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SELF-DRIVING CARS IN THE EVOLVING URBAN LANDSCAPE

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ABSTRACT

To understand the potential for self-driving cars it helps to understand the evolving spatial structure of urban areas as well as the inadequate responsiveness of traditional transportation modes in the face of this change. The typical megacity (> 10MM residents) now covers more than 5000 square kilometers. As urban labor markets continue to increase in size, urban trip patterns are evolving quasi-universally: involving increasingly dispersed origins and destinations over longer distances.

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Self-driving cars in the Evolving Urban Landscape

A preliminary note by Alain Bertaud

To understand the potential for self-driving cars it helps to understand the evolving spatial structure of urban areas as well as the inadequate responsiveness of traditional transportation modes in the face of this change. The typical megacity (> 10MM residents) now covers more than 5000 square kilometers. As urban labor markets continue to increase in size, urban trip patterns are evolving quasi-universally: involving increasingly dispersed origins and destinations over longer distances.

While job and population densities remain high in traditional city centers, the growth of employment and population is occurring mostly in the suburbs. In the United States, the majority of commuting trips are from suburb to suburb while about a third are either within the urban core or from the suburbs to the urban core. The share of metropolitan trips toward the urban core has been declining.

The same trend is observed in large cities of Africa, Asia, Europe and Latin America. Because of the extension of suburbs, the average built-up densities of cities are declining everywhere. This decline is due to the combined impact of land and labor markets. The efforts of urban planners to “design” higher densities are unlikely to succeed in the face of these market forces.

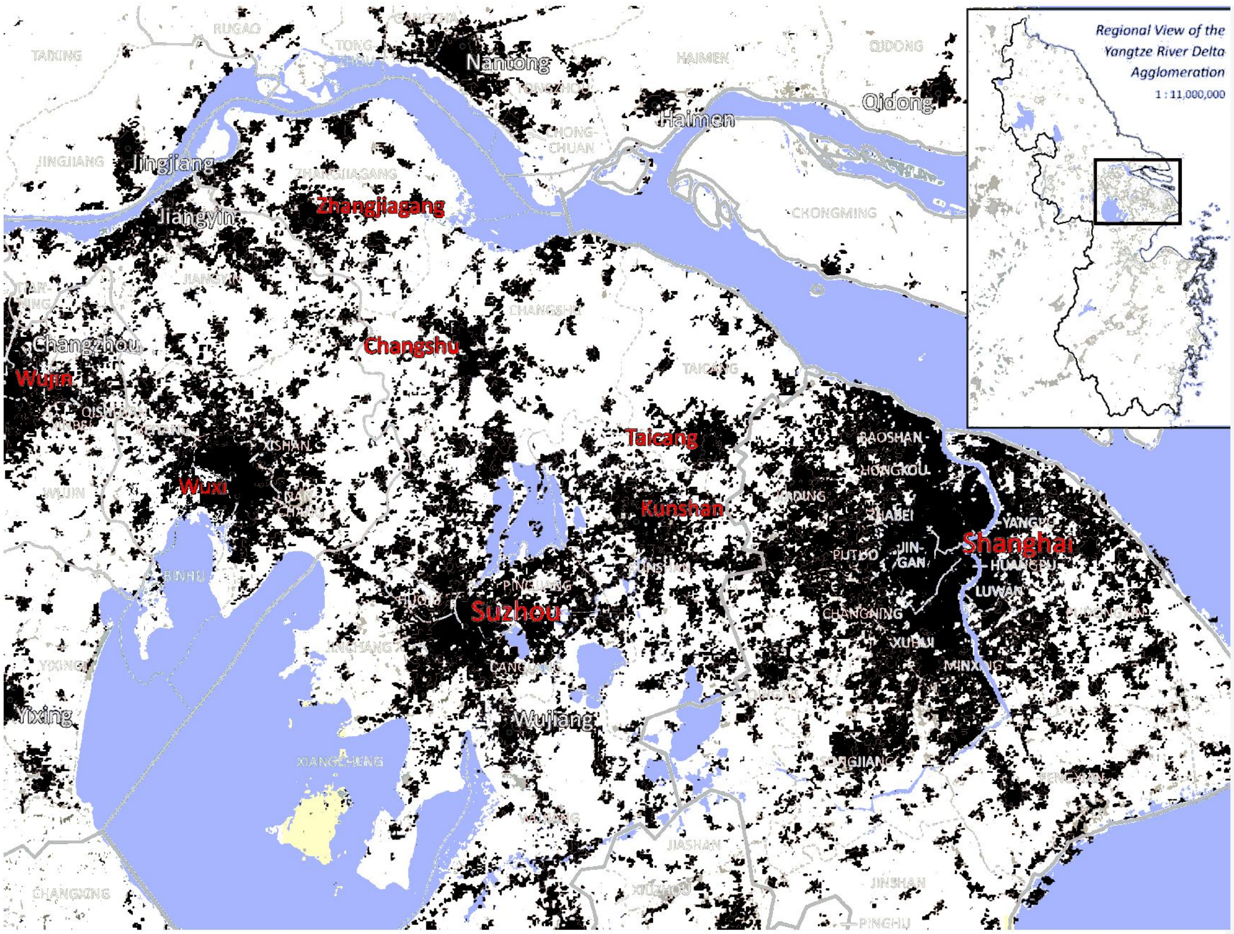
The Inadequacy of Traditional Transit

Traditional transit, subway, bus rapid transit (BRT), and city buses are efficient for bringing a large number of commuters toward concentrated zones of employment at rush hour. They are also efficient for trips within dense center cities — for instance, within Manhattan, within the municipal limits of Paris and Seoul, or within Shanghai city proper.

However, as employment disperses across metropolitan areas, efforts to expand the transit network to serve suburb-to-suburb trips are proving unsuccessful. Traditional transit is ill-adapted to serve trips with dispersed origins and destinations because of the weak demand for each specific commuting route.

Consider, for example, the map of metropolitan Shanghai below. The distance between Changzhou (on the left) and Shanghai (on the right) is 156 km as the crow flies. Bicycles and metros that stop every kilometer cannot meet the demand for trips in this massive metropolitan area. Rapid rail, complemented by individual vehicles, is far more likely to be the preferred mode of transportation between the jobs and residences that are dispersed across such vast distances.

The built-up area of the Metropolitan Region formed by Shanghai, Suzhou, Changzhou in 2010



Source: Map prepared by the University of Wisconsing-Madison, May 2013.

0 **150 km**

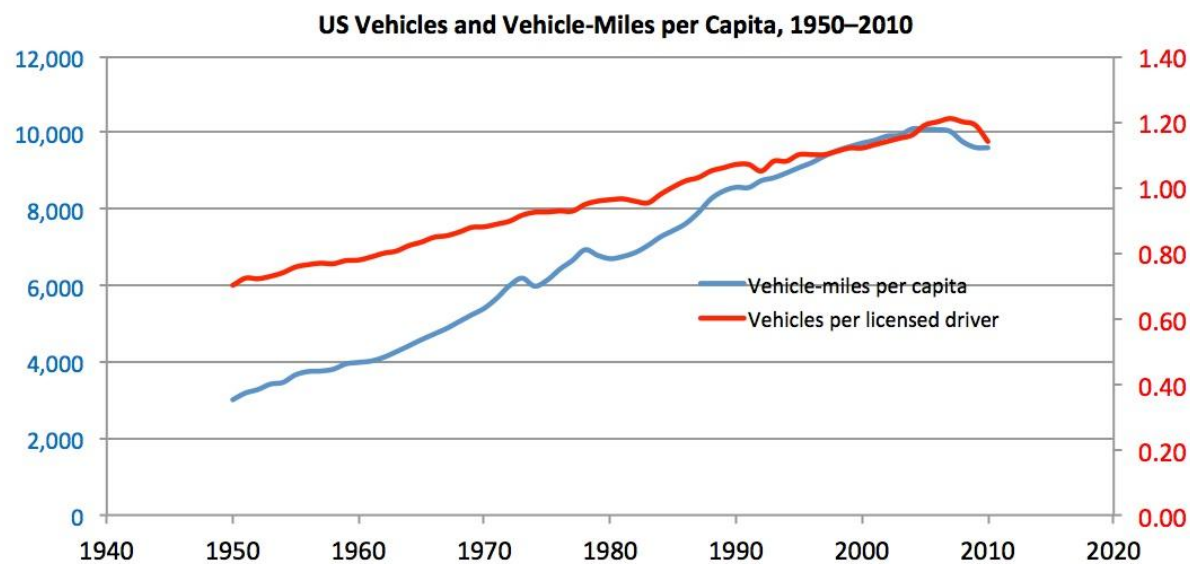
The increased flexibility of working hours in many professions is also serving to undermine the ability of transit to operate efficiently. Transit is often obliged to provide services at all times, leading to low occupancy outside of peak hours. As a result, buses in the US and UK now have carbon emissions per passengers/km that are higher than those generated by private cars.

For the ever-growing number of suburb-to-suburb trips in large metropolitan areas, traditional transit modes are therefore expensive to operate, inconvenient for users (longer trips with many transfers and infrequent service), and energy inefficient. As a result of this inefficiency, individual vehicles – cars, motorcycles, and rickshaws – are becoming the preferred mode of transport for the great majority of suburb-to-suburb commuting trips. See, for example, the table and figure below for data on commuting trips in the United States. In poorer countries, private minibuses and collective taxis offer the on-demand flexibility that fixed-route, scheduled-transit is unable to provide.

Table: Transportation modes, United States

Table 2. Mode to Work[12]	CTPP2000			2006-2010 ACS		
	Number	Percent	MOE(+/-)*	Number	Percent	MOE (+/-)*
	At Place of Residence					
Total Workers	128,279,235	100.0	33,806	139,255,035	100.0	120,716
Drove alone	97,102,050	75.7	32,267	105,840,717	76.0	113,013
2-person Carpool	12,097,345	9.4	13,767	11,115,428	8.0	37,380
3-or-more-person Carpool	3,536,715	2.8	7,561	3,302,878	2.4	61,412
Public Transportation	5,867,562	4.6	9,698	6,872,730	4.9	18,857
Bike	488,490	0.4	2,825	716,535	0.5	7,080
Walked	3,758,980	2.9	7,792	3,962,070	2.8	17,751
Taxi, Motorcycle and Other means	1,243,855	1.0	4,503	1,684,953	1.2	14,400
Worked at Home	4,184,230	3.3	8,215	5,759,724	4.1	19,688

Figure: Commuting trends mode in the US 2000-2010 (US Census, ACS)



The Trouble with Individual Vehicles

While individual vehicles and collective taxis are well adapted to suburb-to-suburb trips, they too have serious inefficiencies and shortcomings. One problem with individual modes of transport (with the possible exception of motorcycles) is their incompressible consumption of expensive real estate. Private cars, by necessity, consume a fixed area of land when parked. The land area consumed by cars increases with speed as they move through streets. A publicly parked car consumes about 14 square meters of street space; a car moving at 30 km/h requires 65 square meters of road.

Because the pricing and recovery of market rent for street space involves large transaction costs, there has been little incentive to reach an equilibrium between supply and demand. Furthermore, the supply of street space is by nature inelastic to changes in demand. The result is congestion that greatly reduces the potential efficiency of individual trips that are door-to-door and on-demand.

Energy use suffers from the same pricing problem — a failure to impose a polluting tax on road trips and a carbon tax on the use of energy. In the near future, the likely multiplication of electric engines for cars and motorcycles has the potential to solve the problem of local pollution. Controlling carbon emissions will, however, require a tax on the source of energy.

Given the inefficiencies of mass transit and individual cars, along with their inherent inability to adapt to changing trip patterns in the modern metropolis, the potential solutions offered by self-driving cars are worth exploring in detail.

Exploring the Potential for Self-Driving Vehicles

The current advance in self-driving cars' technology demonstrates that some of these cars will soon be seen on the road operating under normal conditions. Will the number of users of self-driving cars be limited to the demand from a niche-market (the handicapped, the elderly)? Or, alternatively, will their number become large enough to result in an improvement in urban mobility and by extension in making cities more productive and more energy efficient?

While there will always be uncertainty about a future market response to the eventual supply of mass-produced self-driving cars, we should conduct a debate focused on identifying any comparative advantage that self-driving cars may possess over existing transport modes. If the advantages of self-driving cars appear compelling under certain conditions—for instance, in shared fleets or as individual vehicles, or as a "last mile" extension of metropolitan heavy rail—the conclusions of this debate may help accelerate their future deployment, and may influence their final design.

We should be able to evaluate the potential advantages of self-driving cars against current transport modes using two scenarios.

- First, in an initial transition period when few self-driving cars would be on the road; and
- Second, when they might represent the preferred transport mode for large numbers of urban trips.

In addition, self-driving cars should be evaluated within both the well documented context of metropolitan transport in the US and within the more uncertain environment of fast growing megacities in Asia and Africa, with a diversity of income groups among potential users. It should be assumed that the self-driving technology could be installed on all sizes of vehicles, from minibuses to very compact three wheelers like the Toyota i-Road Personal Mobility Vehicle.

The advantages of self-driving cars over traditional means of transport (transit, collective taxis and individual vehicles) will depend on the manner in which they are deployed: user owned, shared fleet, or a mix of both. In general, the potential benefits that need to be quantified are preliminarily listed below. Once improved by the input of select conference participants, this list can serve as a jumping off point for paper topics leading into the conference itself.

Saving on real estate

1. Driverless vehicles can reduce the use of road space while driving at higher speeds—no need for the two-second human reaction time between vehicles. That said, if used in shared fleets, the self-driving vehicle could use more road space as vehicles will cruise empty to pick-up new passengers.
2. Driverless vehicles can reduce the area needed for parking. This would eliminate the need for costly zoning regulations that require minimum parking levels.
3. Driverless vehicles can save on parking space. Outside of peak hours, vehicle fleets could be stacked in line without space between cars on the sides or in front.
4. When the technology is generalized to the majority of vehicles, driverless vehicles improve the ease with which roads can be priced according to location, weight of vehicle, and time of day.
5. For shared fleets, adjusting vehicle size based on the length and nature of trip (commuting, shopping, leisure) will save on use of road space, road maintenance, and energy consumption.

Mobility

1. Driverless vehicles present the possibility of door-to-door trips at any time of day for any itinerary, free of the supply constraints imposed by transit networks. This flexibility will make the supply of urban land more elastic.
2. The improved mobility implied by driverless vehicles will increase the accessibility of firms in cheaper locations.
3. The use of shared self-driving car fleets at rail stations, increases the possibility of linked multipurpose trips. See, for example, the trials of the Toyota i-Road for last-mile car sharing as an extension of heavy rail in France and Japan.
4. Driverless vehicles improve the potential for car-sharing via pre-selection of passengers based on itinerary and trip time.
5. Driverless vehicles can reduce traffic congestion stemming from accidents and rubbernecking.
6. They can also mitigate the unpredictability of travel time due to the possibility of accidents.

Lower transport cost through better energy efficiency

1. By lowering the probability of accidents, self-driving cars would enable the use of lighter vehicles requiring less energy and less fuel.
2. By running in pods, driverless vehicles moving closer together will reduce drag, and therefore energy use and fuel cost.

Sources of information on commuting in the United States

Resident population and civilian employed persons - U.S. Department of Commerce, Bureau of the Census, Statistical Abstract of the United States–2012, Washington, DC, 2012, Tables 2 and 586. (Additional resources: www.census.gov)

Vehicle-miles - U.S. Department of Transportation, Federal Highway Administration, Highway Statistics 2010, Table VM-1 and annual. (Additional resources: www.fhwa.dot.gov)