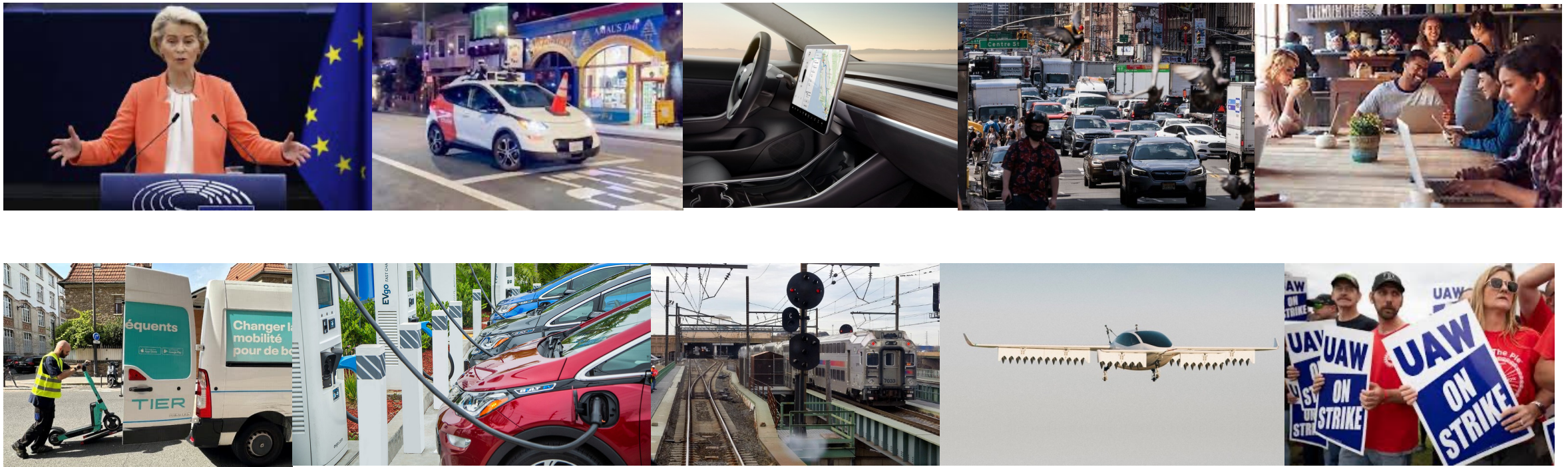


Ten Trends in Surface Mobility: 2023

John Moavenzadeh

Executive Director, MIT Mobility Initiative

MMI Vision Day, November 3, 2023



Geopolitical Bifurcation: Shifting Global Value Chains

Context / Description:

- Chinese automotive OEMs have shifted from imitator to innovator, leading in critical technologies such as EV batteries and advancing in automation
- China exerts influence / control over critical battery minerals: cobalt, nickel, graphite and lithium
- US (Trump-imposed, Biden-continued 25% tariff, IRA EV tax credit restriction) and Europe (EC investigation) react

Headlines:

- How China Is Quietly Dominating the Global Car Market (Bloomberg, Jan. 26, 2023)
- EU to investigate 'flood' of Chinese electric cars, weigh tariffs (Reuters, Sept. 13, 2023)
- Ford halts work on \$3.5B EV battery factory with China's CATL (Tech Crunch, Sept. 27, 2023)



“Global markets are now flooded with cheaper Chinese electric cars. And their price is kept artificially low by huge state subsidies. This is distorting our market.

So I can announce today that the Commission is launching an anti-subsidy investigation into electric vehicles coming from China.

Europe is open for competition. Not for a race to the bottom.”

- Ursula von der Leyen, President, European Commission, September 2023

Autonomous Backlash: AVs Drive into Headwinds

Context / Description:

- Automated mobility has passed through the Gartner hype cycle
- A serious public dialogue has emerged as to why we want this technology and how it should be deployed
- Shift to “driverless” (no test operator) in cities across the US and China raises the stakes on safety and liability

Headlines:

- Baidu, Pony.ai Start Driverless Robotaxi Tests in Beijing (Reuters, Dec. 30, 2022)
- Protesters, Armed with Traffic Cones, Are Immobilizing Driverless Cars (NPR, August 28 2023)
- Citing Safety Concerns, DMV Suspends Cruise’s AV License (SF Inquirer, Oct. 24, 2023)



AV Public Companies Performance are Plummeting, and the industry is going through consolidation

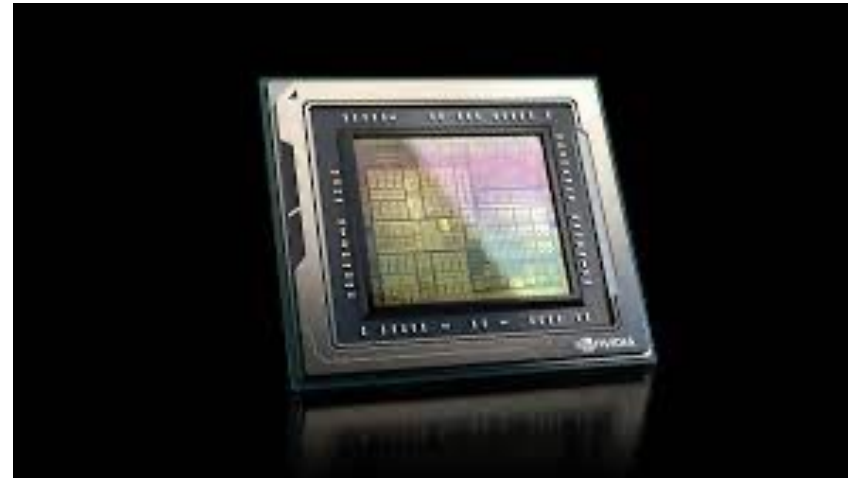
Company	Valuation at IPO	Valuation Today	% Change
Aurora	\$14,000M	\$4,900M	-65%
TuSimple	\$8,500M	\$310M	-96%
Luminar	\$7,000M	\$2,080M	-70%
Embank Technology	\$5,160M	\$70M	-98%
Velodyne Lidar	\$4,000M	\$377M	-90%
Aeva	\$2,100M	\$206M	-90%
AEye	\$2,000M	\$44M	-97%
Ouster	\$1,900M	\$148M	-92%
Innoviz	\$1,400M	\$655M	-53%
Cepton	\$1,400M	\$370M	-74%
Otonomo	\$1,400M	\$40M	-97%
Quanergy Systems	\$1,100M	\$16M	-99%
Arbe	\$722M	\$361M	-50%
CYNGN	\$198M	\$32M	-84%
Total	\$50,880M	\$9,609M	-83%
			Average Decline

Context / Description:

- The personal car emerges as another connected personal device (with the phone, tablet, laptop ...)
- Vehicle architecture has shifted from mechanical-led platform to software-forward design
- Automotive OEMs are challenged to take on the role of lead software architect
- Just like batteries, SoC (System on a Chip) is increasingly viewed as “core business” for auto OEMs

Headlines:

- How OTA Updates Will Change Your Life for Better – and Worse (Motor Trend, March 9, 2023)
- Why Your Car Will Become Even More Like an iPhone (Wall Street Journal, Nov 4, 2021)
- Your Car Is Spying on You: How to See What Data It’s Collecting and Delete It (USA Today, May 21, 2023)



Urban Micromobility: Two Steps Forward, One Step Back

Context / Description:

- Micromobility (bikes and scooters) hold tremendous opportunity to decarbonize urban mobility
- Shared micromobility has evolved from "competition in the market" to "competition for the market"
- Infrastructure needs to adapt to maintain safety: protected lanes, speed segregation, etc.
- Once the "darlings of venture capital", micromobility companies have seen valuations plummet

Headlines:

- Paris Becomes the First European Capital to Ban Rented Electric Scooters (New York Times, Sept. 1, 2023)
- Scooter Company Bird Delisted from NYSE After Stock Collapse (CNBC, Sept. 23, 2021)

The New York Times

Paris Becomes the First European Capital to Ban Rented Electric Scooters

But the city is adding bike lanes, and scooter companies are shifting their focus to electric bikes. E-scooters were involved in accidents resulting in the deaths of three people in Paris last year.



Trend #5

Capturing Externalities: Progress Toward Dynamic Pricing

Context / Description:

- Our mobility system often fails to capture the full economic cost of mobility consumption – e.g. supersized single-occupancy SUVs consuming precious street space during downtown rush hour
- Dynamic pricing based on the current (actual) level of demand can be used to drive mode shift (decarbonization), congestion management and revenue collection
- Congestion pricing, the Godmother of dynamic pricing, has been implemented in Singapore, Stockholm, London and many other cities

Headlines:

- Officials Mark Full Opening of I-66 Express Lanes (Nov 30, 2022)
- Congestion Pricing Plan in New York City Clears Final Federal Approval (New York Times, June 26, 2023)



Trend #6

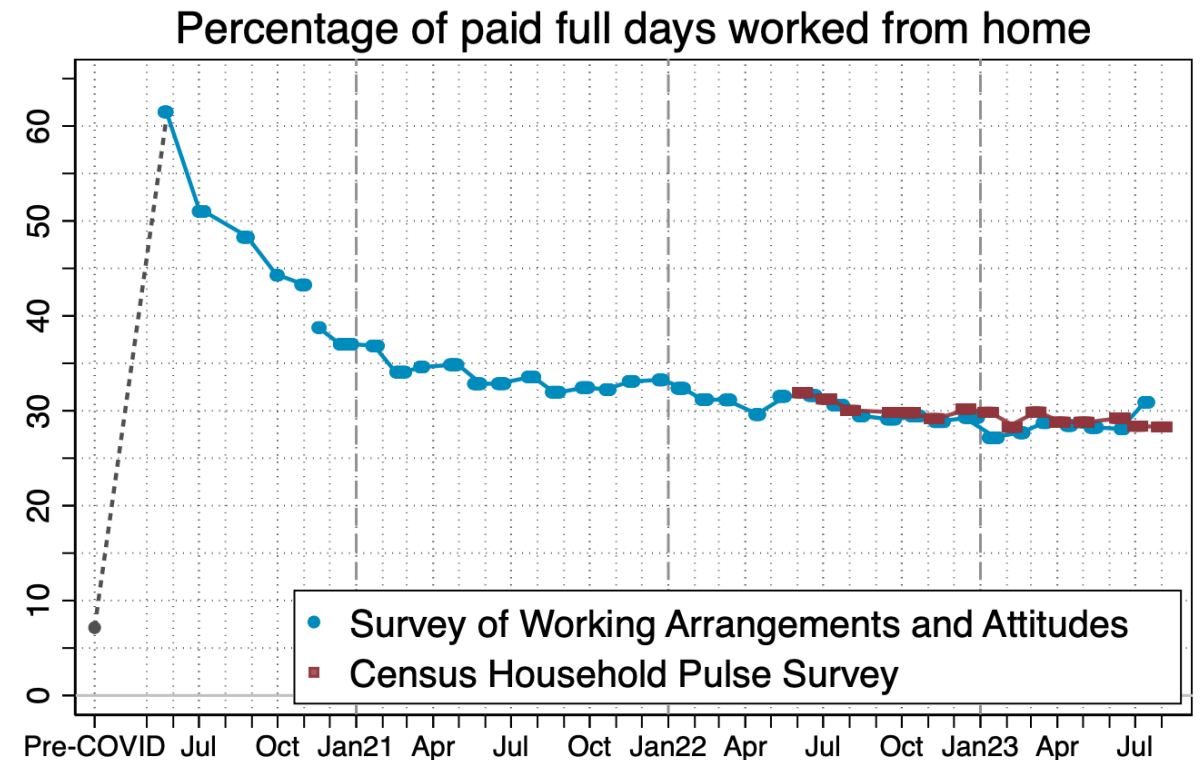
Mobility Demand Patterns: Hybrid Is Here to Stay

Context / Description:

- Levels of Working For Home (WFH) and Working From a 3rd Place (WF3P), such as a café or friend's house, stabilized in 2023

Headlines:

- Hybrid Working Schedule 'Here to Stay,'
Littler Survey Shows
(Bloomberg, May 10, 2023)
- Global Air Traffic Rebounds to 95.6% of Pre-
Pandemic Levels
(The National News, Sept. 7, 2023)



Trend #7

EV Hesitation: Charging, Battery Supply, Cost

Context / Description:

- Securing the supply of battery materials continues to challenge global OEMs and drive cost
- Battery production capacity is being added – but it takes time to build and ramp gigafactories
- Public charging reliability continues to be a challenge – but with some interesting developments

Headlines:

- The US Needs Minerals for Electric Cars. Everyone Else Wants Them Too (New York Times, May 23 2023)
- US EV Market Struggles with Price Cuts and Rising Inventories (Reuters, July 11, 2023)
- Hyundai Follows Volvo, Ford, Honda to Adopt Tesla's EV Charging Ports (Forbes, Oct. 5, 2023)



Trend #8

Rising US Infrastructure Costs: Finding Bang for the Buck

Context / Description:

- By many measures, infrastructure delivery in the United States costs more than comparable advanced nations (e.g., Germany, Japan, South Korea, United Kingdom)
- As the United States makes a massive \$1 trillion investment in infrastructure, how can we ensure maximum “bang for the buck”?

Headlines:

- Why Public Transportation Is Especially Expensive to Build in the US (NPR, July 21, 2023)
- Why Is US Infrastructure So Expensive – And What Can We Do About It? (Wall Street Journal, July 24, 2022)



Trend #9

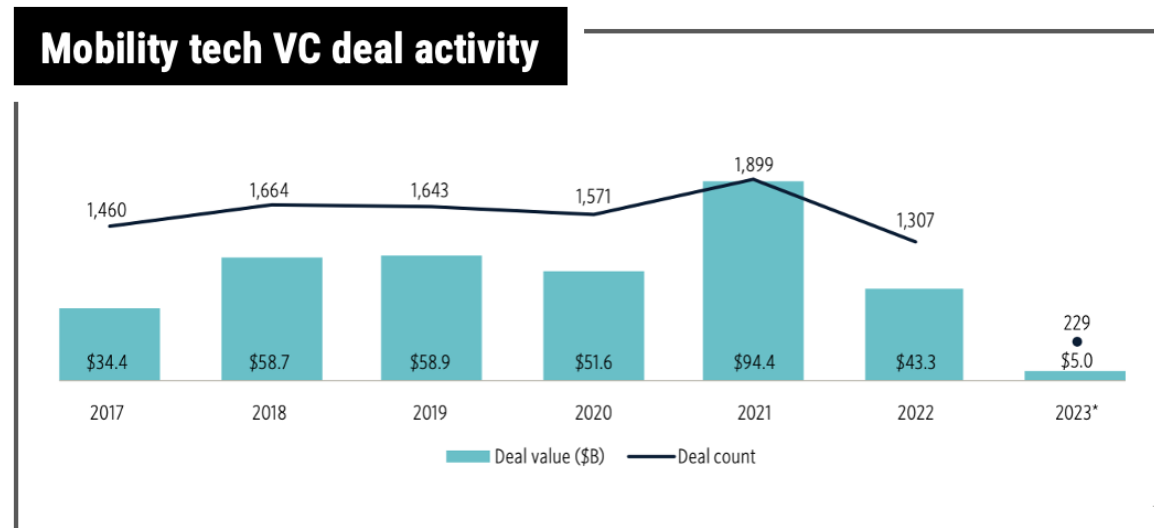
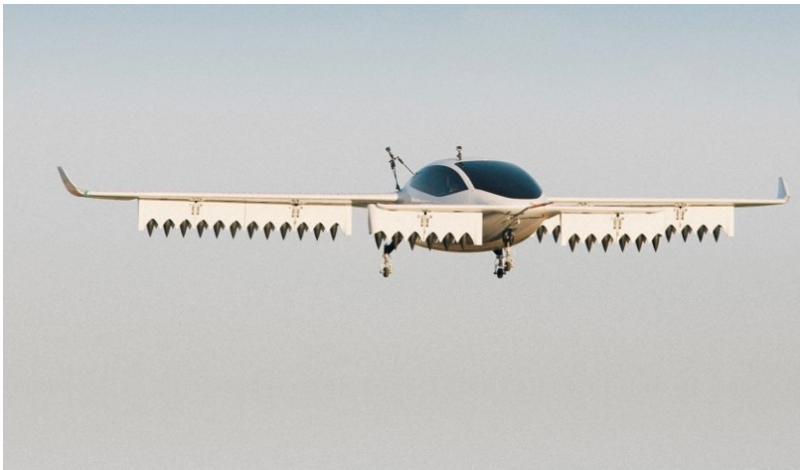
The End of the Froth: Capital Sloshes Out of Mobility Tech

Context / Description:

- Unprecedented levels of capital were invested in mobility technology (eVTOLs, EVs, LIDAR, battery tech, etc.) during the “SPAC wave” of 2020-2021
- Raising capital in mobility ventures is now more challenging

Headlines:

- Flying Car, Anyone? Inside the Perilous Quest to Get Battery-Powered Aircraft Off the Ground (FT, Jan. 12, 2023)
- The Collapse of the EV SPACs: Another One Goes Bankrupt, Others on the Verge (Wolf Street, August 23 2023)
- VC Investment in Mobility, Still Down from Last Year, Appears To Be Leveling Off (Automotive News, Sept 22, 2023)



Future of Work: Rethinking the Social Contract

Context / Description:

- Global transportation system – from services to manufacturing – is still highly labor intensive, and many industries are struggling to hire, re-train, and retain workers at multiple skill levels
- Automotive companies struggle to reskill their engineering talent from mechanical focus to software focus
- US public transit, long-haul trucking, and other transport sectors struggle to find workers

Headlines:

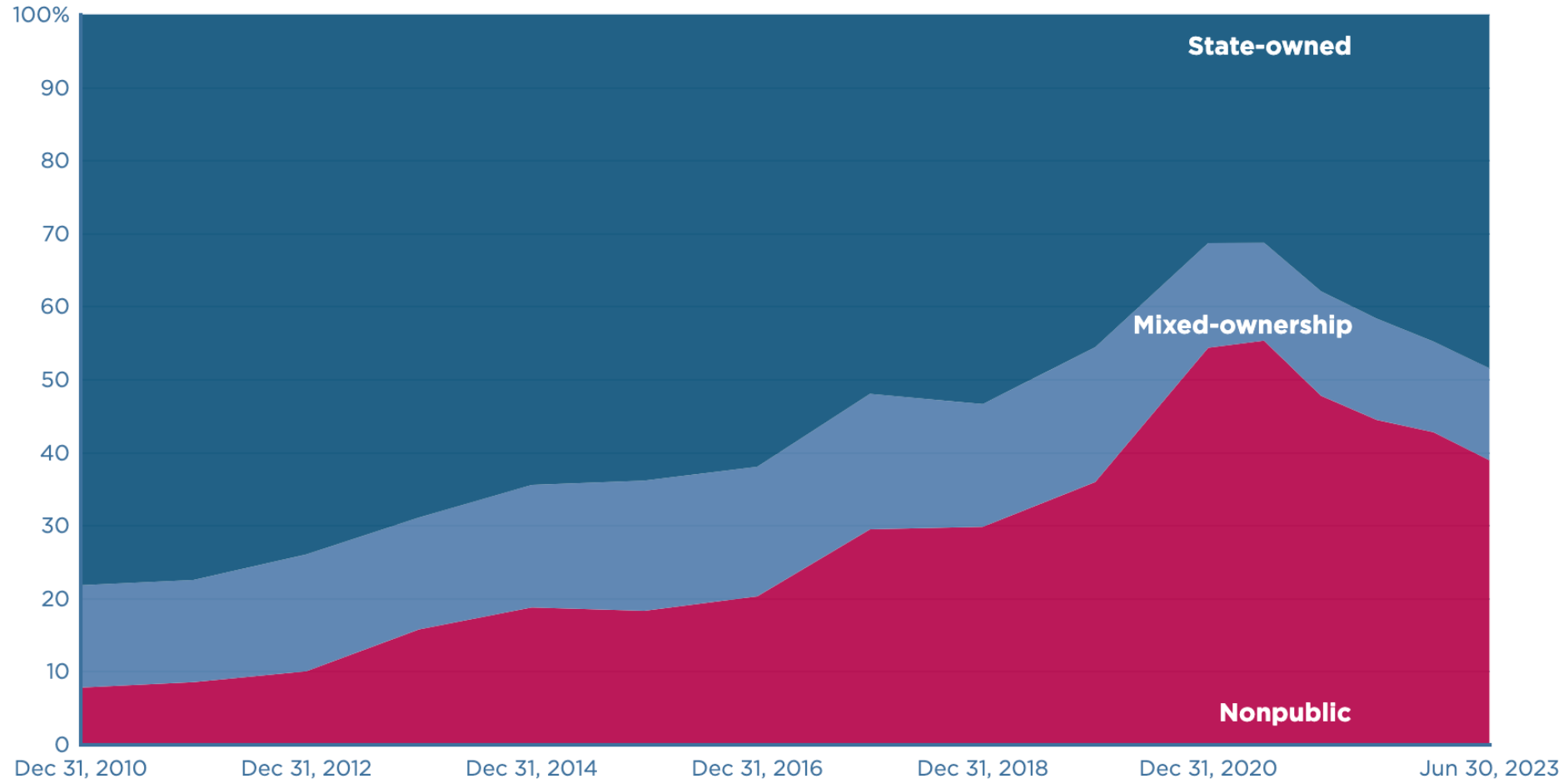
- Software is Now as Important as Hardware in Cars (The Economist, April 14, 2023)
- MBTA Contract Calls for 18% Pay Hike Over Four Years (Boston Globe, August 2, 2023)
- UAW Strikes at Automakers Highlights Skyrocketing US CEO Pay (Reuters, Sept. 20, 2023)



China's Top 100 Firms: By Ownership Share

China's state vs. private company tracker: Which sector dominates?

Share of aggregate market capitalization of China's top 100 listed firms, by ownership, end-2010 to mid-2023





MIT **Mobility Initiative**

Jinhua Zhao

Professor of Cities and Transportation

mmi.mit.edu

We have progressed so far...



Ever since the first hominids left Africa, human beings have been on the move. The canoe was invented in 8,000 B.C. and the first form of public transportation was a stagecoach operated in Paris in 1662. Fast forward to today's self-driving car prototype, and it's clear just how far we've come.

Source: The Atlantic, https://www.theatlantic.com/video/index/397865/animated-history-transportation/?utm_source=fb



Morning traffic on the Southeast Expressway in Dorchester. (David L. Ryan/Globe Staff)



Beijing 1982



We are confused

AV debate:

How safe is safe enough?

When 42,915 people died on the road in 2021,
who took responsibility?

Q1:

What is success?

Technology Themes in Mobility

1 Mobility Decarbonization

To reduce carbon emission by transitioning from fossil fuel to sustainable alternatives :

- Electric vehicles
- EV charging
- Battery technology
- Fuel Cells
- Hydrogen

2 Autonomous Driving

To enable vehicles to operate without or with minimal human intervention, aiming to replace or assist human drivers, including:

- Sensors & processors
- Localization & Mapping
- Perception software
- Full-stack players

3 Connected Vehicle and Infrastructure

To enable real-time data exchange with other vehicles, infrastructure, and external systems.

4 Next-Gen Aviation & Space Tech

Sustainable aviation fuel; autonomous flights; eVTOL; hydrogen aircraft;

SpaceX, BlueOrigin; launch, satellite, manufacturing, in-space services

MIT Mobility Venture Fall 2023

For each theme, we will cover the following content:

- A** The Opportunity
- B** Investment Activities
- C** Trends
- D** Market Landscape
- E** Highlight Startups

Different framings of transportation

As a congestion problem

As a sustainability problem

As a social justice problem

As a personal identity problem

As an urban creativity problem

As a public health problem

Q2:

What defines the future of mobility?

Behavior + Computation

Behavioral thinking

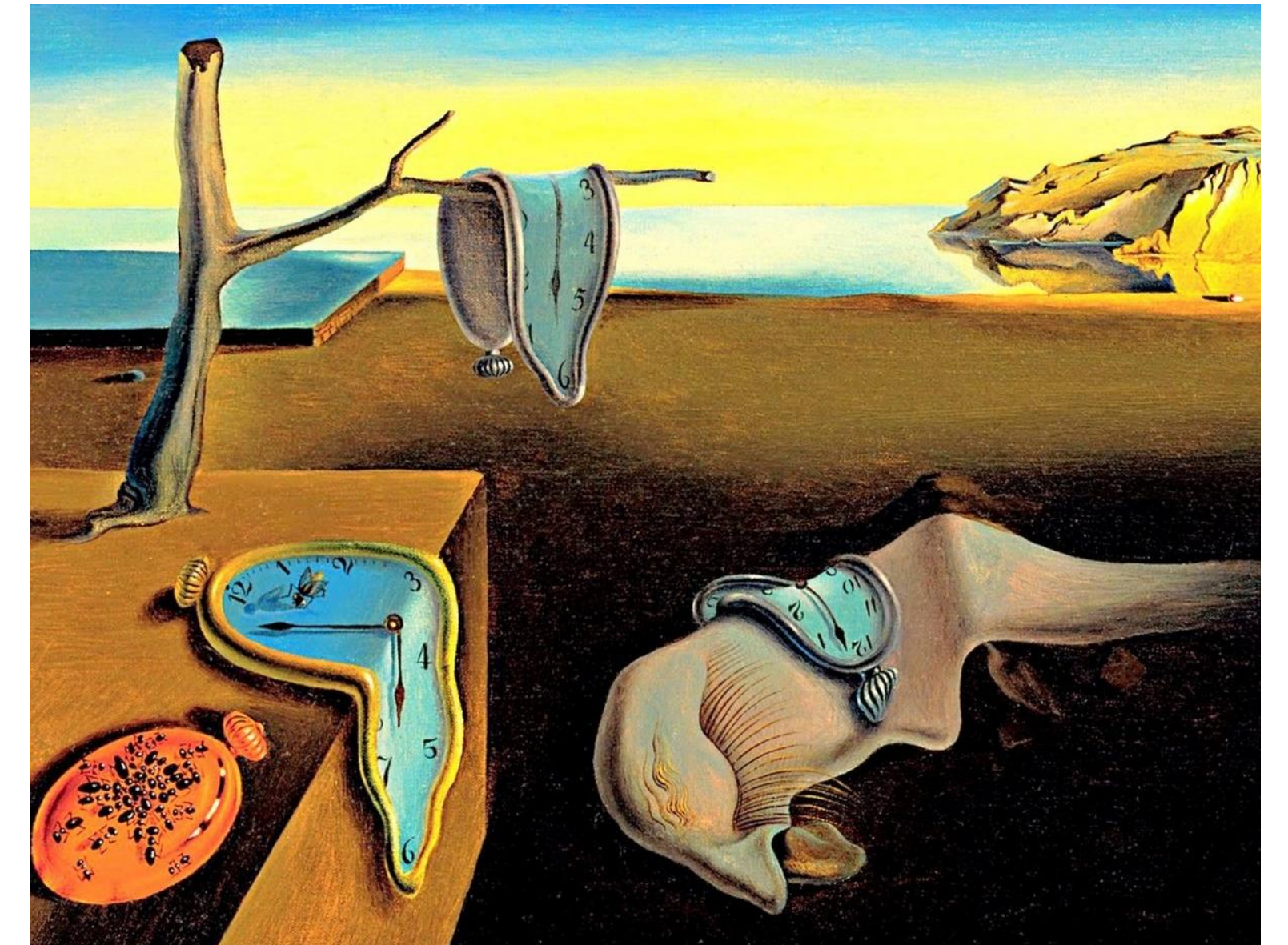
is travel social?



is travel emotional?

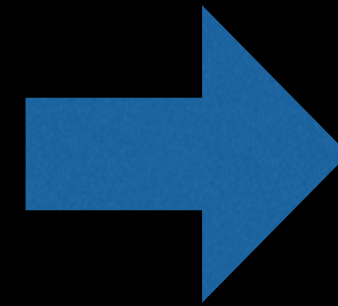


is time absolute?



Business Decision

- EV range anxiety
- Ridesharing Pricing
- AV adoption
- Congestion charge
- Ownership vs access
- Car profit margin
- ...



Behavioral Thinking

- Emotional—> rational
- Preference of sharing
- Risk preference
- Price salience
- Option value
- Car pride
- ...

Behavioral Thinking

- Emotional
- Social
- Perceptual



Transportation Technology

- Electrification
- Automation
- Connectivity
- Sharing

Computational Foundation

- Representation
- Explanation
- Prediction
- Control
- Creation

































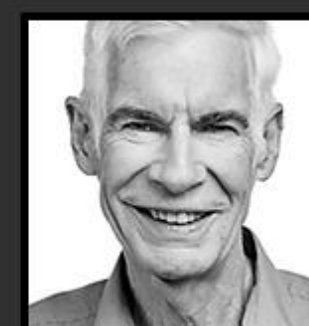
Q3:

How can MIT contribute?

Transportation Faculty and Researchers (Sample)



Mobility Initiative

 <p>Jim Aloisi Lecturer of Transportation Policy and Planning</p> <p>Research Interests: Urban Transportation, Equity, Public Realm Design, Public Transportation Funding and Service Delivery</p>	 <p>Saurabh Amin Robert N. Noyce Career Development Associate Professor</p> <p>Research Interests: Control of Infrastructure Networks, Security of Cyber-Physical Systems, Applied Game Theory and Information Economics</p>	 <p>Steven Barrett Director, Laboratory for Aviation and the Environment</p> <p>Research Interests: Climate Impacts of Aviation, Aircraft Emissions, Biofuels, Electric Aircraft Design, Low Emission and Noise Aircraft Propulsion</p>	 <p>Charlie Fine Chrysler Leaders for Global Operations Professor of Management</p> <p>Research Interests: Operations Strategy, Supply Chain Management, Value Chain Roadmapping, Outsourcing Dynamics</p>	 <p>Daniel Freund Assistant Professor of Operations Management</p> <p>Research Interests: Analytics, Combinatorial Optimization, Management Science, Operations Management, Sharing Economy</p>	 <p>Jason Jackson Ford Career Development Assistant Professor of Political Economy</p> <p>Research Interests: Community Development, Economic Development, Law and Policy, Machine Learning, Transportation and Mobility</p>	 <p>John Leonard Samuel C. Collins Professor of Mechanical and Ocean Engineering</p> <p>Research Interests: AI & Machine Learning, Graphics & Vision, Robotics, Big Data and Transportation</p>	 <p>Elisabeth Reynolds Lecturer, MIT Department of Urban Studies and Planning</p> <p>Research Interests: National and Regional Systems of Innovation, Competitiveness, Manufacturing Ecosystems</p>	 <p>Cathy Wu Gilbert W. Winslow (1937) Career Development Assistant Professor</p> <p>Research Interests: Machine Learning, Control Theory, Multi-agent Systems, Implications of AI & Automation</p>	 <p>Jessika Trancik Associate Professor of Energy Studies</p> <p>Research Interests: Storage Technologies, Environmental Analysis, Energy Technologies</p>	 <p>Chris Zegras Professor of Transportation and Urban Planning</p> <p>Research Interests: Environmental Planning and Management, Healthy Communities and Active Living, Transportation and Mobility, Urban Economics</p>
 <p>Bill Aulet Professor, Sloan School; Managing Director, Martin Trust Center, MIT</p> <p>Research Interests: Entrepreneurship Education, Economics & Business</p>	 <p>Dimitris Bertsimas Professor of Management and Operations Research, Associate Dean of Business Analytics</p> <p>Research Interests: Optimization, Stochastic Systems, Machine Learning, Robust Optimization, Transportation and Finance</p>	 <p>Alexandre Jacquillat Assistant Professor, Operations Research and Statistics</p> <p>Research Interests: Stochastic optimization, data-driven decision-making, analytics, vehicle routing, transportation scheduling</p>	 <p>Fábio Duarte Principal Research Scientist and Lecturer of Transportation Policy and Planning</p> <p>Research Interests: Urban Technologies, Transportation and Planning, Social Construction of Technologies</p>	 <p>John Attanucci Lecturer, Research Associate and Manager of the MIT Transit Research Program</p> <p>Research Interests: Transportation Planning, Transit Management and Operations, Transit Information and Decision Support Systems</p>	 <p>Jing Li William Barton Rogers Career Development Professor of Energy Economics</p> <p>Research Interests: Industrial Organization, Environmental & Energy Economics</p>	 <p>David Mindell Dibner Professor of the History of Engineering and Manufacturing, Professor of Aeronautics and Astronautics</p> <p>Research Interests: Autonomy in Human Environments; Precision Navigation; Ultra-Wideband for Urban Transit</p>	 <p>Don Sadoway John F. Elliott Professor of Materials Chemistry</p> <p>Research Interests: Electrochemistry, Electrochemical extraction & sensors, recycling of metals, lithium solid-polymer-electrolyte batteries</p>	 <p>Fred Salvucci Senior Lecturer and Senior Research Associate</p> <p>Research Interests: Infrastructure, Urban Transportation, Public Transportation, Institutional Development in Decision-Making</p>	 <p>Matthias Winkenbach Director of the MIT Megacity Logistics Lab; Director of the MIT CAVE Lab</p> <p>Research Interests: Multi-tier Distribution Network Design, Urban Logistics, Last-Mile Delivery, Urban Freight Policy, Data Analytics and Visualization</p>	 <p>Sanjay Sarma Vice President for Open Learning (2013-2022) and Professor of Mechanical Engineering</p> <p>Research Interests: Automotive Technologies, Batteries, Digital Learning, Design, Manufacturing</p>
 <p>Hamsa Balakrishnan Professor of Aeronautics and Astronautics</p> <p>Research Interests: Design, Analysis, and Implementation of Control and Optimization Algorithms for Large-Scale Cyber-Physical Infrastructures</p>	 <p>Hari Balakrishnan Fujitsu Chair Professor in the EECS Department</p> <p>Research Interests: Networking, Data Management, Sensing, Mobile and Sensor Computing, Wireless Networks, Overlay and P2P Networks</p>	 <p>Sertac Karaman Associate Professor of Aeronautics and Astronautics</p> <p>Research Interests: Robotics, Autonomous Vehicles, Foundations of Mobility</p>	 <p>Bill Green Hoyt C. Hottel Professor in Chemical Engineering</p> <p>Research Interests: Fuel Chemistry, Evaluation of Alternative Fuels & Engines</p>	 <p>Jinhua Zhao Associate Professor of Transportation and City Planning, Director of MIT Mobility Initiative</p> <p>Research Interests: Urban Transportation, Travel Behavior, Shared and Automated Mobility Planning, Public Transit</p>	 <p>Andres Sevtsuk Charles and Ann Spaulding Career Development Associate Professor of Urban Science and Planning</p> <p>Research Interests: Spatial Analysis, Walkability, Public Transport, Business Location Patterns, Urban Design</p>	 <p>Daniela Rus Andrew (1956) and Erna Viterbi Professor of Electrical Engineering and Computer Science</p> <p>Research Interests: Robotics, Artificial Intelligence, and Data Science</p>	 <p>Anson Stewart Research Scientist</p> <p>Research Interests: Spatial Analysis, Urban Transportation, Public Transportation</p>	 <p>Sarah Williams Associate Professor of Technology and Urban Planning</p> <p>Research Interests: Semi-formal Transportation, Urban Information, Technology, Media Design, Data Action, Urban Design, Data Visualization and Privacy</p>	 <p>Sandy Pentland Toshiba Professor of Media Arts & Science</p> <p>Research Interests: Computational Social Science, Organizational Engineering, Wearable Computing, Image Understanding</p>	 <p>Nigel Wilson Professor Emeritus</p> <p>Research Interests: Public Transportation, Transport System Design, New Transportation Systems</p>

Our Mission

The MIT Mobility Initiative (MMI) is a global platform to accelerate a **safe, clean and inclusive** mobility system through research, education, entrepreneurship and engagement



Research

Catalyze cross-disciplinary research that provides insight to strategic challenges for industry and society



Education

Manage and enhance MIT's transportation degree programs and expand the executive education offering



Entrepreneurship

Leverage MIT's innovation ecosystem to spin off mobility tech startups and support existing startups



Engagement

Foster direct interaction with leaders from business and government on the "front lines" of the mobility revolution

How is MIT contributing?

Solve short-term technical problems

Develop medium-term platforms and capacity

Catalyze strategic, institutional, and social changes

MIT serving the public

Q1: What is success?

Q2: What defines the future of mobility?

Q3: How can MIT Mobility Initiative contribute?



MIT **Mobility Initiative**

Jinhua Zhao

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