

Is Mobility As We Know It Sustainable?

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Abstract: Economic growth, quality of life and mobility are inextricably intertwined in virtually every culture of the globe. With only 1/5 of the world's population living in "Industrial Countries," and with those countries responsible for some 60% of the demand for transport energy and the associated environmental challenges, what will happen by 2035 with almost universally higher standards of living? This paper explores the extent to which known transport technologies can reduce energy demand and greenhouse gas emissions, and identifies opportunities for actions that should be taken to mitigate the impact of the huge growth of the fleet by 2035.

► Introduction

Sustainable mobility provides for the safe freedom of movement for people and goods in a way that uses renewable sources of energy while creating no adverse impacts on the earth and its environment. As such, Sustainable Mobility is today on everyone's lips, yet we have a relatively long history of concern about the sustainability of modern modes of transport. Indeed, there have been doubts about the long-term availability of petroleum ever since the 1920s, if not before. For most of automotive history, the availability of petroleum has been the major factor seen to limit the use of the automobile. Yet the oil industry has continued to provide a seemingly limitless supply, causing some analysts to consider oil as "an infinitely available finite resource."

Because we have so far been able to prove as false such predictions of impending doom, we as a society have become more or less hesitant to take such forecasts too seriously. Only relatively recently have concerns over climate change begun to raise everlasting questions about the mobile lifestyle of modern developed nations and the implications of the global spread of the motor car. In January 2008, the announcement of the microcar "Nano" by India's Tata Group was greeted with expressions of grave concern by environmental groups worldwide. Giving access to a very low-cost car to a market of a billion people is thought certain to have a profound effect on not only demand for fuel, but also on an already CO₂-sensitive global environment.

This paper attempts to quantify the likely impact of the motorization of developing markets, put our current conservation efforts in context of what is needed in the long term, and propose some long-term solutions to the challenge of sustainable mobility.

► The Modern Model of Mobility

Mechanized mobility has become essential for our modern way of life. Economic prosperity grows on the back of goods transport modes. The more goods we can move faster to market, the greater the wealth resulting from the value created by those goods. Globalization, an economic concept based on the specialization of nations or regions producing those goods for which they are best suited, is an extreme case, but is not an essential prerequisite for high levels of motorization.

A strong correlation exists between per capita income and the number of 4+ wheeled vehicles (both cars and trucks) per capita (motorization rate). This correlation appears in Figure 1 and can be characterized by equation 1.

$$\text{Vehicles}/1000 \text{ People} = -0.5413(\text{PC GDP})^2 + 37.375(\text{PC GDP}) - 131.53 \quad (1)$$

Increasing wealth is accompanied by an increase in the motorization rate that begins in earnest at about \$5,000 per person and levels off in the range of \$35,000 per person, on a globally normalized basis of Purchasing Power Parity (PPP – meaning that the value of the dollar is normalized such that in each country it has the same purchasing power)

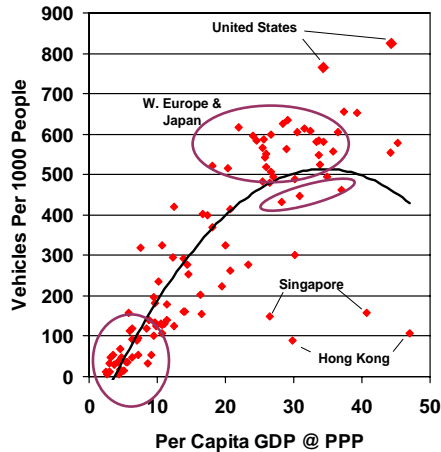


Figure 1: Historical relationship between individual wealth and motorization rate (data from 2002 and 2007)⁽¹⁾

At the \$5,000 level, most of the vehicles are Light or Medium commercial vehicles used for goods transport. As populations become wealthier, the mix of vehicles includes more Heavy commercial vehicles for goods transport, and passenger cars begin to dominate the in-use fleet. As populations become even wealthier, the markets become saturated and are limited by the number of licensed drivers. As a result, the motorization rate levels off. Another important factor ultimately limiting motorization is the movement of populations into cities where a combination of congestion, high ownership costs and convenient access by foot or public transport to most essential destinations (shopping, work, and leisure) can be accomplished without a private motor vehicle. In extreme cases, very high levels of taxation, outright limitations of motor vehicle numbers, congestion or other external factors cause the motorization rate to be very low, despite high levels of per capita income, as in Singapore and Hong Kong.

► Growth of the In-Use Fleet

At the moment, there are globally an estimated 800 million 4+ wheeled vehicles in-use today. Many estimates of the future growth of this fleet expect this number to double by 2050, with the associated consequences in terms of air quality, fuel consumption and climate change. Most policy makers, in turn, base regulatory targets on the expected impact of this growth in the local or global vehicle parc and establish performance targets for vehicles such that the impact of this larger vehicle fleet will be reduced to acceptable levels.

In reviewing the estimated impact of these future fleets on fuel consumption and CO2 emissions, the author began to question the basis of the forecast for overall fleet size. This questioning gave rise to the following analysis.

Economic forecasts expect increased prosperity in all regions of the world. These forecasts indicate that by 2035, national economies will grow such that every region of the world will have a per-capita GDP above \$5,000 at PPP. Populations will grow significantly in Asia and

Africa (see Figures 2, 3 and 4). Highly populated regions of the world will be climbing the rising side of the motorization curve of Figure 1. China and the combination of the U.S. and Canadian economies will grow by about the same amount in terms of total GDP.

Changes in purchasing power of the various currencies present a somewhat different view than might be first apparent from the overall wealth of nations. There are relatively large differences in overall change in wealth of the various countries or regions (Figure 2). Differences in per capita purchasing power of the consumers in the various countries are further impacted by stagnation or decline in the population of the developed markets. As a consequence, there is much more purchasing power in the hands of the Japanese, Europeans and Americans as well as the Chinese than the relative growth in GDP would at first suggest.

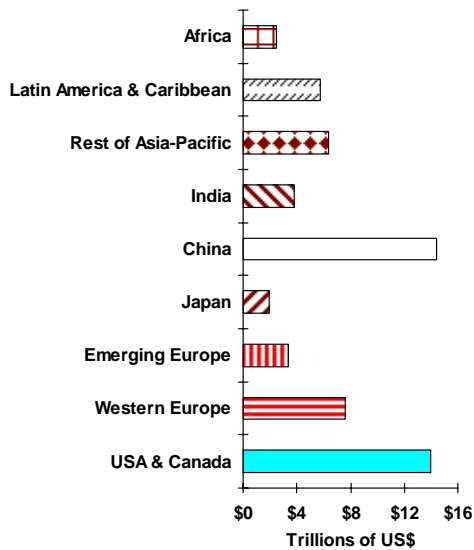


Figure 2: Regional gains in GDP, 2000 to 2035⁽¹⁾

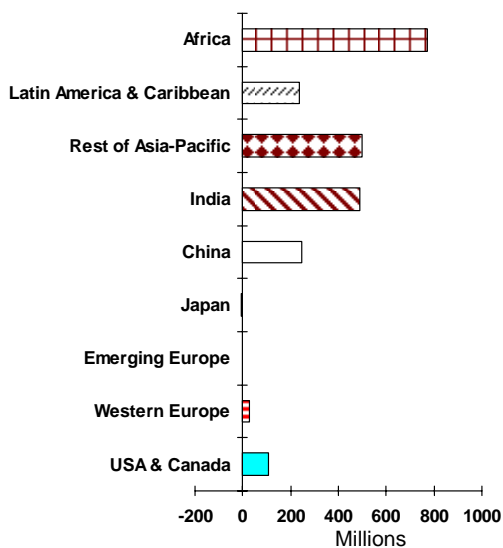


Figure 3: Africa, Asia and India Outstrip China in terms of population growth, 2000 to 2035⁽¹⁾

Forecasts of Per Capita GDP at PPP enable us to project the motorization rate in each of these countries or regions. Equation 1, previously developed, is the model of mobility as we know it today. Applying equation 1 to the PPP GDP, and then multiplying by the population gives us an overall estimate of the economic demand or potential for the size of the regional or national and global in-use fleet by 2035.

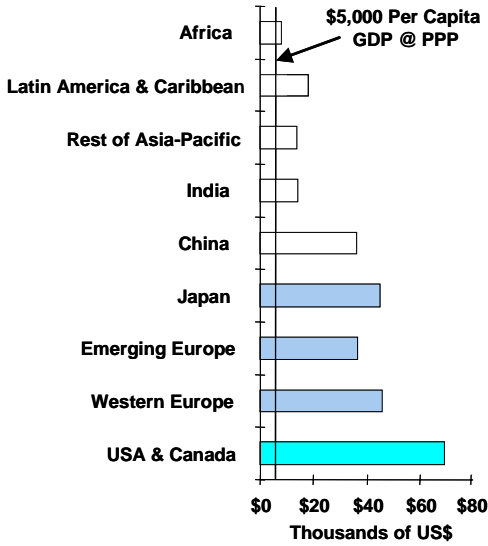


Figure 4: Per Capita GDP at PPP⁽¹⁾

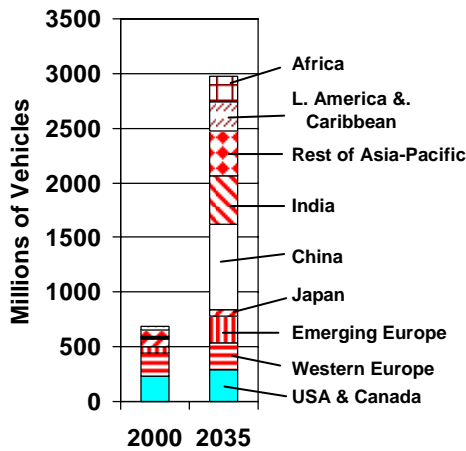


Figure 5. By 2035, the economic potential for the size of the in-use fleet will be about 3 billion vehicles, an increase of almost 4 times that of the current in-use fleet.

This model projects that the global in-use vehicle fleet will be on the order of 3 billion vehicles by 2035. This is an in-use fleet that is 3.75 times the size of the current fleet. That is, almost three to four times the demand for physical space, raw materials and fuel that exists today, and 3 to 4 times the input to the atmosphere of toxic and climate-changing emissions (assuming no change in vehicle characteristics and similar annual distances travelled).

► The Consequences

Is this possible? No-one expects this fleet size to be achieved simply because the implications of such an occurrence are staggering. The significant increases in vehicle population would occur in regions where the roadway and parking infrastructure is least capable of accommodating large numbers of vehicles. The demand for fuel and natural resources is enormous. Clearly, these are improbable factors, by themselves, never mind

the consequences of the resultant manufacturing and tailpipe emissions. Still, if demand for mobility follows current patterns, the economic potential is headed in this direction, and the consequences are clear, present and onerous.

Why make this calculation? As stated at the outset, no other forecaster has publicly entertained such a massive in-use fleet. The sheer numbers are staggering, and the consequences boggle the mind. However, no other forecaster has been able to clearly state how and why such an economic demand will NOT occur. Projections of a fleet only half this size by 2050 are more readily accepted, and the consequences deemed manageable, albeit with much challenge.

The danger comes in not recognizing the plausibility of this scenario, and taking the necessary steps to ensure that it does not occur. Every person with access to modern communications sees the freedom and extent of mobility available to people in the developed nations. Every one in emerging and developing nations aspires to similar levels of mobility. Clearly, applying our contemporary model of mobility to the rest of the world is not sustainable, yet most of the world clamours for just that.

► **"Out Of The Box" Thinking Needed**

There are tremendous technical advances available to us today to get us part of the way towards minimizing the impact of the future in-use-fleet. Powertrain technology alone can reduce CO2 and fuel consumption by about 40 and 50% respectively (Figure 6) compared to conventional gasoline engines.

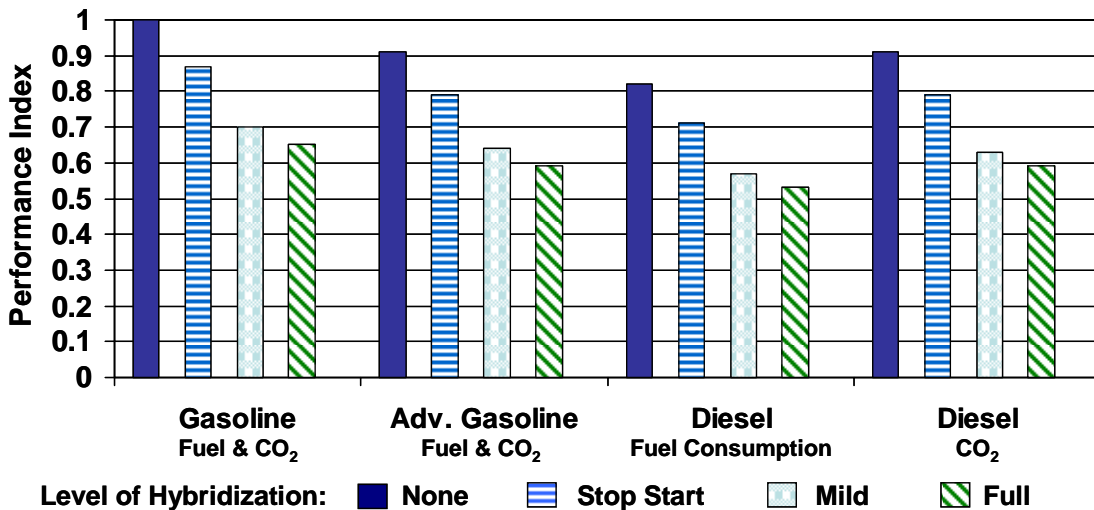


Figure 6: Indexed fuel consumption and CO2 performance of advanced Diesel, gasoline and hybrid powertrains⁽²⁾

Alternative fuels can displace more of the conventional fuels, but many are alternative forms of fossil fuels which are ultimately in limited supply and add carbon sequestered naturally from previous generations into our biosphere. Fuels made from vegetable stock are more benign, and once the transition disruptions are addressed, represent a viable alternative to replace at least 15% of our transportation energy demand before we run into a food-fuel conflict.⁽³⁾

A significant shift towards smaller vehicles that fundamentally require less energy to propel them will also help, of course. However, without measures that many consumers would deem oppressive, a massive shift is unlikely. We have modelled the implementation of relatively severe circulation taxes (taxes paid every year based on the CO₂ output of a vehicle) and assessed their impact on the sales of vehicles of different size classes. An extreme case is one in which the costs for transportation as a percentage of disposable income in Western Europe is similar on average to the current situation in Italy. On that basis, the market shares of the different vehicle segments in Europe would shift by 2025 to be similar to that of Italy today as shown in Figure 7. Impacts in other regions would be similar.

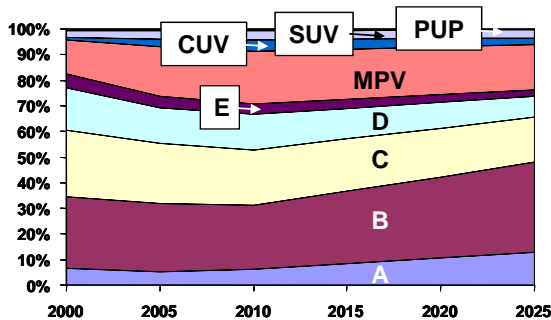


Figure 7: Possible vehicle segment market share shifts in Western Europe due To high levels of CO₂-based taxation

Such an apparently substantial change in the market mix actually results in only a modest change in net transportation energy demand. If everything else (including the market shares of different powertrains in each segment) is held constant, possible shifts in the markets of W. Europe, the U.S. and Japan result in a net decrease in the fuel consumption of each region by 4%, 12% and 5%, respectively. The very low impact in Europe is due to the predominance of gasoline engines in the segments of smaller vehicles, and the popularity of Diesels in the larger, heavier vehicles. As the market moves from large to small vehicles, the consequential shift (in this analysis) from diesel to gasoline offsets the gains obtained from reduced vehicle size and mass. Clearly, a shift to smaller vehicles must be accompanied by a shift to advanced propulsion systems.

The net benefit, then, of deploying technical changes combined with plausible CO₂- or fuel-conscious changes in the market mix of otherwise conventional vehicles is a net reduction on the order of 40% on average per vehicle in W. Europe (given that a little more than half the new vehicles are already Diesel) and about 60% elsewhere. With the forecast quadrupling of the vehicle in-use fleet and a 3 to 4 fold increase in net transportation energy demand, these gains, as significant as they may be, are nonetheless insufficient to achieve even a net status quo in terms of CO₂ and fossil fuel demand. If the current mobility model remains in place, we will still see an approximate doubling of land transport-related energy demand and fossil-related CO₂ emissions even with full deployment of our most advanced powertrain technologies and a downsizing of the fleet.

Clearly, non-conventional solutions are needed.

► Possible Solutions

The search for non-conventional solutions needs to embrace the full spectrum of options. Most attractive in the list of possibilities is the fuel cell. The attraction is not so much due to its use of hydrogen (the well-to-wheels benefits of which are often questionable) but more because it promises freedom from the efficiency constraints of the combustion process, having the potential to yield fuel consumption benefits that are almost double those of the best piston engines. While this doubling will be insufficient to offset the almost fourfold potential increase in the number of in-use vehicles globally, it will be a part of the solution, but not the entire solution.

Combinations of technologies can enable further reductions, as we've already seen with the combination of electric and internal combustion engines in today's hybrids. A move to smaller, lighter vehicles will also help. Substantial weight- and size-related improvements will come only when the vehicle is significantly smaller.

Fuel-cell powered 2-wheelers have been demonstrated, but they are not for every purpose. Indeed, much of the developing world wants to move away from 2-wheels and get on 4! Do we tell the developed markets they must move from 4-wheels to 2 (Figure 8)?



Figure 8: Daimler demonstrated a fuel-cell-powered scooter at the 2007 Challenge Bibendum in Shanghai, the epicenter of China's shift from 2- to 4-wheeled personal transport.

Or, do we:

- Force everyone into Nano-sized vehicles?
- Focus on pure electric vehicles charged from an emissions-free electric grid?
- Change the model of mobility away from physical mobility and towards virtual mobility via the internet or some other means?
- Prevent by some means the natural increase in the global fleet?
- Fundamentally change everyone's expectations of the necessary attributes of a personal motor vehicle, moving towards perhaps something like Toyota's i-swing (Figure 9)?



Figure 9: Toyota's i-swing, intended for personal mobility, is conceived for equal ease and safety on sidewalk and motorway alike.⁽⁴⁾

If one considers the fundamentals, it makes the most sense to:

- Create energy conversions (fuel to electricity, for example) on a large scale, as these are usually the most efficient.
- Adopt cogeneration principals to make the best use of all energy released in any given process
- Minimize the number of times we convert from one form and/or state of energy to another (electricity to hydrogen gas then to compressed gas or liquid and back again, for example)
- Utilize the smallest possible (least energy intensive) vehicle for any given mission

Is the answer, then, to develop and build large stationary fuel cells, powered by natural gas, and in combination with other sources generate power for the electrical grid, and then charge batteries in electric vehicles from the grid?

► Conclusion

Is mobility as we know it sustainable? Clearly, No!

Instead, the global model of mobility will change to embrace all these solutions and more. A wholistic approach must adopt political, market, regulatory and fiscal measures to evolve our current model towards one that minimizes the fundamental energy intensity of personal and goods transport.

What we must do is view the current regulatory standards for the next decade as the first steps, not the final objective. These are the foundation upon which we will build a new era of mobility.

The challenge before us is to recognize on a global scale that these are the necessary choices, and act soon enough such that the transition to this wholistic approach is managed as an opportunity rather than reacted to as a crisis. Left unabated, the natural economic demand for mobility will overwhelm the ability to sustain it, and we will enter into an era of profoundly disruptive change: a crisis of resources, of pollution, of mobility, with all the resultant political and economic consequences.

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¹ Source: *Global Insight, Inc.*

² Source: *Future Powertrain Technologies, 2010 to 2025, May, 2007, Global Insight, Inc. and TIAX LLC*

³ *The Biofuels Boom, copyright 2007, Global Insight, Inc.*

⁴ *Picture courtesy of Toyota*