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Sustainable mobility: from technological innovation to societal learning

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Abstract

This paper addresses a persistent and worsening societal dilemma worldwide: the ecological unsustainability of the automobile as the primary means for providing personal mobility. The solution to this problem will require input from all segments of society, and must include technological innovation, changes in the physical infrastructure and land use, and social, cultural, and institutional changes. A fundamental rethinking of the entire system of personal mobility is necessary. Governments can play a significant role in promoting change: by stimulating technological innovation through regulations, incentives and subsidies, by investing in the infrastructure, by providing leadership, and by organizing and supporting a debate with a focus on the system as a whole: its spatial characteristics, the motives for transport, and the alternatives that are presently not developed. From the technological perspective, one of the much-discussed solutions is a hydrogen-powered automobile. We argue that the future of this approach is questionable, and propose a fundamental re-framing of the significance of hydrogen: from viewing it as a solution to the personal mobility problem to seeing it as a medium for transporting and storing energy that has been generated elsewhere (preferably by renewable resources). A new and radically different way of seeing the problem of individual mobility, and of the roles of various stakeholders in finding solutions, is also necessary. This is the essence of higher order learning. To facilitate such learning among various societal groups, we advocate a combination of multi-stakeholder visioning processes, scenario building, backcasting exercises, and small-scale socio-technical experiments. These approaches may be practiced at various levels, from local to national, with experimentation probably being best suited for a smaller scale. An ongoing process of visioning future mobility in the Boston Metropolitan area illustrates how such approaches may be used.
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1. Introduction

This paper addresses a persistent problem of our society: the ecological unsustainability of the automobile. The car is the dominant form of maintaining personal mobility. Its benefits are powerful: it is a door-to-door transportation system, the means to gaining access to life necessities and employment, and a source of pleasure and social status. So are its disadvantages, including local air pollution, greenhouse gas emissions, road congestion, noise, mortality and morbidity from accidents, and loss of open space to roads, parking lots and urban sprawl. Many people are aware of the disadvantages but see no comparable substitutes to the automobile. The dilemma of an automobile owner is similar to that of a herd owner described in the classic case of a 'tragedy of the commons'[1] [1].

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[1] The metaphor is a community sharing a pasture. For an individual it is advantageous to increase his cattle stock. For the collective this means eventually overgrazing the field.

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The anticipated worsening of the negative effects of car dependency keeps this issue on the public agenda. In the USA, the discussion of urban sprawl is intense [2]. Local air pollution has prompted the State of California to develop the zero-emission vehicles (ZEV) policy [3] while on the national scale the Environmental Protection Agency (EPA) is introducing the long-delayed regulations of SUVs [4]. Europe is also seeking tighter controls of toxic emissions from cars. The greenhouse gas problematic is high on the European agenda as well as in many states, municipalities, and civil institutions in the US. In the rapidly developing countries, the problems of urban mobility are also drawing increasing attention. In New Delhi a recent court order requires that taxis and buses switch from gasoline and diesel fuel to the cleaner liquid natural gas fuel (LNG) [5]. Cities such as Curitiba and Bogota are carrying out daring experiments with alternative mobility systems [6]. Brazil has had its gasohol (alcohol from biomass for car propulsion) program for many years [7].

These efforts, however, pale *vis-à-vis* the projected growth in population, affluence, and people's appetites for the type of personal mobility car can provide. This is clearly evident in China, where car ownership is steeply rising, from 1.6 million in 1990 to 10 million in 2000, to 80–90 million anticipated in 2020. In July 2003 over 1.07 million cars were sold in China, compared to 1.06 million in the entire year of 2002, an increase of 98% [8]. Although in absolute numbers this is still low, compared to the US, the relative increase is staggering. Road accidents in China are growing as well. In the first 10 months of 2003 there were 90,000 fatal car-related accidents, with 400,000 wounded. Bicycles are being banned from car-congested large cities. The total level of carbon dioxide emissions in China is already second to the US, and will continue to rise steeply [9].

While the developed world is in no position to criticize the developing world for their desires to match them in affluence and mobility, the ecological consequences of these parallel trends will be disastrous. In that context, some developed countries have acknowledged bearing a responsibility for finding alternative ways to satisfy these needs and wants. During the 1990s, the Dutch program Sustainable Technological Development argued that increasing population growth and increasing production and consumption could only be met in a sustainable way by developing so-called 'factor 20 solutions'', meaning a 20-fold reduction in the intensity of consumption of energy and materials per capita by 2050 [10,11]. For greenhouse gas emission, especially CO_2, reductions of 75–85% per unit of need fulfillment are now generally accepted as necessary in the long term (see, for instance, [12]).

Such ambitious goals will require a mix of radical solutions. One of those is significant technological change in the automobile design. The car industry has demonstrated that dramatic reductions in tailpipe emissions are possible: since the passage of the US Clean Air Act of 1970 individual automobile emissions have declined by a factor of between 8 and 20, depending on the type [13]. The hydrogen fuel cell is considered by many to be the next major technological breakthrough in car design [14]. We discuss its promise and limitations in the next section.

But technological change in car design, however successful, is unlikely to suffice to counteract the current social trends in consumption. Fundamental rethinking of the entire system of personal mobility is also necessary [15]. The most radical solution would be a reduction of the transportation needs by either redesigning the infrastructure and land use to reduce the distances to work, shopping, recreation, and so on, or by increasing the reliance on tele-commuting, tele-shopping, e-conferencing, e-tourism and e-fun. A less radical and probably more realistic solution would be to shift to other modes of mobility: walking, cycling, using other types of vehicles, and public transportation. A third approach would centre on mobility services. These might include car-sharing (which unfortunately results in a relatively small reduction of the environmental burden), and creative chain mobility services, like joint transportation to and from work organized by employers as a way of increasing productivity [16–18].

The development of these solutions presents a great challenge to society, the governance system, and the market place, owing to the entrenchment of the car–petroleum system. The resilience of this system is enormous, not only for economic and infrastructural reasons, but also because of the resistance by the vested interest of powerful societal actors, such as car and gasoline manufacturers, filling stations, dealers and repair shops, and of the scientific and technological infrastructure that endorses the present situation. Moreover, the cultural symbolism of a car, and the social resistance to change in lifestyles and daily routines, are equally strong [19,20].

Governments, while having a limited impact on fundamental lifestyle choices, can be change agents in other ways. As discussed earlier, governments can, and do, regulate air quality, fuel type, emissions of pollutants from automobiles, and to some extent car use through availability of parking and roads. They can facilitate fundamental technological innovation through regulations, incentives and subsidies. They also have considerable power to affect systemic socio-technical change by providing leadership, facilitating emergence of a widely shared vision of the future, by forming crucial networks among the key societal actors, and by creating platforms for interactions and learning. Examples of these types of efforts have been accumulating, like the Dutch transition management explained in the paragraph below. In California ZEV regulations facilitated the R&D expenditures by car and fuel manufacturers in alternatives propulsion systems. Switzerland has become a primary example of replacement of personal automobile with an efficient public transport [21].

In another interesting shift, the Dutch government has adopted 'transition management' as a guiding principle of its National Environmental Policy Plan-4 (NEPP) [22]. *Transitions* are conceptualized as long-term, continuous processes in which a socio-technical system on a scale of the entire society changes fundamentally. They entail interconnected and mutually reinforcing changes in technology, economy, institutions, ecology, social norms, and belief systems. The concept of transition draws on the ideas of system dynamics and

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