Cars and Civilization

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William & Myrtle Harris Distinguished Lectureship in Science and Civilization

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Jesse Ausubel is Director, Program for the Human Environment, The Rockefeller University, 1230 York Avenue, New York, N.Y. 10021. http://phe.rockefeller.edu/. This talk draws occasionally on J.H. Ausubel, C. Marchetti, "The evolution of transport," *The Industrial Physicist* 7(2): 20-24, 2001. The results and insights presented here come from many years of cooperative research with Nebojsa Nakicenovic, Cesare Marchetti, Arnulf Gruebler, Perrin Meyer, Iddo Wernick, Alan Curry, and others. Thanks to all, and to the Office of Net Assessment for encouraging the new work on peak use. This talk followed an opening address by Nebojsa Nakicenovic on the history of transport technology. This version includes more material than the time of the oral presentation allowed.

Title page photo credits: Sotheby's 2013

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Thanks to the Harris Family and the Cal Tech community, especially Jed Buchwald and Diana Kormos Buchwald, for the honor to speak with you about "Cars and Civilization." The first speaker, my long-time research partner Nebojsa Nakicenovic, concluded his remarks with the transition from sail to rail about 1830. My title page shows both a horse-drawn coach, the Brewster Park Drag, custom made in 1892 for the Vanderbilt family, who made their fortune in shipping and railroads, and the 1964 Chevrolet research vehicle CERV II with a top speed of 320 km/h (200 mph), and the power of 500 horses. In November 2013 Sotheby's auctioned the horse-drawn coach for $253,000 and the Chevy for $1,100,000.

As the second speaker, I will offer some theory to help explain the observations about travel behavior that Nebojsa has told, and then zoom into where cars now fit in the evolution of mobility. In the end I will conclude, with some relief, that America is peaking in its use of cars and petroleum. I will also conclude with nostalgia and respect, because cars multiplied human mobility 50-fold, reorganized civilization, and provided some of the greatest cultural expressions of the twentieth century. The Vanderbilt coach and the Chevy flag the start and the peak of the car race.

Travel instincts

I begin earlier than the Vanderbilt coach, and even earlier than Nebojsa, two to three billion years ago, with bacterial civilization, and the essentials of mobility. In a spatially inhomogeneous system, mobility favors a living organism. A couple of billion years ago bacteria were already equipped with rotating flagella, stirred by electric micromotors of the kind we today call step motors, capable even of traveling in reverse. The ancient, ubiquitous *E. coli* bacteria of the gut swim, run, and tumble in three dimensions (**Figure 1**).

When sufficient oxygen permitted multicellular architecture, mobility was assured with specialized structures, the muscles. Pterosaurs were flying 200 million years ago.

Predators develop in every ecosystem, including that of monocellular organisms, and so sooner or later, fast long-distance management becomes imperative, and with it the premises for a nervous system to evolve. The gazelle must be faster than the lion and perceive the chance to run. Human primacy in the biosphere is tied to the nervous system, so one sees how much we owe to the imperative of mobility. Following Immanuel Kant, one might even say the categorical imperative, though Kant famously never traveled more than 16 km (10 miles) from his home in Koenigsberg, two to three hours on foot.

These few premises let us see that human mobility is visceral. The basic instincts descend from the evolution of humanity. And four of them allow us to make sense of the complex use that humans make of transport.

The number one instinct is to stick to the budget of time spent in mobility. Humans reside in a protected base, be it a cave, condo, or dorm room. Like all animals having a protected base, we measure carefully the time in which we expose ourselves to the dangers of the external world, be they wildfires, drunken drivers, or narco-traffickers such as Los Zetas.

Travel time was accurately measured in various parts of the world by the late Yacov Zahavi, a leader of research about transport for the World Bank and the U.S. Department of Transportation in the 1970s. I tend to trust data from Japan and Switzerland, which perform meticulous surveys, and explain outliers by differences in methods or definitions. As you can see from **Figure 2**, many surveys give similar results, which allow us to assert a *Law of Constant*

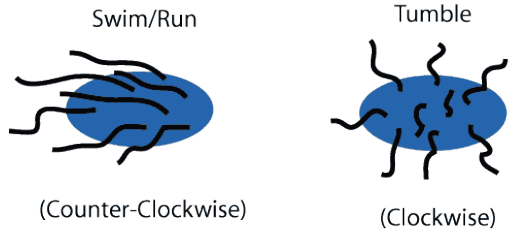


Figure 1. *E. coli* motion.
Source: http://www.mit.edu/~kardar/teaching/projects/chemotaxis%28AndreaSchmidt%29/finding_food.htm.

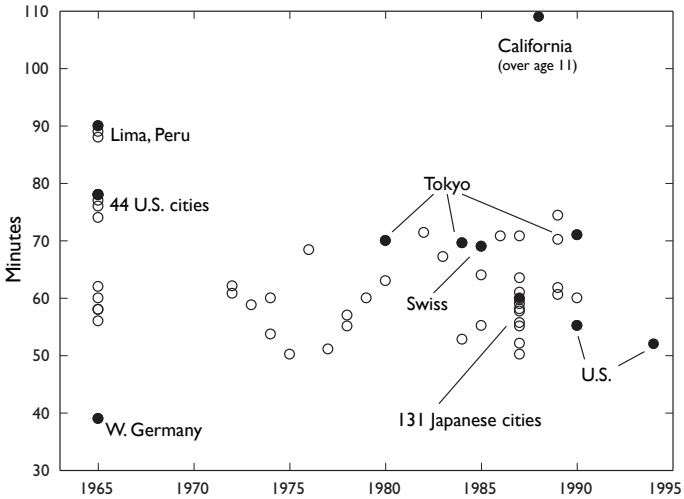


Figure 2. Travel time budget (minutes of travel per day, various studies).
Source: Ausubel, Marchetti, and Meyer, 1998.

Travel Time. Measured over the year and the whole adult population, humans spend about one hour per day on travel. Figure 2 shows one report from California notably higher than the U.S. average, and the high number may reflect a phenomenon known to sociologists as "time deepening." One can think of it as multitasking or partial attention, for example, eating a hamburger or talking on a cell phone while driving.

Here let me digress briefly on civilization. In the 1960s and 1970s, a comedy group from Los Angeles called the Firesign Theatre made several popular albums, starting with "Waiting for the Electrician or Someone Like Him." One of their funniest sketches was a quiz show about death called Beat the Reaper. It was not good for a contestant to lose. Anyway, people try to beat the reaper by time deepening, but deepening is risky, as partial attention tends to increase accidents and miscues.

I will show later that the travel time budget was also about an hour 5,000 years ago, but first I cite a 1995 survey of how the average American divided his or her daily time over a week (**Figure 3**). This survey, which did not allow for deepening or double counting, reported a mere 51 minutes daily for travel. In 2014, the 154 minutes for "Watching TV and Videos" and 43 minutes for "Reading" would be largely applied to activities involving the Internet, smart phones, and tablet computers. Robert Herman, one of the founders of traffic science and also a discoverer of the cosmic background radiation, used to call time the "disgusting coordinate of the Universe," and the meager daily budgets of 25 minutes for child and pet care and 18 minutes for hobbies show reasons we express disgust at time.

By the way, telecommuting fails to save energy or traffic because when we travel fewer minutes to work, we travel equally more minutes for shopping and leisure.

The number two instinct is to return to the lair in the evening. As seen in **Figure 4**, even sunlit Californians spend almost two-thirds of their time at home indoors. Trips almost all depart from the home, the center of one's world, using the best means of transport. The homing instinct lies at the core of the success of airlines. Airbus found that about 60 percent of the air passengers in Europe do their business and return in the same day, notwithstanding

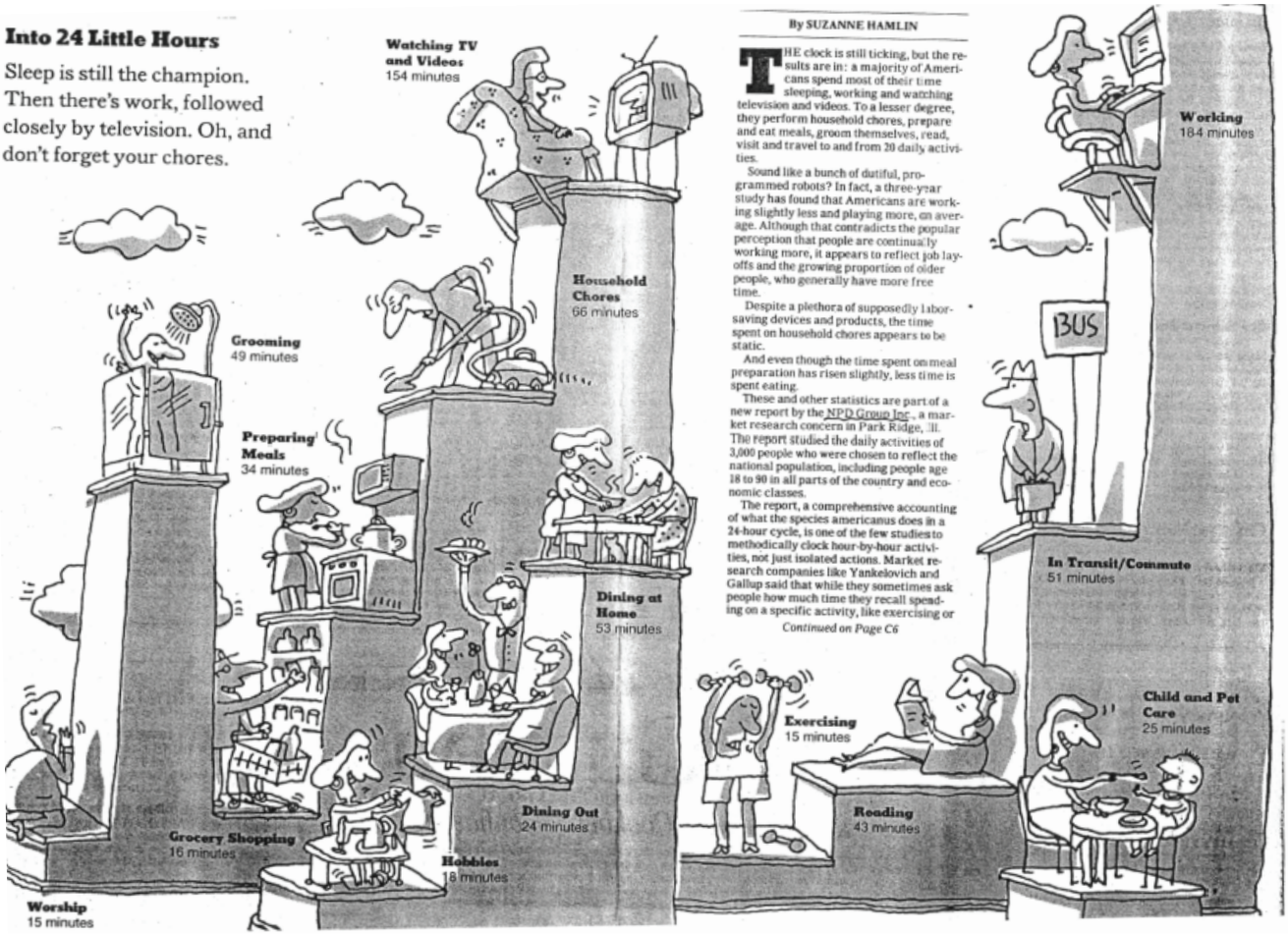


Figure 3. American time budget. Sleep, not included here, accounts for 7 hours 25 minutes, or 445 minutes, per day. Source: NY Times/NPD Group.

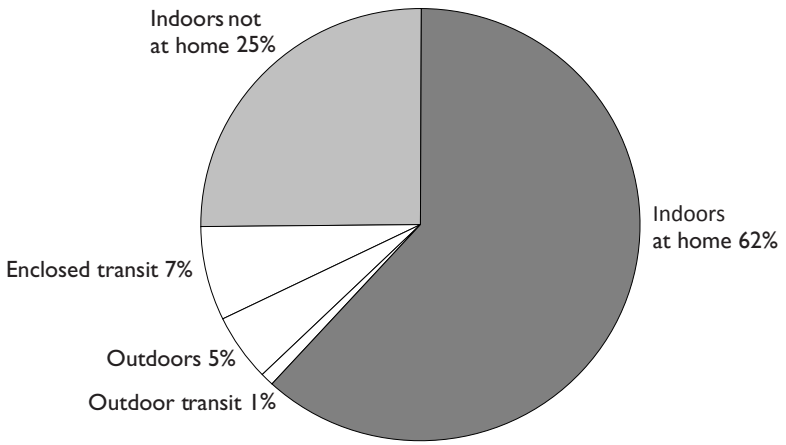


Figure 4. Percentage of time spent in major locations by Californians (over age 11)
Source: Wiley et al., 1991.

Table 1. Travel expenditures. Percent of disposable income, various studies.		
United States	1963–1975	13.2%
	1991	14.75%
United Kingdom	1972	11.7%
	1991	15%
West Germany	1971–1974	11.3%
	1991	14%
France	1970	14%
	1991	14.75%

Source: Zahavi, 1979; Schaefer and Victor, 1997.

high European fares. I would guess the air shuttles operating from Los Angeles carry the same proportion of day-trippers. The costly revival of the Amtrak trains, which do not comfortably permit a roundtrip day-return between Los Angeles and San Francisco, has barely scratched the airplanes, which appreciatively charge more than $400 for a one-way fare.

To the instincts associated with dangers of staying away from home, add the number three instinct: the travel money budget. Families spend about 12 to15 percent of their disposable income for mobility (**Table 1**). Zahavi's team measured the phenomenon 40 years ago, and recent checks show the same. **Figure 5** shows the 10 percent of GDP spent on mobility during 1995–2011 in the USA, a measure that by definition runs a bit lower than the fraction of disposable income. The chart shows strong persistence, as the 2008 recession caused only a temporary dent.

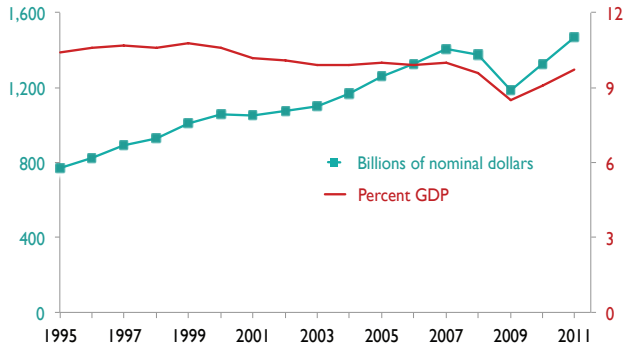


Figure 5. U.S. transportation spending, 1995–2001. Travel money budget: 10% of GDP (or somewhat higher fraction of disposal income).
Source: U.S. Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics, *National Transportation Statistics*, table 3-9, available at www.bts.gov as of October 2013.

The fourth and final instinct stems from the fact that humans are territorial animals. I do not need to spend much time to explain it. Most history is a bloody testimony to the territorial instinct. Think of Ukraine or the Bloods and Crips in South LA, or the gang neighborhoods near Pasadena shown in **Figure 6** from the fascinating Web site Streetgangs.com. The objective of the territorial animal is to have a territory as large as possible, within the natural limits of the possibilities of acquiring and managing it.

For humans a large, accessible territory means greater liberty in choice of the three points of gravity of our lives: the home, the workplace, and the school.

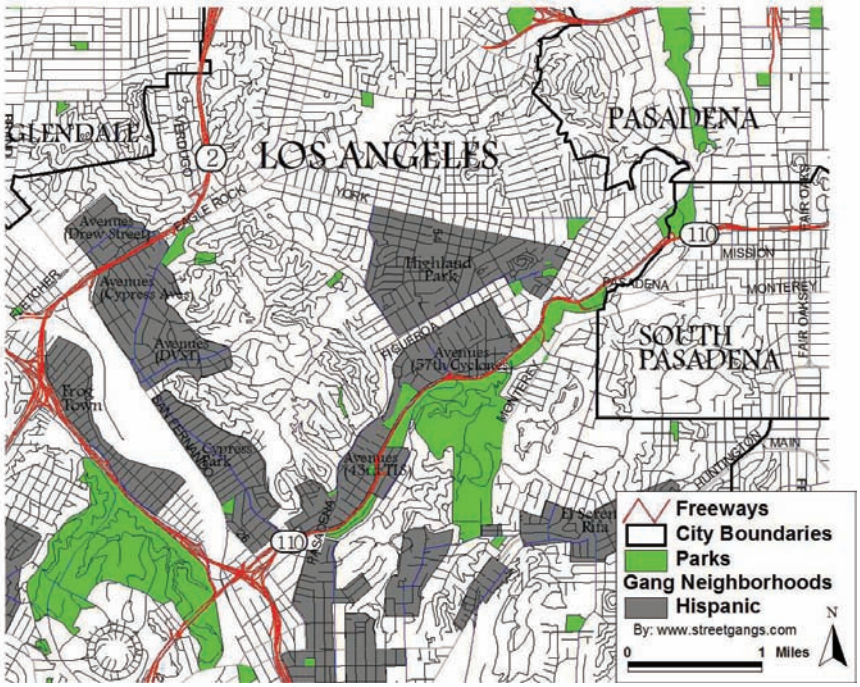


Figure 6. Streetgangs.com map of nearby neighborhoods.

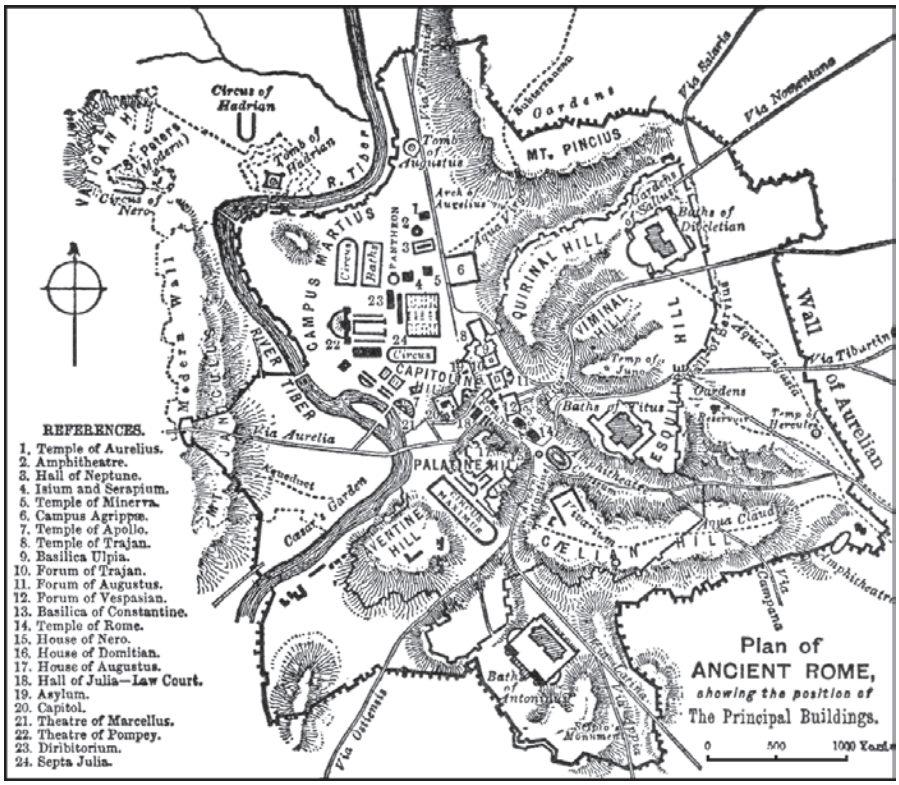


Figure 7. Imperial Rome.
Source: http://www.best-of-rome-italy.com/support-files/ancient_rome_map1.pdf.

Four-fifths of all mobility ends in this triad.

With these requirements of travel time and money budgets, the nightly return home, and maximization of territory, we can begin to interpret the world of movement and its substrate of geography.

Speed

Now turn to the speed that connects the requirements. By foot, a pedestrian, covers about 5 km in an hour. Going and returning home, a pedestrian's territory has a radius of 2.5 km and thus an area of about 20 km^2. We can define this area as the territorial cell of the individual on foot, exemplified by Kant, known for his clockwork habits. Maps of settlements and communities until about 1800 (and even for much of the world today) show territory that is paved by tiles with cells of about 20 km^2, often with a village at the center. So, the Law of Constant Travel Time has operated for thousands of years.

When the career of a village flourishes and it becomes a city, the 20 km^2 progressively fills with people. However, its borders are not breached. Numerous examples of belts or walls of ancient cities show that they never exceeded 5 km in diameter. Even imperial Rome spanned only about 5,000 yards, or 20 km^2, as **Figure 7** shows. Vienna started with a small medieval wall, its Ring, and then around 1700, after its victory against the Turks, made a triumphal second belt, the Guertel, at 5 km. Pedestrian Venice is elliptical, with a maximum diameter of about 5 km.

As Nebojsa showed, the human situation remained remarkably pedestrian, almost stationary, until about 1800. There were horses, but few relative to riders because of their cost. Horses served as an exhibition

of riches and an instrument of military power and communication. As **Figure 8** shows, horses could be quite fast. In 1861 after a hybrid journey involving a telegram from New York, the Pony Express could carry a letter from Missouri to San Francisco, about 3,100 km (1,900 miles), in 10 days, with a respectable average speed of 13 km/h. Alas, the 120 riders, 184 stations, and 400 horses cost a customer $1.00 to ship a half ounce, or $26 in current money, about 50 times a present first-class stamp. Horses of course also provided energy in agriculture. In fact, most horses worked on farms. Around 1815, Sweden appears to have topped horse ownership with about one per six people, while the rich, imperial UK had only about one per 10. Around 1900 in the USA, where hay was cheap (as gas soon would be), horses per capita peaked at about one horse for four people. Compare that ratio to today's four motor vehicles per five Americans. Notwithstanding many paintings and sculptures of riders and galloping mounts, horses did little for human mobility.

Thus, horses did not make cities grow. Augustan Rome had about one million inhabitants. Istanbul, Europe's largest city in 1700, had about 700,000. London, which would become number one in size, had only 676,000 in 1750. Basically, a city remained the area one could span in an hour, and as long as speed remained pedestrian, city span and population were capped. In 1800 the great networks of roads created by the Romans still served much of Europe for the administrative messengers and the movement of goods and also troops. Infantry, foot soldiers, made up the armies; cavalry were precious and few.

Starting about 1800, new machines for transport entered the field. They permitted ever-higher speed and revolutionized territorial organization. As Nebojsa described, the highly successful machines are few — the train, auto, and plane, introduced in successive arcs over 200 years. Inside cities, subspecies such as the bicycle, electric tram, bus, and subway are also important for the internal organization of the city and its dimensions.

The diffusion of the train, car, and plane technologies has been slow. Each has taken from 50 to 100 years to saturate its niche. Each machine carries a progressive evolution of the distance traveled daily that surpasses the 5 km of biological mobility by foot.

Figure 9 shows on a semilogarithmic scale how matters proceeded in the USA from 1880 to 2000. The pattern resembles the even longer span for France plotted by Arnulf Gruebler (1990) shown by Nebojsa. The dashed line indicates that American mobility grows on average about 2.7 percent per year, a doubling about every 25 years. I wonder if physical mobility is a deeper indicator of social change, and

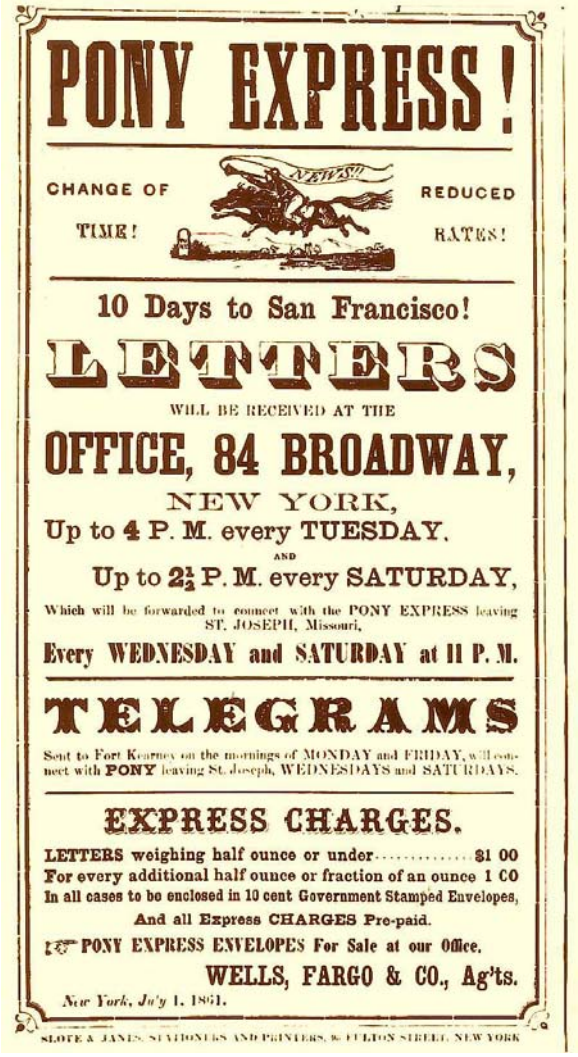


Figure 8. This 1861 poster advertises the Pony Express reduction in rates from $5 per half ounce to $1. Source: Wikipedia and originally Smithsonian National Postal Museum.

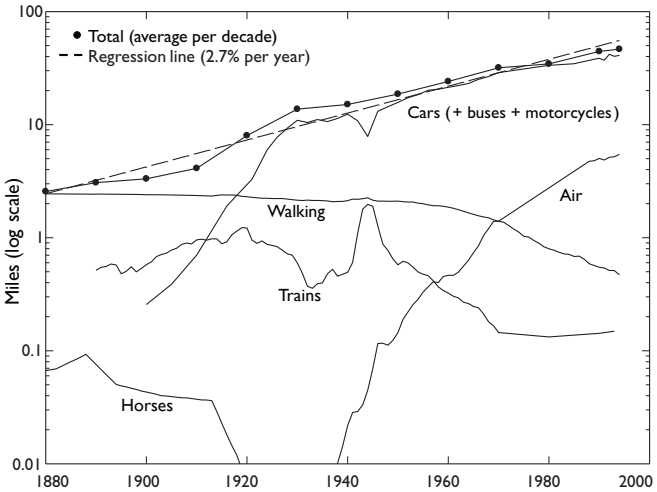


Figure 9. U.S. passenger travel per capita per day (range). Source: http://phe.rockefeller.edu/green_mobility/.

even progress, than many other indicators more often reported.

As we see from Figure 9, cars surpassed trains and feet in America by 1920 to become the number one means of mobility. Nevertheless, since about 1920, the time of Henry Ford's big success, cars have an average speed in most countries of about 35–40 km/h. That is, all the kilometers cars travel each year divided by all the hours that cars travel each year equals about 35 km/h. A hundred improvements in vehicle and road design ranging from headlights and windshield wipers to lane demarcation and roundabouts only conserve our speed. Given that one hour is the daily budget of the traveler and that car owners on average now use their cars 55 minutes per day, daily mobility in California or Europe is little more than 35 kilometers per day. The escape from these rigid boundaries, as I will explain later, is by air.

Angelenos know that the automobile and its mechanical cousins destroyed the village and invented the megalopolis. If the use of the Ford gives a mobility of about 35 km/h, then it affords a territory of about 1,000 km^2, 50 times greater than the 20 km^2 of the pedestrian city. Mexico City, for example, is based on the auto as the instrument of mobility. Its official population today exceeds 21 million. Fitting an equation to its growth, one extrapolates development to a saturation of about 50 million. In principle, 50 times the territory equals 50 times the population, although practical problems as well as cultural changes in family size are likely to keep the numbers lower.

Age of the car

Rather than complain about smog, I would like now to offer an interlude honoring the car, more precisely half a dozen cars auctioned at Sotheby's in November 2013 in addition to the Chevy. Engineers and designers as well as businessmen and consumers understood the importance of the car and lavished artistry and money on it. When people in future centuries ponder the twentieth, the car may well symbolize our civilization. In 2000, cars still provided Americans about seven times as much mobility as planes for all travel and about four times as much for intercity travel.

Let's begin in 1912 (**Figure 10**) with a Stutz Bearcat, the car in which the author of The Great Gatsby, F. Scott Fitzgerald, and his wife Zelda sped back and forth between country and city. The car came to symbolize the Roaring Twenties in America.

The 1930s brought a new streamlined look, and few cars surpassed the elegant French Delahaye 135S Teardrop Coupe. Buying and storing one would have been a good investment, as the recent auction price was $2.4 million (**Figure 11**).

The 1938 French-Italian Talbot-Lago Teardrop Cabriolet with a long wheelbase and an aerodynamic form would have been an even better investment, as the model elicited more than $7 million in the same sale (**Figure 12**).

In the 1950s, cars began to feel the competition of planes, and designers offered cars like the 1956 Aston Martin Supersonic (**Figure 13**). That year the car sold for about 3,000 British pounds (about $100,000 today)

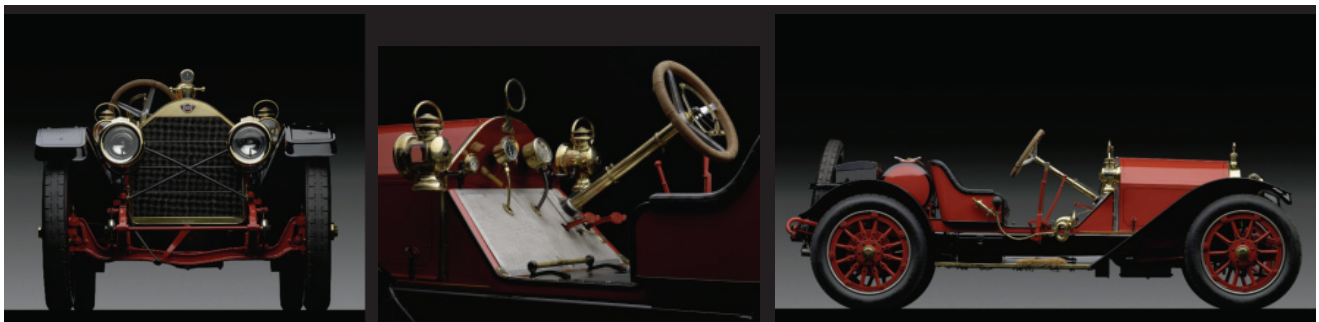


Figure 10. Stutz Model A Bearcat, 1912, $770,000.

Figure 11. Delahaye Type 1355 Teardrop Coupe 1936, $2,420,000.

Photo credits: Sotheby's 2013

and auctioned for $2.3 million last November. Aston Martins glorified drivers, such as James Bond in the 1964 film *Goldfinger*.

Returning to the USA, General Motors symbolized American affluence and comfort in 1958 with a 126.5-inch-wheelbase Oldsmobile with a V8 engine, power steering, air suspension, electric clock, color-accented wheel disks, abundant chrome, and interiors that could be ordered in a variety of colored leathers (**Figure 14**).

Humans began traveling in space in the early 1960s, and the 1964 Chevy on the title page looked poised to compete. Rated at 370 kW, the single car had more horsepower than the 400 horses of the Pony Express relaying a cargo from Missouri to San Francisco a century earlier.

By 1970, car culture had diversified into humor and fully merged with other popular culture. Chrysler introduced the Plymouth Road Runner with a protruding nosecone, rear wing, and a horn that sounded like the beep-beep of the popular Road Runner in cartoons (**Figure 15**).

The giddy, carefree run, indeed overshoot, of cars in America, came to an end about this time. The horn

Figure 12. Talbot-Lago T150-C SS Teardrop Cabriolet 1938, $7,150,000.

Figure 13. Aston Martin DB2/4 MK II Supersonic 1956, $2,310,000. The gentleman's rocketship.

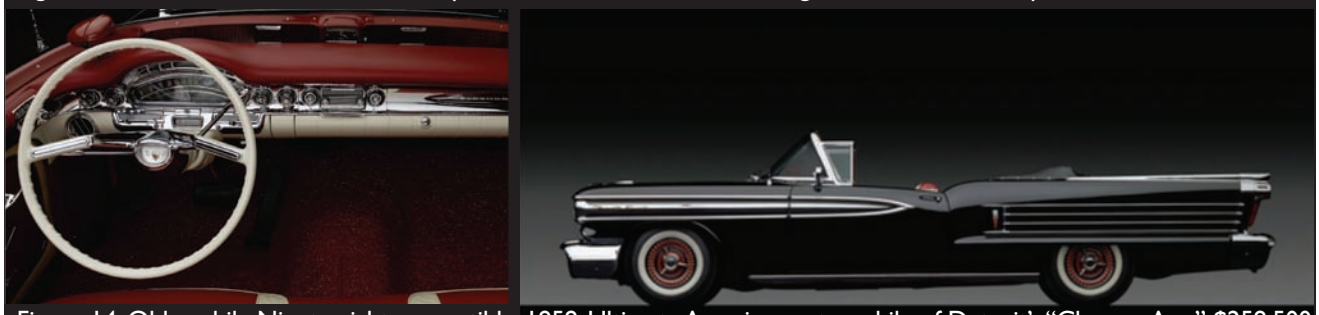


Figure 14. Oldsmobile Ninety-eight convertible, 1958. Ultimate American automobile of Detroit's "Chrome Age," $258,500.

Figure 15. Plymouth Road Runner Superbird, 1970. Muscle car known as The Winged Warrior, $363,000.

Photo credits: Sotheby's 2013

also sounded for air pollution in 1970, as the USA legislated its Clean Air Act roughly marking peak pollution, and the first oil crisis of 1973–74 abruptly brought higher gas prices and introspection about automobility.

Today, in the developed countries there is a motor vehicle for nearly every licensable driver. The mode of transport is saturated. When we fit a logistic curve to the number of personal vehicles in the USA since 1900, the result shows 90 percent saturation (**Figure 16**). Not only are Americans near peak cars, we are also at peak vehicle miles traveled with personal vehicles (**Figure 17**). For the past decade more cars do not mean more vehicle miles traveled.

Gasoline consumption in America also peaked, but somewhat surprisingly about 40 years ago at 4,000 kilograms per capita per year. From 1900 to 1970, it looked like the sky was the limit, as cars like the 1955 Lincoln in **Figure 18** guzzled ever more gas per person. In **Figure 19** we again fit a logistic curve, and see the overshoot of the 1970s, the oscillation around a plateau from about 1980 to 2010, and the recent decline to about 3,000 kg per capita in 2012, fully a quarter below 1970.

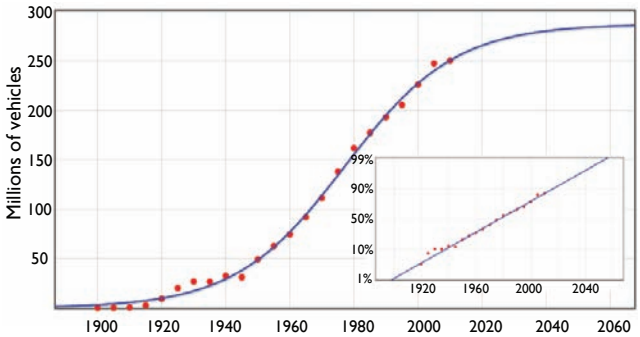


Figure 16. Vehicles in USA, approaching peak car.
Source: Garrison and Levinson, 2014.

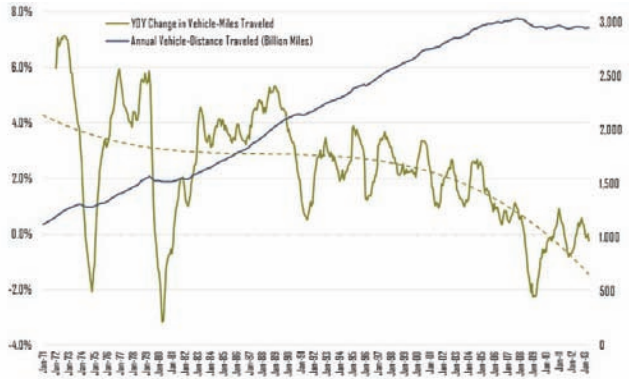


Figure 17. Peak vehicle-miles traveled in personal vehicles, USA, 1971–2013.
Data source: U.S. Department of Transportation, Federal Highway Administration. http://www.fhwa.dot.gov/policyinformation/travel_monitoring/14martvt/.

Naturally one wonders about consumption in other nations. As **Figure 20** shows, Japan's experience matches America's very closely in time, while Korea's peak followed in 1996. The saturation levels for these

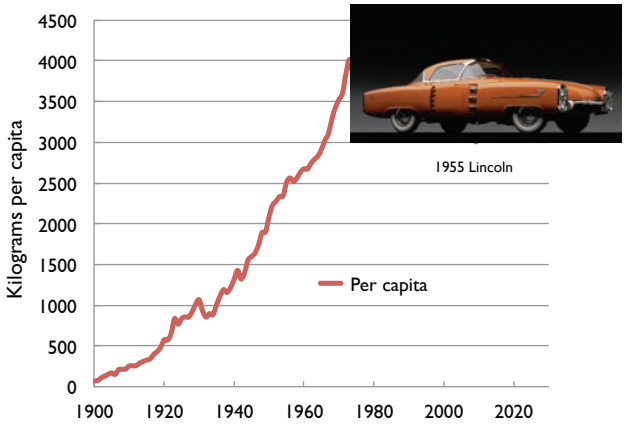


Figure 18. Historic U.S. petroleum growth.
Data sources: USDOE Energy Information Administration, 2013. Ausubel, Wernick, and Curry, 2014.
Photo credit: Sotheby's 2013

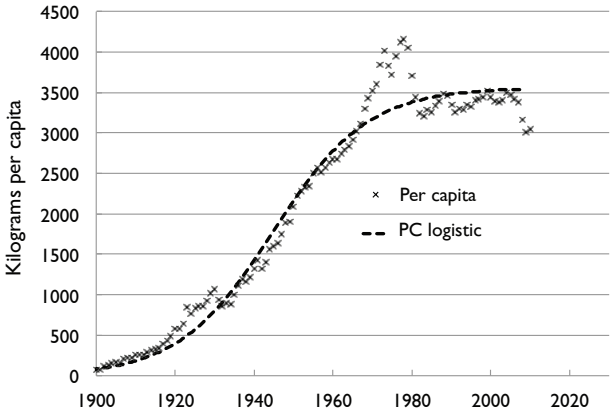


Figure 19. U.S. peak petroleum, logistic fit. Per capita apparent consumption.
Data sources: USDOE Energy Information Administration, 2013. Ausubel, Wernick, and Curry, 2014.

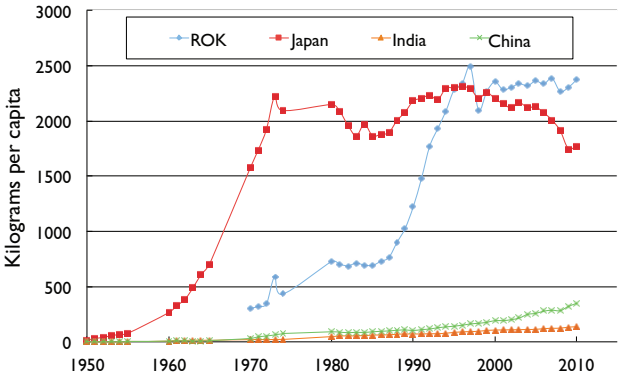


Figure 20. Petroleum use in four Asian nations. Per capita apparent consumption.
Data sources: USGS, British Geological Survey. Ausubel, Wernick, and Curry, 2014.

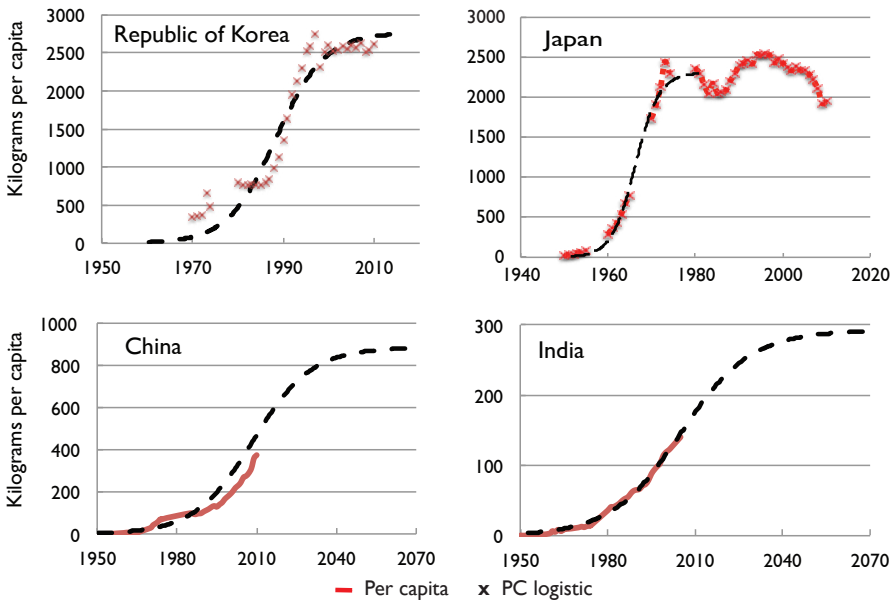


Figure 21. Estimated saturation of petroleum use in four Asian nations.
Data sources: USDOE Energy Information Administration, 2013; British Geological Survey, International Energy Agency. Ausubel, Wernick, and Curry, 2014.

nations were about 2,500 kilograms per capita per year, about 30 percent less than the American 3,500. China and India appear early in their growth, and **Figure 21** suggests their peaks will come in about 2040 and 2050, respectively, but at much lower levels. If the forecasts are right, Chinese per capita oil use will saturate about one-third the Japanese and Korean level and India one-eighth.

Arnulf Gruebler (1990) has established this pattern of later adopters saturating at lower levels for many technologies. For example, no one built rails as densely as the exuberant British, who began the craze about 1830. The passage of time and associated learning allow later adopters to extract superior services with more efficiently designed and operated systems as well as integration of new alternatives.

Of course, carmakers may try to sell more cars until we each have a second car at our second home and a third as a fashion accessory or tailored for particular errands. However, the added cars will not lift our mobility, as we already hit the limit of our travel time budget, as Figure 17 suggested.

By the way, subways or metros can flourish if they beat the average speed of the car, the 35 km/h door-to-door inclusive travel time. We reject forms of mass transit, carpooling, and other modes that slow our travel time, which includes walking to the bus stop and waiting for the bus or a friend for a ride share.

Environmentally, the one-license, one-car equation means that each car on average must pollute little. Incremental efficiency gains to internal combustion engines will help and so might a fuel shift from petroleum to natural gas, but these may not suffice. The electric alternative of 300 million large batteries in the USA made with poisonous metals such as lead or cadmium poses materials recycling and disposal problems.

One answer is the zero-emission fuel cell, where compressed hydrogen gas mixes with oxygen from the air to give off electric current in a low-temperature chemical reaction that also makes water. If refining is directed to the making of hydrogen, its cost should resemble that of gasoline. Moreover, the electrochemical process of the fuel cell is potentially 20 to 30 percent more efficient than the thermodynamic process of today's engines. Toyota and other manufacturers now plan to penetrate the market by about 2020 with various forms of fuel cell and hydrogen cars. Because of the large, lumpy investments in plant required, the traditional 10-year lifetime of cars, time for diffusion of refueling and service infrastructure, and gradual public acceptance, it will take two to three more decades before the winners in the renewed competition of motors and fuels become fully apparent.

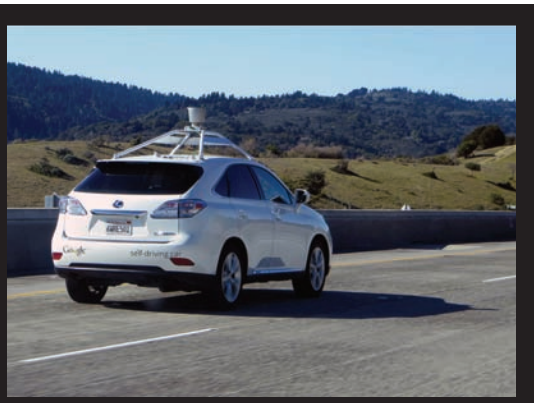
While newer motors and fuels are clean and efficient, they do not enhance speed. Some increase in the speed of the fleet might come from intelligent transport systems, that is, total computerization of the vehicle and its context. I am inclined to think these systems will mostly pack more vehicles safely into the system at the same speed. Let's not forget that more than one million people die each year in the global bloodbath called traffic.

Figure 22. Google Chauffeur: self-driving car.

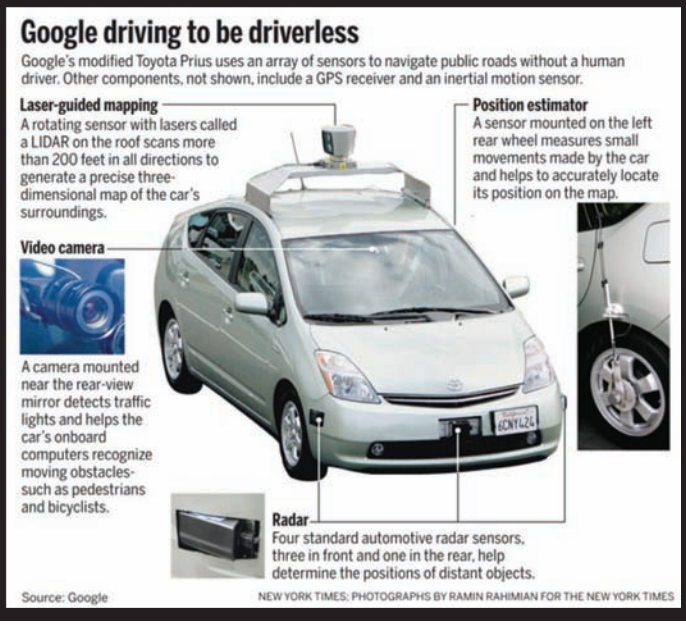
Nevada passed a law on June 29, 2011, permitting operation of autonomous cars.

In August 2012, the team announced that they have completed over 300,000 autonomous-driving miles (500 000 km) accident-free.

A car also traversed San Francisco's Lombard Street, famed for hairpin turns.



Actor Sean Connery as James Bond, with the Aston Martin DB5 from *Goldfinger*.



Systems such as Google Chauffeur's self-driving car (**Figure 22**) could reduce accidents and will allow time deepening, i.e., multitasking. The car can become an office, café, or bedroom. The driverless car shifts the drama of car travel from James Bond at the steering wheel to a programmer who writes the code or possibly a drone pilot with a joystick and to the backseat. It will also eliminate millions of jobs for drivers of taxis, buses, and trucks. Manufacturers will compete to sell more bits rather than horsepower.

With the actual state of travel technologies, we can seriously augment our mobility, that is, our average speed, only by augmenting the present quota spent in the air. The mean speed of a plane is 600 km/h, more than an order of magnitude faster than a car. As **Figure 23** shows, air has been gaining in the competition for intercity passengers, but in 2000 still accounted for only about one-fourth of the U.S. passenger kilometers (or miles) that cars did. Amazingly, in the USA our daily air time is still only about one minute, while Europeans (in 27 EU nations) fly only about half a minute daily. A mere 100,000 km (or 60,000 miles) by air per year means a person flies about 30 minutes per day, as many of us do. Thus, a huge rise of our national average is doable without breaking our health. And rising incomes mean a higher travel money budget that can accommodate airfares.

If everyone flew 30 minutes per day, however, present infrastructures would be violently stressed by a rise in traffic of 30 times in the USA or 60

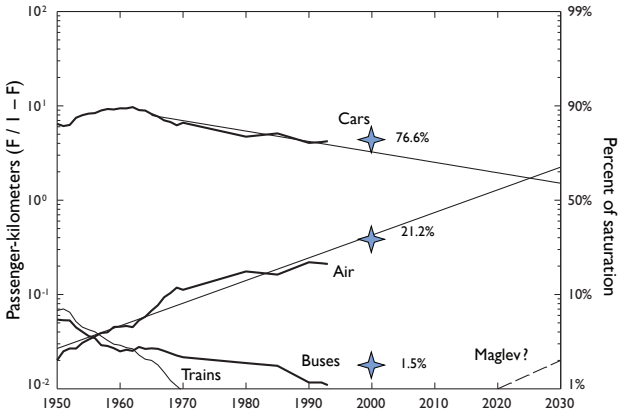


Figure 23. U.S. domestic intercity passenger traffic, fitted with logistic substitution model.
Source: http://phe.rockefeller.edu/green_mobility/.

times in Europe. Until recently, the system held up well in large part by augmenting the productivity of the planes in proportion to the traffic, that is, the passenger kilometers per hour of flight, or the capacity divided by velocity. The Airbus 380 with twin decks and four aisles is certified up to 853 passengers. Replacing old planes with larger and faster ones held the core (Western) commercial fleet constant around 4,000 planes until about 1980. According to Boeing, the in-service fleet of Western-built commercial single-aisle planes alone soared to over 13,000 in 2013 and jammed the air and airfields as cars jammed roads in an earlier cycle.

For the present airports, growing high-speed transport will be hard. Even with more efficient airports, environmental and safety problems loom. Airplanes will consume a big fraction of the fuel of the transport system, a fact of interest to both fuel providers and environmentalists. Today's jet fuel may not pass the environmental tests of future air traffic volumes.

We need a high-density mode with the performance of top airplanes without the problems. The key is a new mode of transport. In the last 200 years the system has given birth to a new means of transport every 60 years or so, integrated with larger economic and technical pulses. **Figure 24** shows the smoothed historic growth rates of the major components of the U.S. transport infrastructure. Canals came with hay and horses to tow the barges. Rails came with coal and steel for steam engines. The telegraph was the nervous system. Roads came with gasoline and cars and internal combustion engines. The phone was the nervous system. Air came with turbines and advanced materials and radio in various wavy forms, and may require cleaner fuel, eventually hydrogen, to achieve its full extent.

One can view these infrastructures as products competing for market share. The secular evolution is

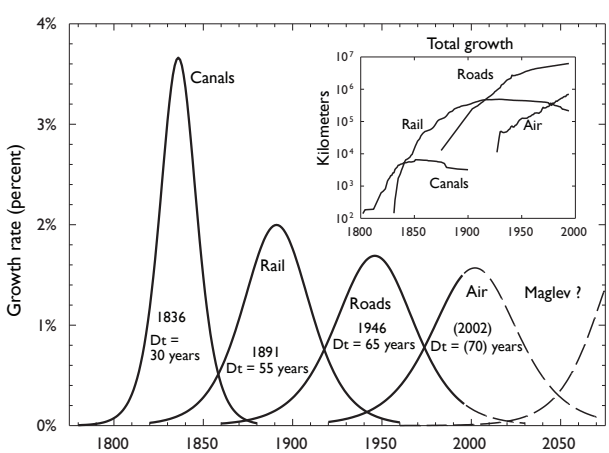


Figure 24. Idealized growth of U.S. transport infrastructure.
Source: Ausubel, Marchetti, and Meyer, 1998.

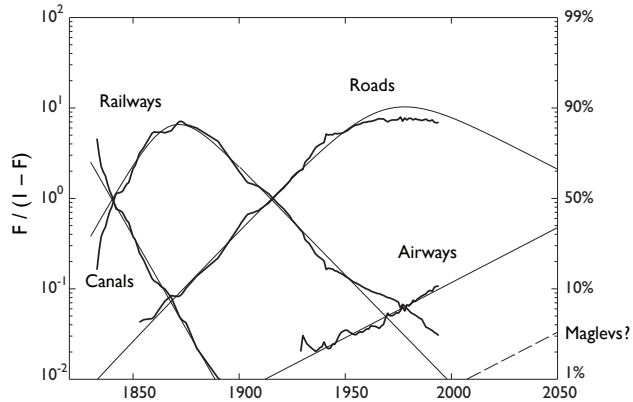


Figure 25. U.S. infrastructure, fitted with logistic substitution model.
Source: Ausubel, Marchetti, and Meyer, 1998.

beautiful, as **Figure 25** shows. Clearly, air will be the big winner for the next decades.

Future modes of transport

But the twenty-first century should also prove fecund for a new mode of transport. According to our studies, the best bet is on magnetically levitated systems, or maglevs, "trains" with magnetic suspension and propulsion. Elon Musk has proposed a variant called the hyperloop that would speed between Los Angeles and San Francisco at about 1,000 km/h, accomplishing the trip in about 35 minutes and thus comfortably allowing daily round trips, if the local arrangements are also quick (**Figure 26**).

The maglev is a vehicle without wings, wheels, and motor, and thus without combustibles aboard. Suspended magnetically between two guard rails that resemble an open stator of an electric motor, it can be propelled by a magnetic field that, let's say, runs in front and drags it.

Hard limits to the possible speed of maglevs do not exist, above all if the maglev runs in an evacuated tunnel or surface tube. Evacuated means simulating the low pressure that an airplane encounters at 10,000 to 20,000 meters of altitude. Tunnels solve the problem of permanent landscape disturbance, but tubes mounted above existing rights of way of roads or rails might prove easier and cheaper to build and maintain.

Spared a motor and the belly fat called fuel, the maglev could break the rule of the ton, the weight rule that has burdened mobility. The weight of a horse and its gear, a train per passenger, an auto which on average carries little more than one passenger, and a jumbo jet at takeoff all average about one ton of vehicle per passenger. The maglev could slim to 300 kg, dropping directly and drastically the cost of energy transport.

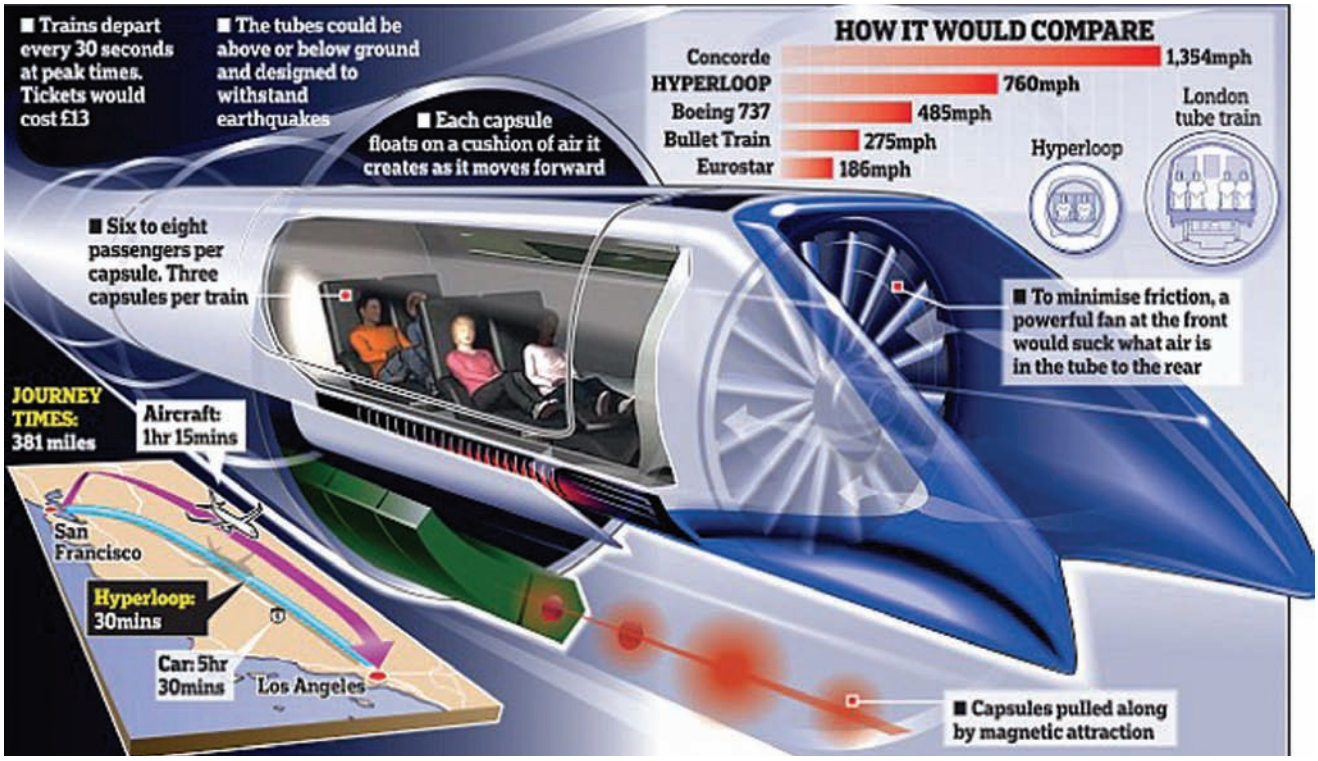


Figure 26. California Hyperloop.
Source: http://www.dailymail.co.uk/news/article-2390672/Elon-Musks-Hyperloop-SuperTube-shoot-LA-San-Francisco-30-MINUTES.html.

Maglevs also offer a way for electricity to penetrate transport, the sector from which it has been largely excluded. French railroads, of course, are already powered cleanly and cheaply by nuclear electricity. For a decade maglevs have routinely shuttled between Shanghai Airport and the center city, and now begin in Korea too.

Will maglevs make us sprawl? This is a legitimate fear. In Europe, since 1950 the tripling of the average speed of travel has extended personal area tenfold, and so Europe begins to resemble Los Angeles. In contrast to the car, maglevs may offer the alternative of a bimodal or "virtual" city with pedestrian islands and fast connections between them. Maglevs can function as national and continental-scale metros, at jet speed.

Looking far into the twenty-first century, we can imagine a system as wondrous to today's innovators as our full realization of cars and paved roads would seem to the maker of the Stutz Bearcat. Because the maglev system is a set of magnetic bubbles moving under the control of a central computer, what we put inside is immaterial. It could be a personal or small collective vehicle, starting as an elevator in a skyscraper, becoming a taxi in the maglev network, and again becoming an elevator in another skyscraper. The entire bazaar could be run as a videogame where shuffling and rerouting would lead the vehicle to its destination swiftly, following the model of the Internet. In the end, a maglev system is a common carrier or highway, meaning private as well as mass vehicles can shoot through it.

Let me come back to Pasadena at this point and synoptically review my picture of mobility. Humans search for speed because, with a fixed travel time, speed gives us territory and its access to resources. A person on foot has 20 km^2, while a person in a car has 1,000 km^2, and that makes a difference. The jet set can have a continent. Cost affects choices for mobility through incomes. As a rule, the choice is to consume both the time and disposable money budgets, maximizing the distance, that is, the speed.

Rising incomes mean rising speed at all social levels. The rich, of course, accelerate more than the poor. While poor means slow, even the slow today speed when compared with Queen Victoria. In industrial countries, a poor man has a car and mobility superior to an ancient nobleman and at least equal to the Great Gatsby. When new travel modes are introduced, such as supersonic Concorde planes or maglevs, they will first be the province of the rich.

Old technologies can persist, fight back, and sometimes revive. After steamships had operated for 50 years, clipper ships, whose towering masts supported vast sails, could speed faster than 16 knots (30 km/h) in good winds, and enjoyed their golden age in the 1850s. Like carriage makers building the elegant Vanderbilt coach in 1892, designers will still

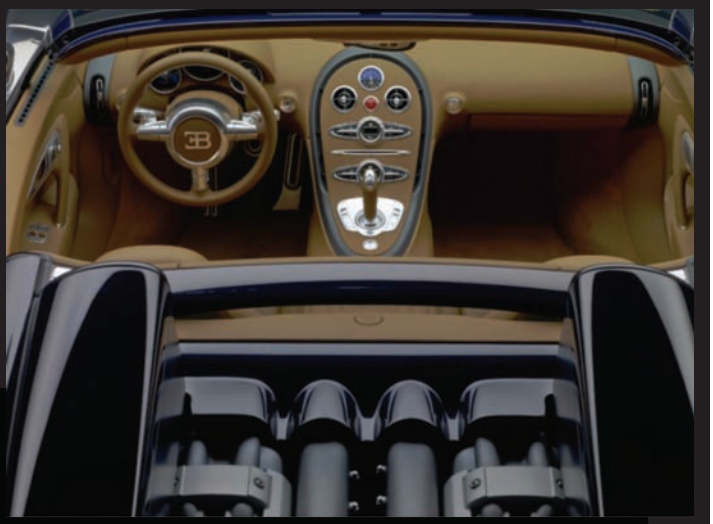
make extravagantly beautiful and powerful cars like the 1,000 horsepower 2011 Bugatti Blue Night or their drone successors (**Figure 27**). Artistry attracts buyers.

Still, though a car can now equal 1,000 horses, peak car and peak petroleum have passed in the USA. The fast 1964 Chevy looks like the inflection point of the growth of the automotive age. Soon after, we began to apply brakes to cars and shift to other modes for speed that better fit our basic instincts, namely travel time and money budgets, the nightly return home, and the maximization of territory.

In conclusion, we see that the drive for mobility is one of the deepest human drives and elicits some of our cleverest solutions, which we call civilization.

Figure 27. Bugatti Veyron 16.4 Grand Sport Bleu Nuit, 2011, top speed of 400 kph, 750 kW, 1,000 hp, $2,310,000. A clipper ship of cars?

Clipper ship *Flying Cloud* held the record for fastest passage between New York and San Francisco, 89 days 8 hours, 1854–1989. After print by Jack Spurling, 1926.



Photos: Sotheby's 2013

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