, new technologies are crucial to overcome all challenges.

Despite the diffusion of more efficient Internal Combustion Engine Vehicles (ICEV), air quality problems abound in urban areas and evidence suggests strongly that climate change is being induced by carbon emissions. Clearly, higher efficiency is being offset by increased motorization and mobility and by diverting the technological improvement gains into non-fuel saving features. Altough the situation is improving in general, problems remain and in many respects the question of accelerating the renewal of fleets towards cleaner technologies seems dominant.

The transition to a more sustainable transportation system requires a fleet conversion policy that efficiently absorbs new, clean and retires old, polluting technologies. However, technological turnover of fleets has been essentially determined by the retirement of older vehicles and replacement with new models. This can last over 10 years before total displacement of older technologies, leading to the technological obsolescence of the running fleets and its malign consequences, specially in more saturated fleets where the turnover is even lengthier (which is the case of the Portuguese car fleet, our case study). One way to reduce this delay is to reduce the lifetime of vehicles by accelerating the turnover of fleets. However, overall environmental impacts of ICEV can increase in a lifecycle perspective, due to additional energy and raw materials consumption (and generation of emissions or solid waste) from new car production and scrappage. In fact, reducing lifetime of cars below a certain limit is not always the best option.

Here we propose to transplant new technologies (here, we call it organs) into used-cars to extend their service time while keeping them technologically up-to-date, obtaining positive lifecycle results. Furthermore, it would contribute to dematerializing the automotive industry, by reducing the need to build new cars. Organ transplant in cars corresponds to replacing parts, modules and systems of the powertrain (including depollution equipment) and other energy intensive ancillary equipments (e.g., air conditioning) of the car that are technologically outdated, downgraded or malfunctioning while keeping the remaining components and parts that are state-of-the-art and fully operative, in order to improve its energy and environmental efficiency and possibly reach 'like new' performance standards, over its service life.

The present paper is relevant for the conference and more specifically for the topic of Innovation in Transport Planning and Governance, since we propose a new means of fostering the transition to new and more efficient technologies in private car ownership, while the deployment of breakthrough technological innovations (namely, electric drive vehicles) are being delayed.

In general terms, the methodological approach to the problem is to evaluate if transplanting new organs into older vehicles is sufficiently attractive when compared to common car ownership, i.e. buying, using and maintaining new or remarketed cars. In that sense, we estimated the environmental implications and final energy balance of technological transplants and verified if the additional energy and environmental burdens associated to the production of transplanting kits and scrappage of replaced equipments are offset by the expected gains from the increased car efficiency. Likewise, we analyzed to what extent car organ transplant is attractive from the car owner's perspective (in economic terms) by analyzing, among other indicators, what are the payback periods of the transplant investment.

We used lifecycle analysis methodologies to compare energy consumption and environmental impacts of five different ownership alternatives of a midsize gasoline-powered car: keep car over 20 years; buy new car periodically, over the same time period; buy remarketed cars; buy remarketed cars that were transplanted; or keep car while transplanting new and cleaner technologies periodically. Furthermore, we calculated total car ownership costs for these strategies. Economic results include annual ownership costs, total lifetime ownership costs, life cycle pollutant damage costs, payback periods and net present values analysis. Our analysis includes an estimate of what can be car organ transplant costs and determines what would be the optimal swapping (or organ transplanting) periodicity of cars based on standard economic calculations, for each scenario.

The key results obtained with the present research are:

- Fixed costs (which include financing, depreciation, insurance and taxes) correspond to 50% of 20-year-car ownserhip total costs, suggesting that, from the economic perspective, extending the service time of the car is a rational and more profitable option for the owner.
- We estimated that a transplating kit can cost about 4500€ for a mid-sized gasoline car. The corresponding payback period is 6 years if the car is rtansplanted at the age of 5.
- Energy and environmental burdens associated to the production of transplanting kits correspond roughly to 20% of the vehicle’s lifecycle burdens. All included (energy consumption and compounded environmental damages costs – CO2e, CO, NOx, NMVOC and PM), the energy and environmental payback period of technological transplant is 6 years, if the car is transplanted at the age of 5.
- Producing one transplanting kit requires less 1200 kg of raw materials and less 100 GJ than a conventional midsize car. Correspondingly, the production of a car generates 670 kg of solid waste, almost 7 times more by mass than is generated during transplanting kits production (100 kg of solid waste per kit). As such, car transplant (alone) reduces material flows when compared to a conventional car.
- When compared to conventional car ownership strategies, we conclude that transplanting the car twice over 20 years results in the smallest economic and environmental costs. Conversely, buying two new cars in 20 years is the least attractive economic option. Finally, flow materials are reduced when buying transplanted vehicles specially when compared to buying new cars.

Overall, our research suggests that the automotive industry can envisage a new approach to car ownership and that consumers could be guided to consider technological transplant when deciding to swap their car.

Keywords: Technological Transition, Car Organ Transplant, Energy efficiency, Environment Impacts