HISTORY, GEOMETRY, AND FUTURE OF THE AUTOMOBILE: FACTOIDS AND FACTS AROUND MOBILITY

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MEGATRENDS AFFECTING THE FUTURE OF TRANSPORTATION

- **Urbanization and exploding urban populations**. Today there are 28 megacities or metropolitan areas with total populations of more than 10 million people. In 2030 we expect at least 41 megacities.

- **Rapid growth of the global middle class,** expected to double from 2 billion to 4 billion people by 2030. Many aspire to own a car.

- **Health risk** due to poor air quality and congestion.

- **Changing customer attitudes and priorities** regarding vehicles and transportation.

FUTURE OF THE AUTOMOBILE

- What is the future of the personal automobile?
- What can we learn from history and constants of human nature?
  - "Those who do not remember the past are condemned to repeat it", George Santayana
  - "History does not repeat itself, but it rhymes", Mark Twain
- What can we learn from simple geometric and physical considerations?

Is the Personal Automobile Doomed?

Factoid/opinion	Fact
Public transportation is far more efficient (lower CO_2) than cars.	?
By 2025 67% of world will live in urban areas (shocking trend).	?
Increasing urbanization means increasing density.	?
Global gridlock is inevitable – private cars are doomed.	?
New transportation modes are required.	?

Factoid definition: “an item of unreliable information that is repeated so often that it becomes accepted as fact” [Oxford English Dictionary].

Modal Energy Efficiency in US

Mode	Occupancy (load factor)	Btu/ passenger-mile	CO_2 g/passenger-mile
Average Car (23 mpg)	1.55	3193	246
Average Light Truck (18 mpg)	1.84	3561	274
2015 Small Car (35 mpg)	1.55	2127	164
2015 Mid-size SUV (25 mpg)	1.84	2509	193
Bus (all types)	9.2	4030	319
Rail (all types)	26.7	2481	196
Air (commercial)	104	2484	189

Data source: Davis, Stacy C.; Susan W. Diegel; Robert G. Boundy (2014). Transportation Energy Data Book: Edition 33. US Department of Energy. Table 2.12. This comparison assumes that the car, LDT, and SUVs are running on gasoline, the bus on diesel fuel, the train on electricity generated from diesel oil, and the aircraft on Jet kerosene.

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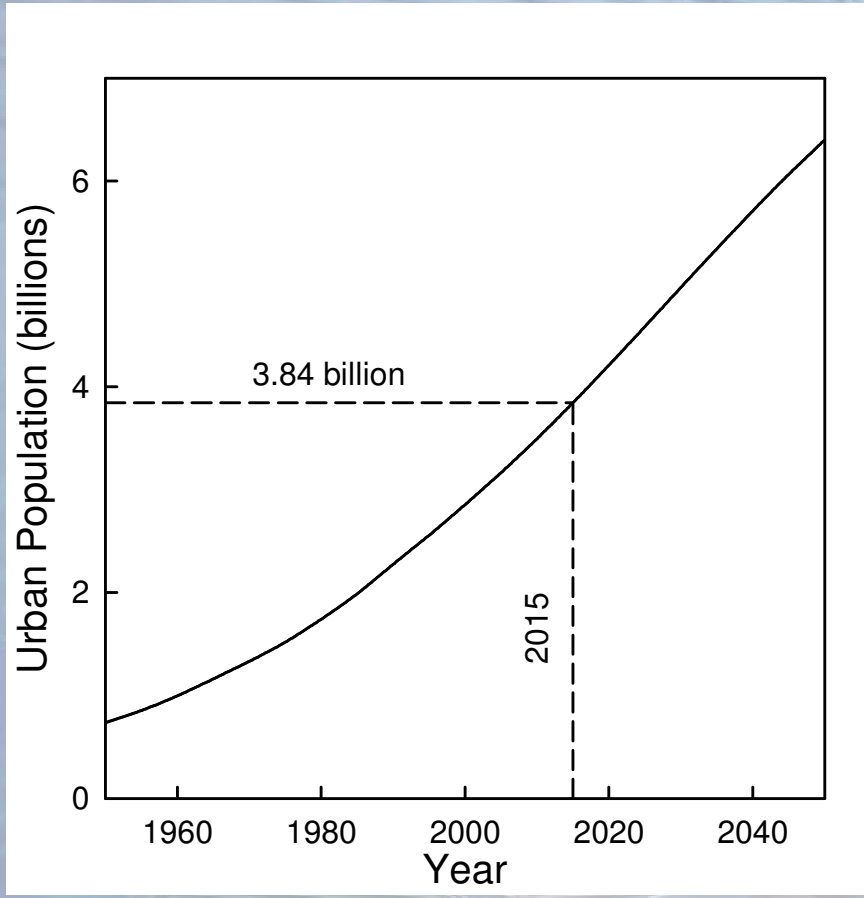
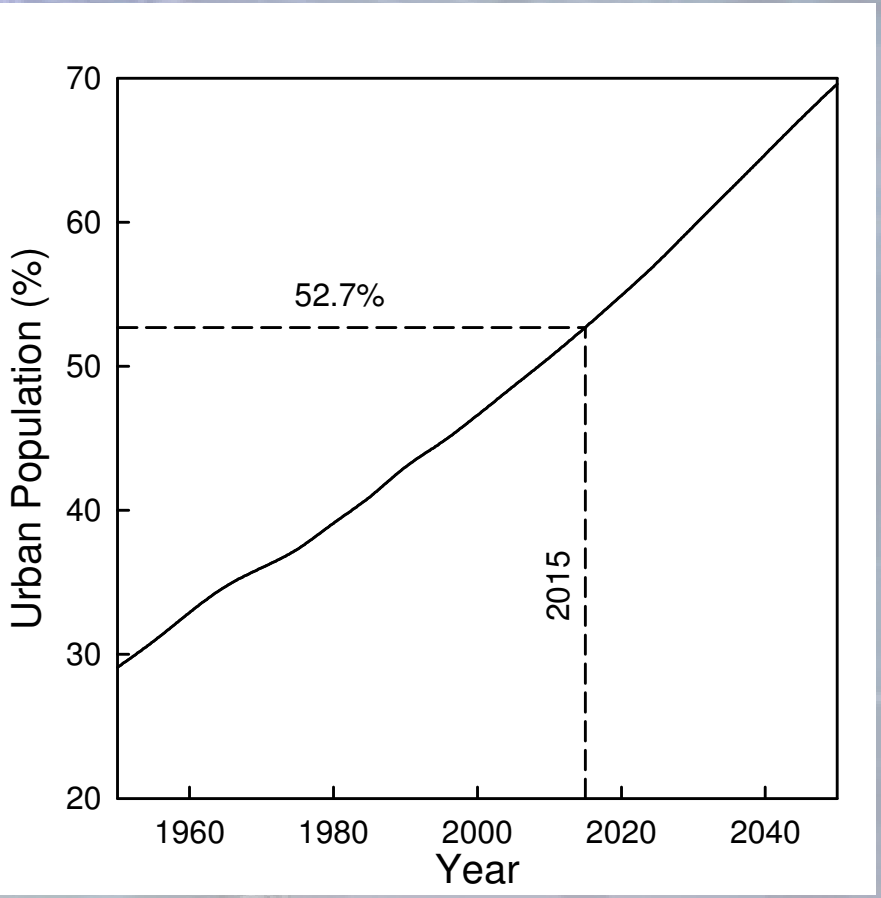
URBANIZATION





Strong and consistent trend of urbanization over past 50 years projected to continue. Majority of global population now lives in urban areas.

Data source: UN Population Division http://esa.un.org/unup/

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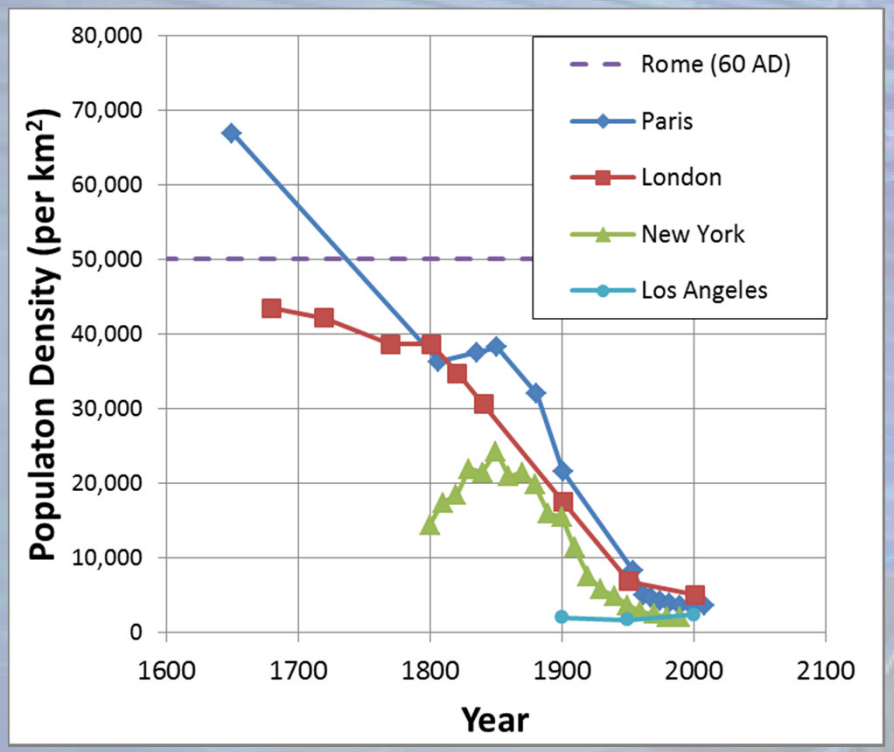
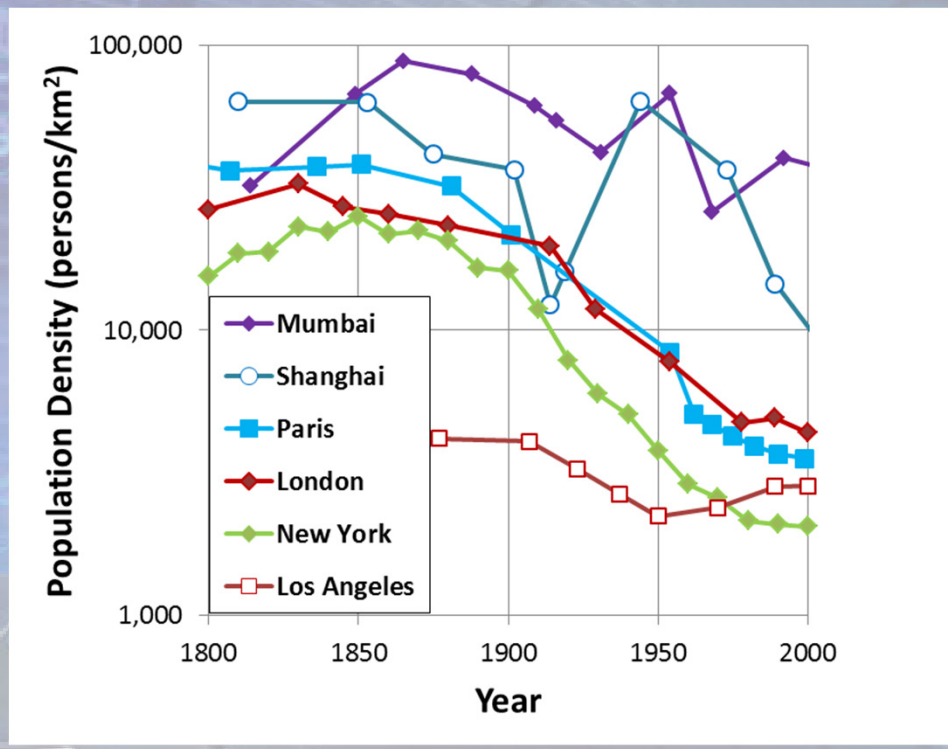
URBAN DENSITY HISTORY





- Pre-Industrial population densities were very high.
- Post-Industrial population densities generally decrease with new transport modes and the wealth to use them.
- Post-Industrial density 'spikes' due to migration

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Are Personal Automobiles Doomed?

- Three possible outcomes for automobiles:
  - Dominant as in the US, Canada and Australia today
  - Coexistent as in the EU and Japan today
  - Extinct as predicted for Asia (and even elsewhere)

- Three driving factors:
  1. WANT: Emotional desire – cars have been an aspirational symbol of wealth and freedom for 100 years
  2. NEED: Practical need – available alternatives often do not meet travel needs
  3. CAN: Physical viability – use densities of people and vehicles as metrics

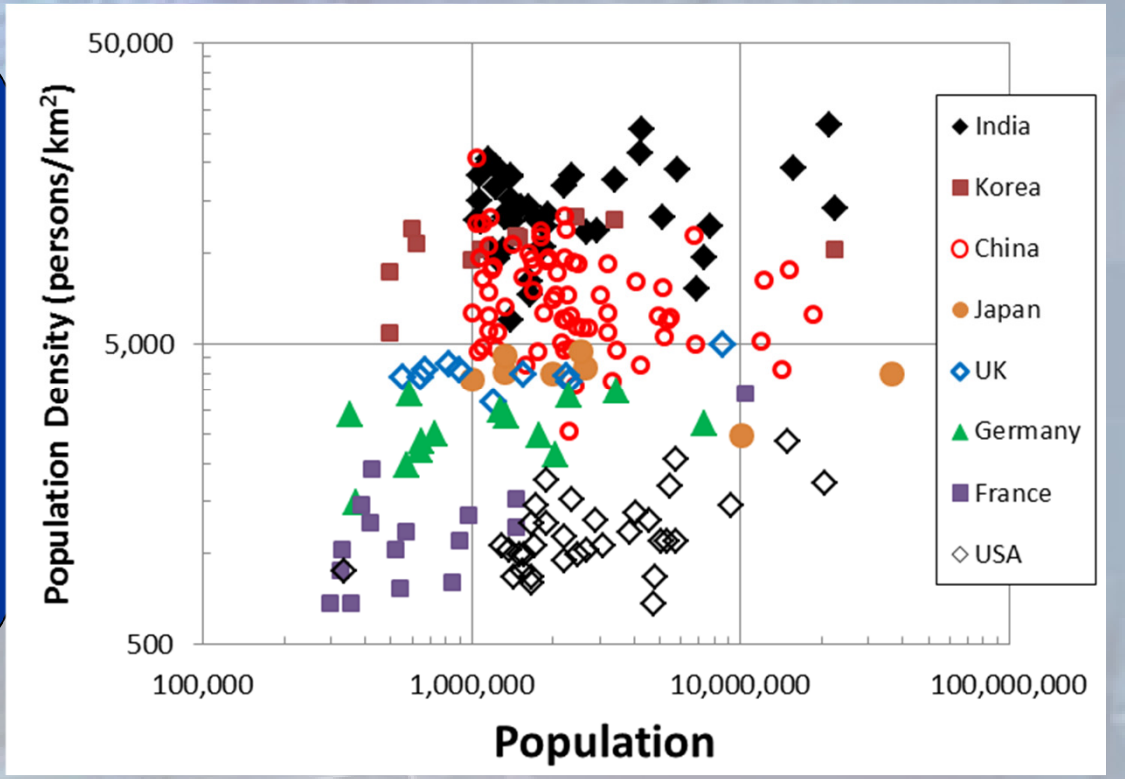
Need and viability can be anticipated by consideration of population density and constants of human behavior.

City Size and City Density

- **Individual choices** are expressed immediately within the as-built environment and are expanded by individual wealth.

- **Collective choices** are expressed gradually as the result of policies and investments that change the as-built environment.

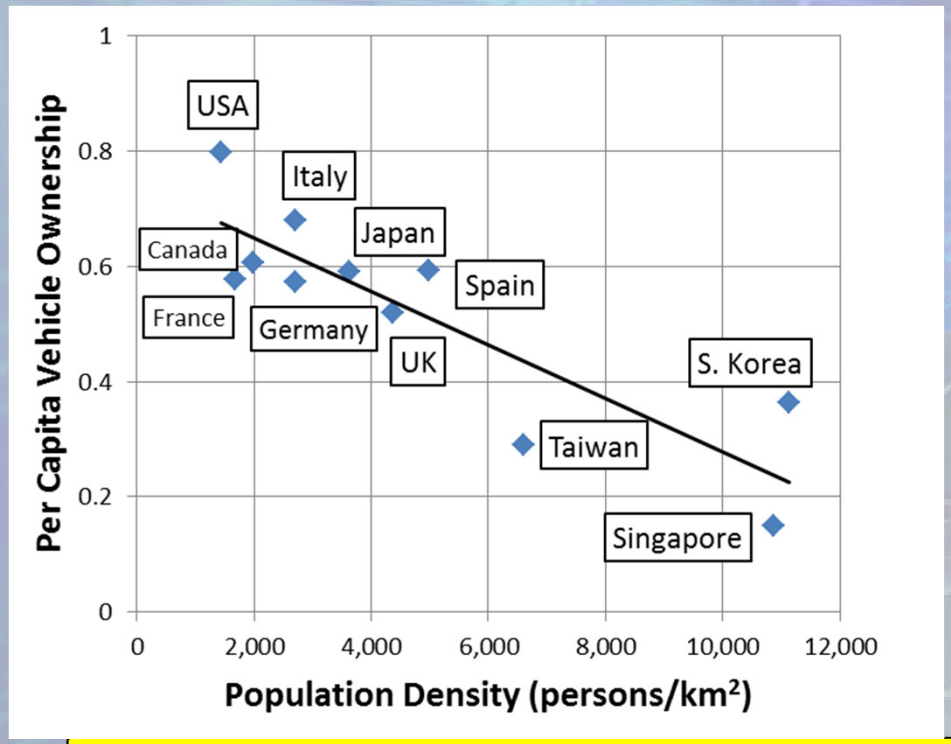
- **Results in a characteristic national urban density!**

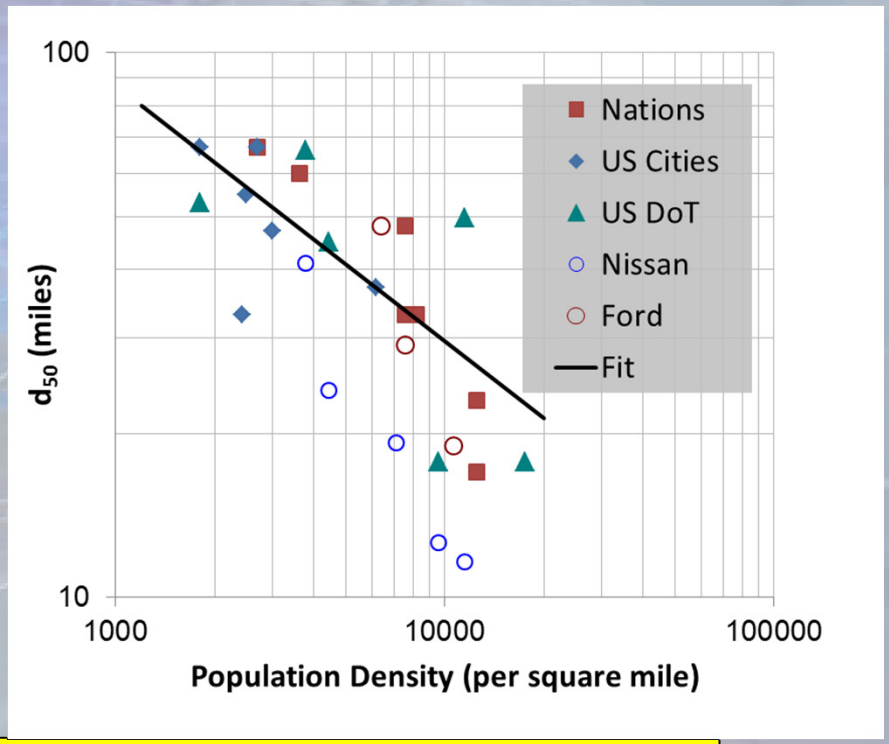


- **Population is intrinsic.** Cities exist, prosper and grow (in population) due to enhancement of human interaction, division of labor and reduced movement of material. However, these 'efficiencies' do not correlate with physical size.
- **Population density is characteristic.** Density expresses a balance between living space, amenities and time.

VEHICLE OWNERSHIP AND POPULATION DENSITY

- Vehicle ownership declines gradually with density.
- Vehicle usage declines steeply with density.





Personal vehicle ownership is viable and popular in high density regions, though usage patterns are very different.

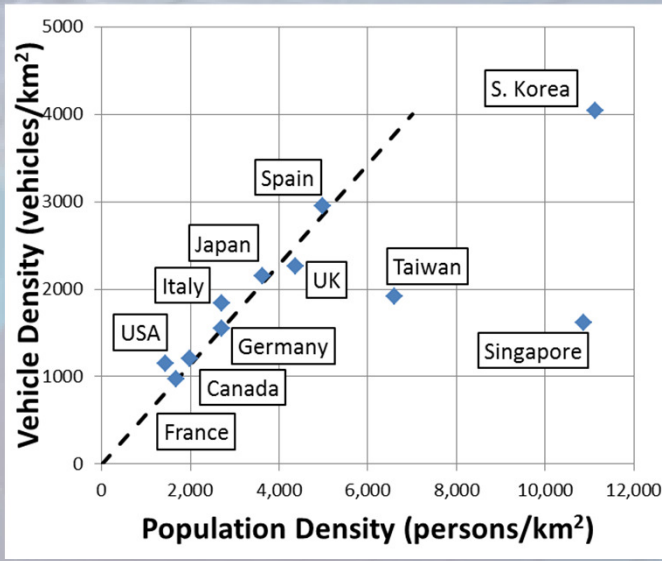
HUMAN CONSTANTS

- Time: Marchetti's constant:
  - Through history, people are willing to spend ≈ 1 hour/day for routine travel.
- Distance:
  - Pre-Industrial: L_1 = ½ x 1 hr x 5 km/hr (walking) = 2.5 km (1-way)
    - Spacing between Greek villages (≈ 5 km)
    - Ancient Rome (≈ 20 km^2, radius ≈ 2.5 km)
  - Post-Industrial: L_2 = ½ x 1 hr x 50 km/hr (riding) = 25 km (1-way)
    - Average US auto commute (1-way): 20 km (NHTS)
    - Boston, LA, Chicago: (≈ 6000 km^2, radius ≈ 40 km)
- Walking and waiting:
    - Studies of mass transit design show willingness to walk 800 meters (10 minutes) and wait 8 minutes for transport.
    - **Walk-up mass transport is viable only at extremely high population density**

Data source: Marchetti, C. (1994). Anthropological Invariants in Travel Behavior, Technological Forecasting and Social Change , 47, 75-88, Internal Publication, International Institute for Applied Systems Analysis, Laxenburg, Austria.

GLOBAL GRIDLOCK?

- Cities typically have ~20 km of traffic lane per km^2.
  - Multilane boulevards or tangled alleys.
- Traffic slows as following distances falls below 25 m.
- Total gridlock threshold = 800 cars/km^2 (on the road)
  - True value will be much lower due to local variations and disruptions: working guess = 300 cars/km^2.
  - Even at rush hour, ≈ 10%-15% of cars are on the road
  - City can accommodate car density, ρ_c, ≈ 3000 cars/km^2
  - At 0.5 cars per inhabitant (US: 0.8, EU: 0.6, Japan: 0.56) **ρ_L ≈ 6000/km^2 …. Typical of UK & Japan**



Automobiles are viable in quite dense cities!

Congestion may be a chronic problem, but not systemic.
Effective traffic management is critical (lights, re-routing, smart devices)
Daytime parking will be difficult (50% of cars in 10% of the area).
Congestion and parking may dictate an alternative mode in high-density districts.

A Tale of Two Cities: the Concentration Effect

- The 'night city' accommodates 100% of the population – and 100% of the private cars - in 70% of the land area.
  - Night concentration slightly lowers the density threshold to ~4000/km^2; still very high
- The 'day city' accommodates ~50% of the population (that doesn't stay at or very near home) in 10% of the land area.
  - If 50% of population moves to a destination on a weekday, $\rho_D = 5 \times \rho_L$.
  - If all visitors arrived by car: $\rho_c = \rho_D$.
  - At 'rush hour' street density is $0.2 \times 5 \times \rho_L$.
  - Destination districts become undriveable at ρ_L = 300-800/km^2.

An alternative mode is required within destination districts

- If most people arrive by car, cars can't move inside the DD.
- If most arrive by other modes, the few cars can move …
- … but either way, the default mode within the DD is walking.

Personal Mobility in Destination Districts

- People arrive at DD via conventional full-function automobile or mass transit. All must move to/from point of arrival (station, parking lot, etc.)
  - Smaller, slower micro-car only partially solves gridlock problem.
  - Alternative ownership does not reduce # of vehicles on the street.
- System within DD must be accessible and extend the functions of the modes by which people arrive.
  - Children, seniors & disabled
  - All-season functionality
  - Light cargo (luggage, packages, etc.)

Flavors of Urban Areas

Population Density[1] (km^{-2})	Autos viable in urban area?	Autos viable in destination district?	Mass transit viable Inside destination district?	Mass transit viable outside destination district?	City Type
< 300	Yes	Yes	No	No	All-car
300-3000	Yes	No	Depends on Size	No	Park & Ride Uber/Lyft
3000-6000	Yes	No	Yes[2]	Viable[3]	Coexistence
> 6000	No	No	Yes[2]	Required	Few cars

1. Construct based on very rough estimates
2. Can be the urban transit system if existing
3. Limited appetite for massive projects. Los Angeles had the most extensive light rail system in the world until ~1920 when cars became affordable.

The personal automobile will be physically viable in most places for the foreseeable future. However, viability does not predict desirability – how will tastes change? Wealth is choice – how will density change?

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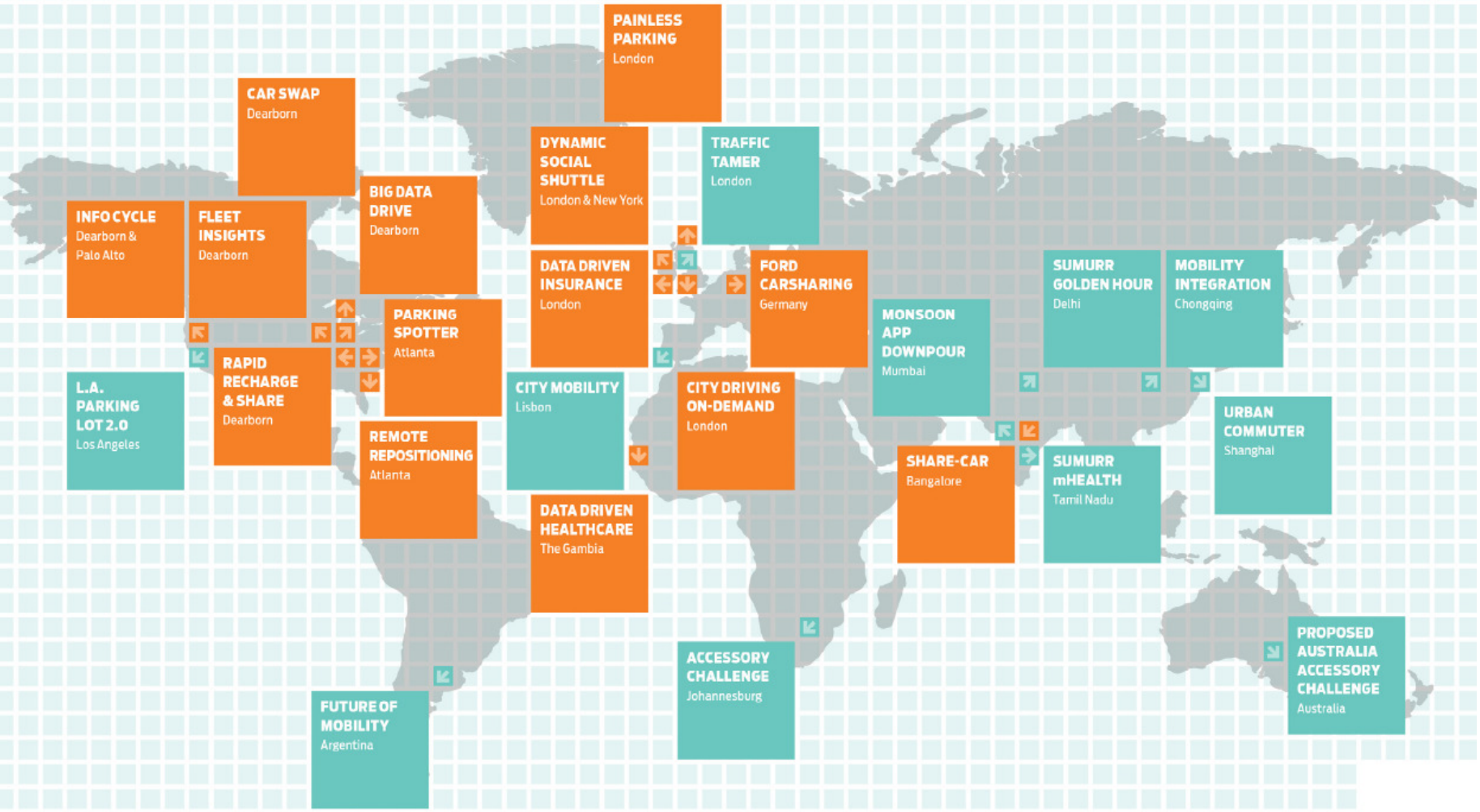
Increasing urbanization means increasing density.	Urban densities have generally decreased with time.
Global gridlock is inevitable – private cars are doomed.	The auto will remain viable for most uses in most places.
New transportation modes are required.	Only in the densest cities and high density districts.

FORD SMART MOBILITY

Use innovation to take company to next level in connectivity, mobility, autonomous vehicles, the customer experience, and big data. 25 global mobility experiments launched this year to test new ideas and address transportation challenges

FORD **SMART MOBILITY**

Ford Smart Mobility is a plan to use innovation to take Ford to the next level in connectivity, mobility and more. It begins with 25 mobility experiments and challenges across the globe to help change the way the world moves.



Experiments

Innovate Mobility Challenge Series

Go Furt

CONCLUSIONS

Simple, but robust, geometric, physical, and historical arguments strongly suggest that cars will be a viable transportation mode in most areas for the foreseeable future.

Massive projected growth in global middle class provides huge opportunity for vehicle manufacturers.

While cars are viable in the future we can do a lot to get more out of them: V2x, smart parking, vehicle sharing, autonomy, improved interface to other modes (walking, bus, rail, etc.), ...

Exciting and challenging time for automotive industry!