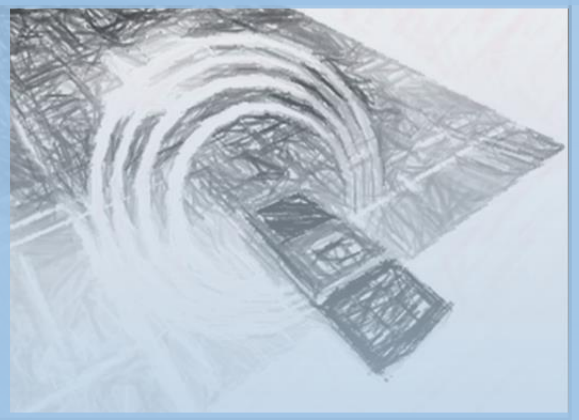
# Future of Urban Mobility: Trends, Implications and Opportunities

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World Cities Forum

## Future of urban mobility: A Vision

- Leverages advanced technology for high quality and safe travel
- Offers travel choices to diverse communities
- Responsive to societal changes
- Sustainable and environmentally efficient
- Socially just and humane
- Affordable
- Integrates with other city functions for seamless service delivery
- Supports economic development and innovation ecosystem
- Integrates urban design, encourages citizen engagement and enhances city context and character
- Makes a city more livable and healthy

# Trends that will shape the Future of Urban Mobility

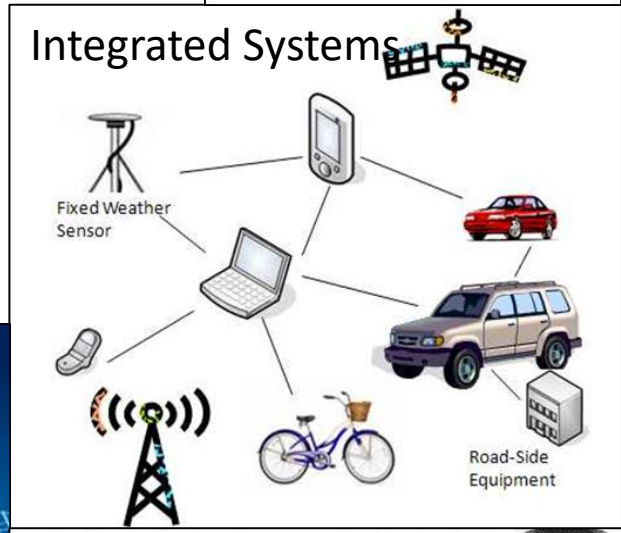
- **Transportation trends and needs affecting urban mobility:**
  - *Technology:* Breakthroughs in automation, Artificial Intelligence, Generative AI, big data
  - *Process:* Inclusion of advances in data science for urban mobility planning
  - *Transportation needs:* New and existing infrastructure and operational needs
  - *Prices:* Volatility in car and fuel prices
  - *Consumer/traveler choices* and citizen participation in planning
- **Non-transportation trends affecting future of urban mobility:**
  - *Climate change:* Sustainability, energy efficiency/renewable energy use and disaster resilience considerations
  - *Health:* Transportation and public health & Social Determinants of Health
  - *Population trends:*
    - *Sociodemographic changes:* Increasing urbanization, decentralization of residential locations and jobs, changes in household structure
    - *Future of Work:* Increasing automation and telecommuting and changing nature of work
    - *Social justice:* Diversity, inclusion and equity considerations
- **Opportunities for the future**

# Transportation trends and needs affecting urban mobility

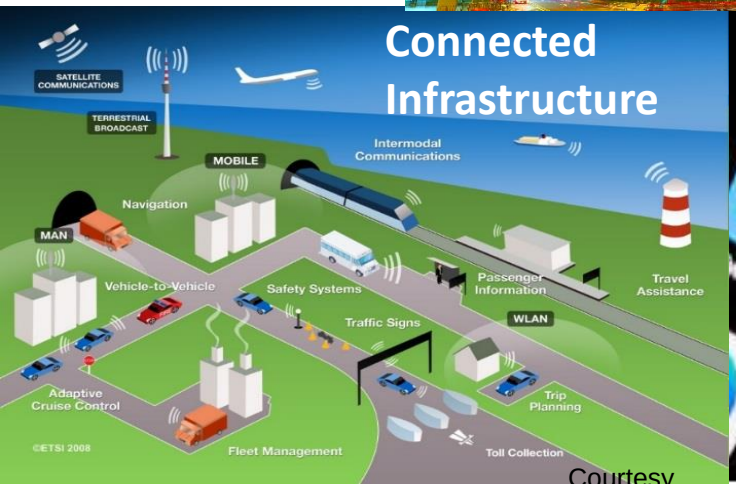
# Trends

Explosion of information technology & data

- Sensor Systems
- User-Generated Content
- Private Sector Data
- Arts & Humanities Data
- Synthetic Data
- Administrative Data

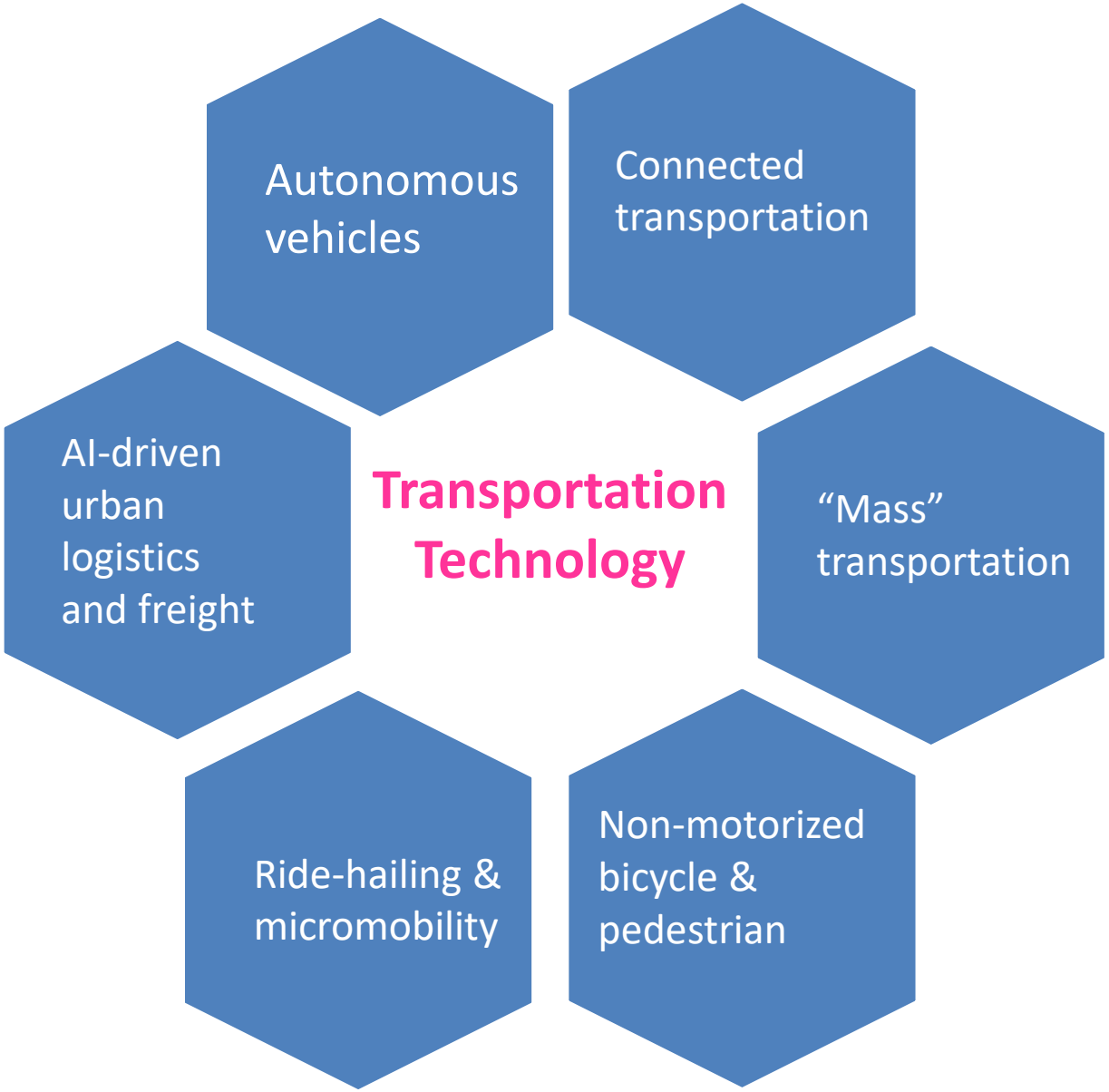





Courtesy

# Rutgers Urban & Civic Informatics Lab



# Autonomous Vehicles

Potential to improve safety by removing driver error.

Reduce traffic congestion by improving traffic flow, reducing the need for parking, and enabling platooning.

Optimize driving patterns, reduce fuel consumption, and lower emissions.


**Complex and unpredictable situations and vulnerabilities due to hacking and cyberattacks.**

**Programming AVs to make ethical decisions in challenging situations, and addressing the ways AVs interact with pedestrians and human-driven vehicles.**

**Assignment of liability in accidents involving AVs -development of a comprehensive legal framework for AVs.**

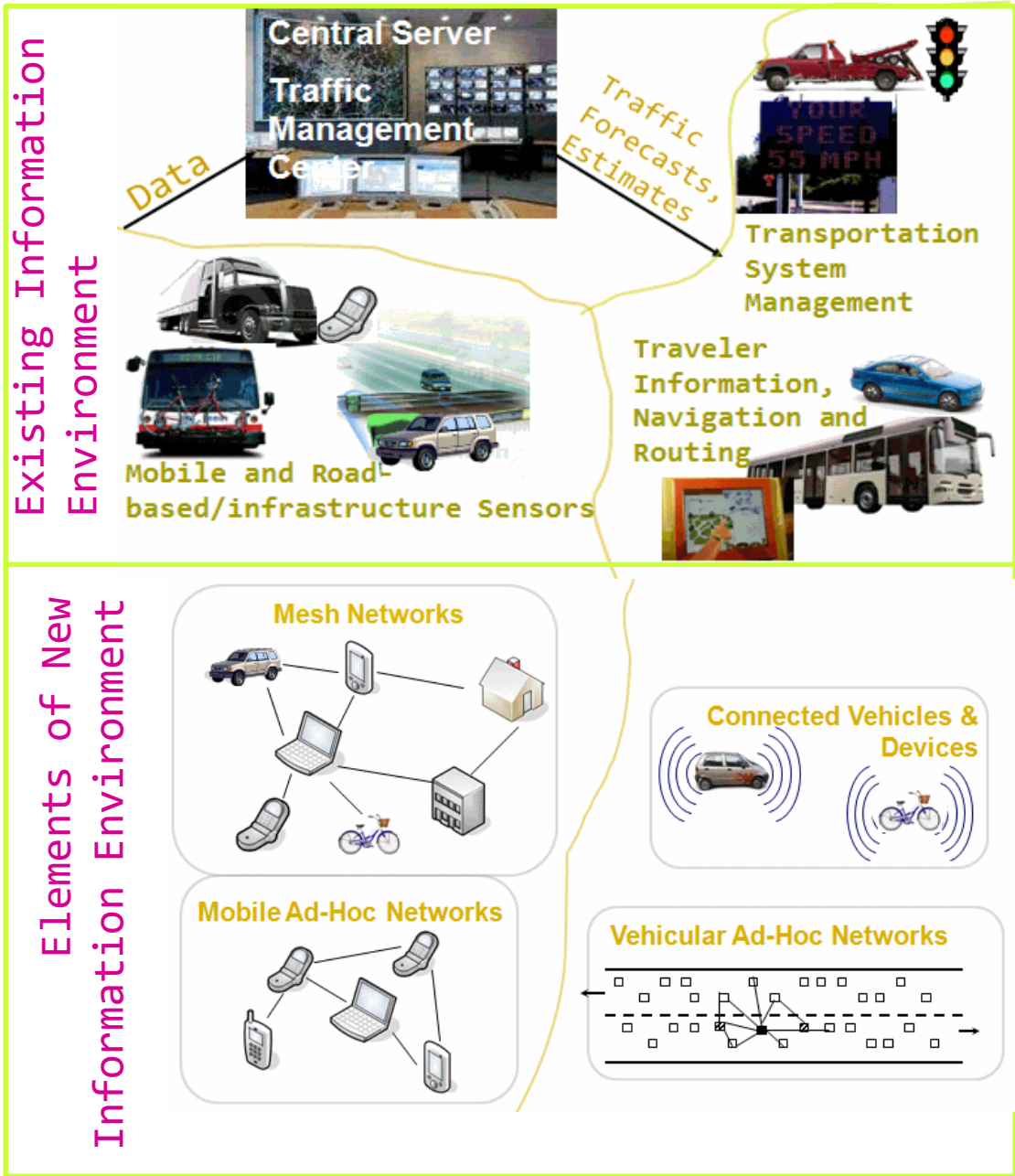
**Integration of AVs may necessitate infrastructure updates, including improved road markings, sensor-equipped intersections, and vehicle-to-infrastructure (V2I) communication.**

# Connected, Cooperative and Anticipatory

- Intelligent Transportation Systems
- Structural Health Monitoring for asset management
- Connected systems V2X:
  - Vehicle-to-Vehicle (v2v)
  - Vehicle-to-Infrastructure (v2i)
  - Vehicle-to-Grid (v2g)

Thakuriah, P., N. Tilahun and M. Zellner (2017). Seeing Cities through Big Data: Research, Methods and Applications in Urban Informatics. Springer, NY.

Thakuriah, P. and G. Geers (2013). Transportation and Information: Trends in Technology and Policy. Springer, NY.



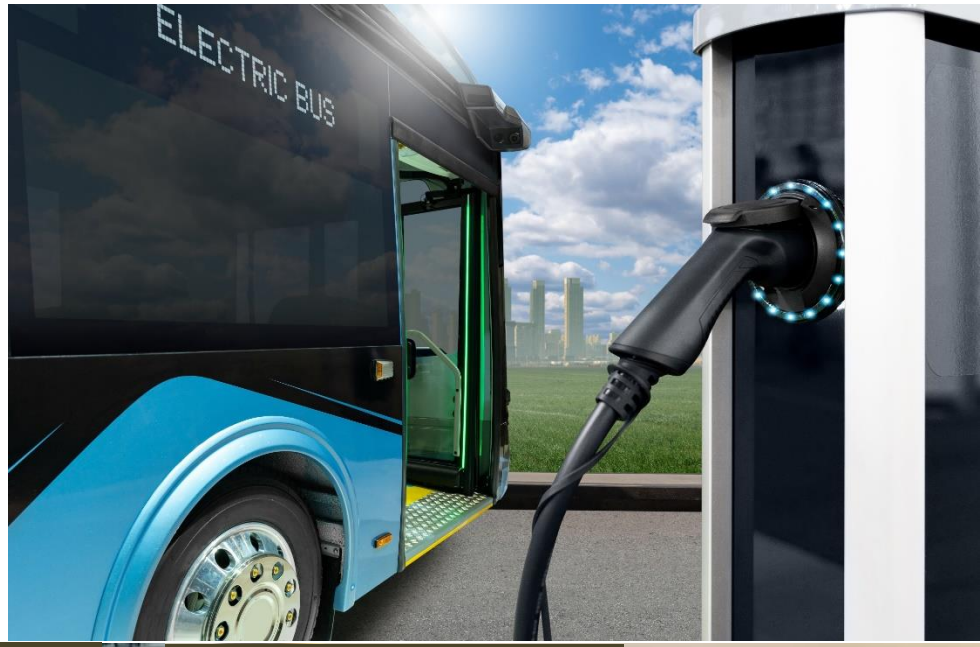
# New forms of mass transportation

New forms of mass transportation services are either under development or in operation

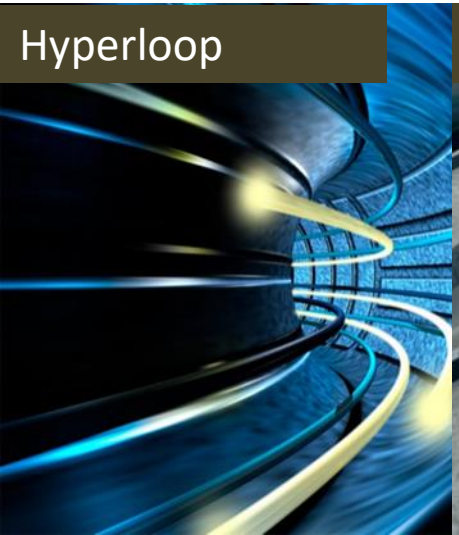
Some have become ubiquitous – such as electric buses

Many others are in development or exist as prototypes – hyperloop, autonomous microtransit, urban air mobility

"Last-mile" transportation




Hyperloop



Autonomous Microtransit

Urban Air Mobility

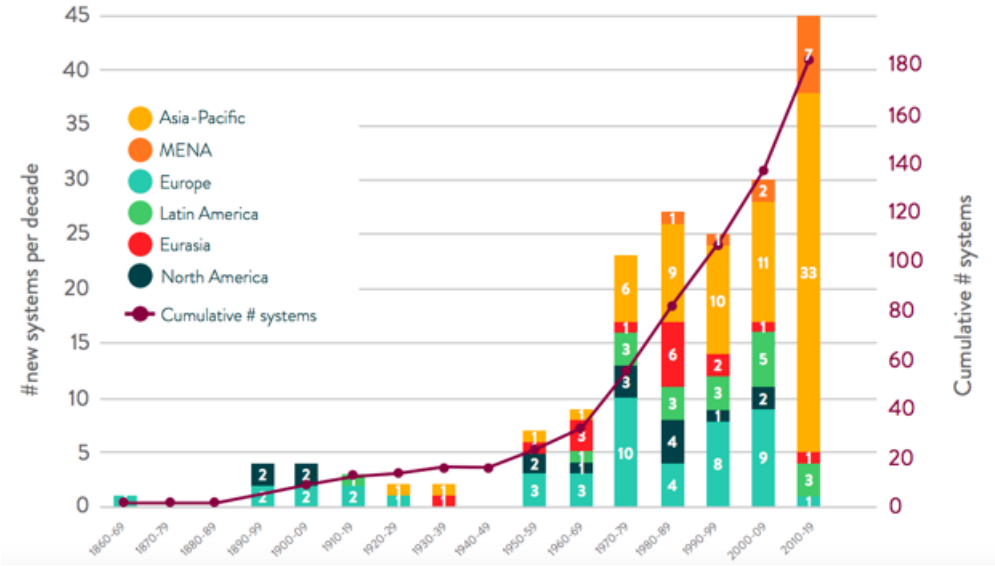
# Mass transportation

Mass transit carried an estimated 53 billion passengers in 2017

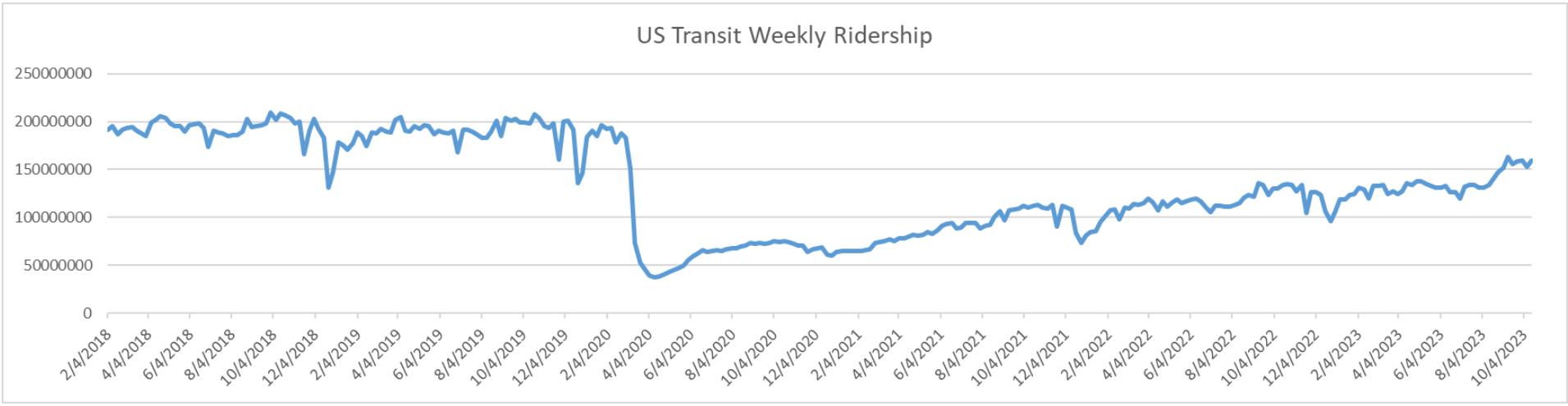
Metro systems expanded in many countries such as China, India, and Iran

Bus Rapid Transit systems have also expanded over time

**In some countries, COVID has negatively impacted ridership and a multi-faceted strategy is needed to stabilize public transportation use**




https://www.bloomberg.com/news/articles/2018-09-20/the-global-mass-transit-revolution



# Mobility-as-a-Service & Ride-hailing

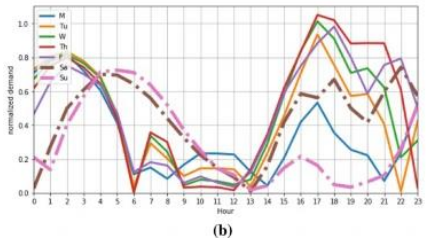
- Mobility-As-A-Service: Sharing economy for transportation
- Ride-hailing: hire a car with driver for a trip
- Car-sharing: short-term rentals
- Peer-to-peer car rental: allow vehicle owners to rent out their cars to others when they're not in use
- Peer-to-Peer Ride and Carpooling: Facilitates long-distance ridesharing and carpooling, connecting drivers with passengers traveling in the same direction
- Driving services: Hire a car driver
- Station car: rent a car at a station for a short trip


**Opportunity to reduce car-ownership and to provide services to those who do not drive (seniors, persons with disabilities) and to reduce the externalities associated with parking and the financial burden of owning and using private cars**

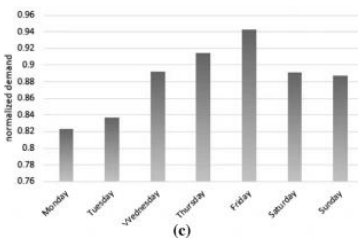
# Rutgers Urban & Civic Informatics Lab

## Short-Term Prediction of Demand for Ride-Hailing Services: Deep Learning Approach using a modified WaveNet for multivariate predictive analytics

(a)



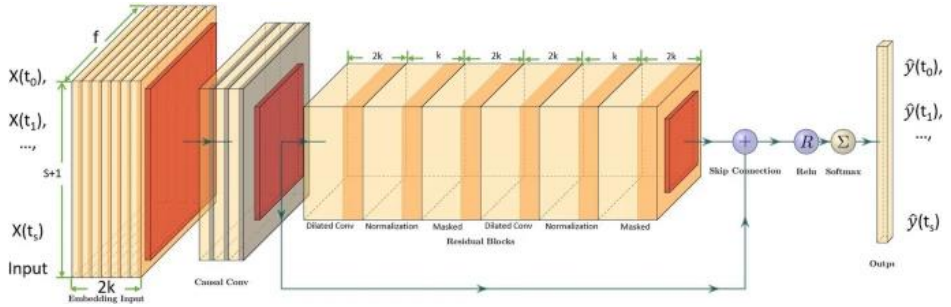
(b)




(c)

Predict pick-ups by temporal and real-time features (e.g., time-of-day, day-of-week, and hourly weather conditions), demographic and socioeconomic features, travel-to-work characteristics, social and built environment characteristics, including crime levels.

Uses a deep learning model based on WaveNet technology – a Convolutional Neural Network originally used for generating and predicting audio waveforms.




Chen, L., Thakuriah, P.V. & Ampountolas, K. Short-Term Prediction of Demand for Ride-Hailing Services: A Deep Learning Approach. J. Big Data Anal. Transp. (2021). https://doi.org/10.1007/s42421-021-00041-4

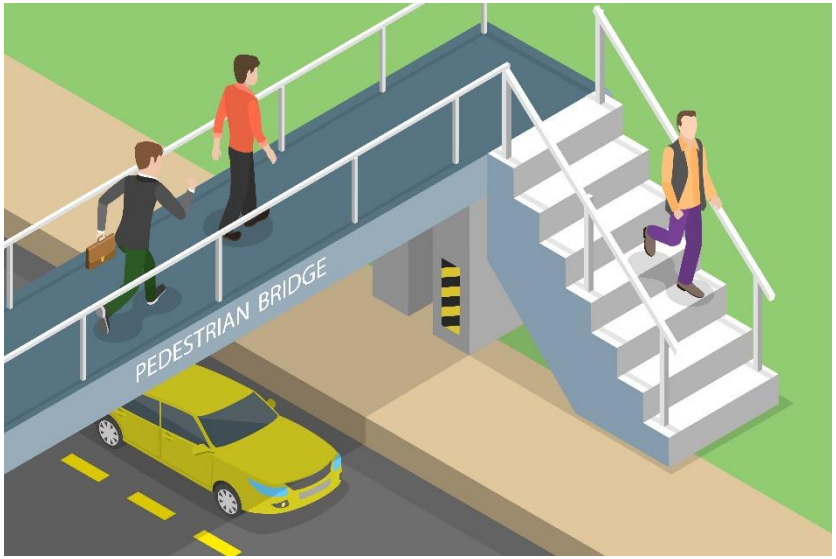
# Bicycles & Pedestrians

Increasing build-up of awareness of the link between sustainability, health and active travel

As of Fall 2021, NYC has over 650 miles of dedicated cycling space. At least 50 more miles of protected bike lanes to be installed in 2023 and 250 miles from 2022 to 2026.

Many other cities – Paris, Amsterdam, Brussels – continue to lead the way, while other cities – Delhi, Nairobi – are making investments

Pedestrian sidewalks are a crucial part of urban infrastructure in many parts of the world although they are of varied quality, have multi-uses including street vendors and lack universal design



# Micromobility & Active Travel

- Electric Scooters: Electric scooters, both stand-up and sit-down models can be rented for short trips and leave them at their destination.
- Bicycles: Shared bicycles, including traditional and electric-assist bikes, are available for rent at docking stations or through app-based systems.
- Electric Skateboards and Hoverboards: These compact electric vehicles provide personal transportation for short distances.
- Electric Unicycles: Although less common, electric unicycles offer an option for individuals to travel short distances.

E-scooter

Bike-sharing

**Tremendous opportunity to integrate these modes through urban design, Complete Streets, "Programmable Streets" and other initiatives connecting transportation with livable, healthy cities**

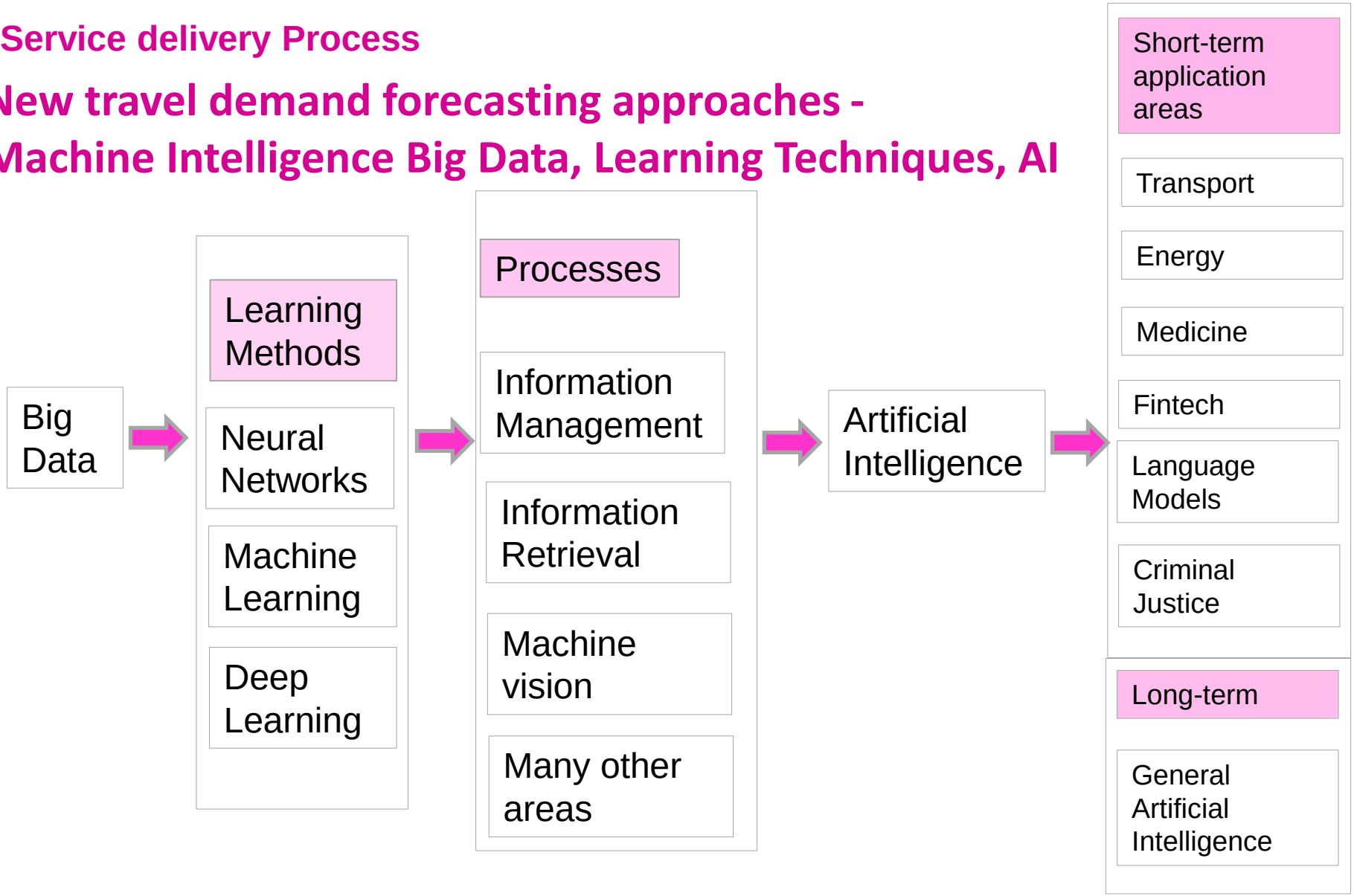
# AI-driven Urban Logistics and Freight


- The e-commerce sector is exploding but significant labor shortages are predicted for trucking and related sectors
- Blockchain in logistics
- Automation in ports and intermodal connections
- Robotic logistics
- Autonomous trucks
- Neighborhood-scale autonomous delivery robots & city-scale drone services
- Freight-forwarding & last-mile delivery using self-driving delivery vans and automated loading systems

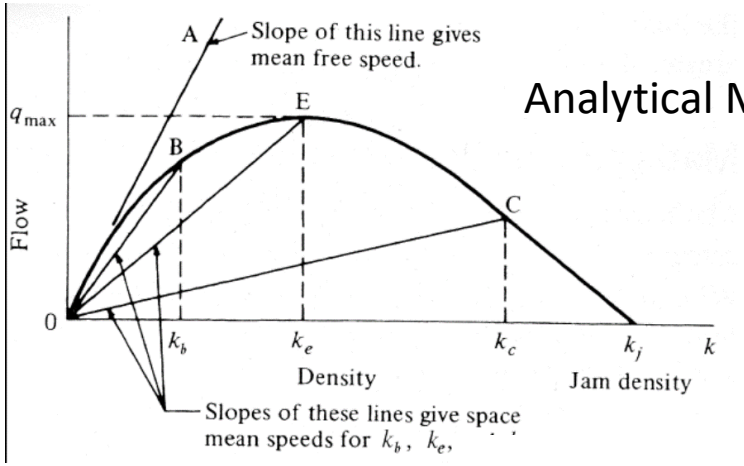
**Has the potential to address labor shortages in the commercial freight sector, as well as to address rising congestion due to trucks and delivery vans on the road due to growth in e-commerce**

## Service delivery Process

# New travel demand forecasting approaches - Machine Intelligence Big Data, Learning Techniques, AI

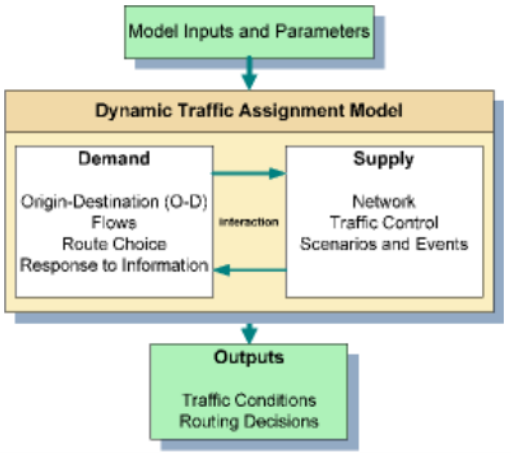


# Generations of models of transportation "demand"

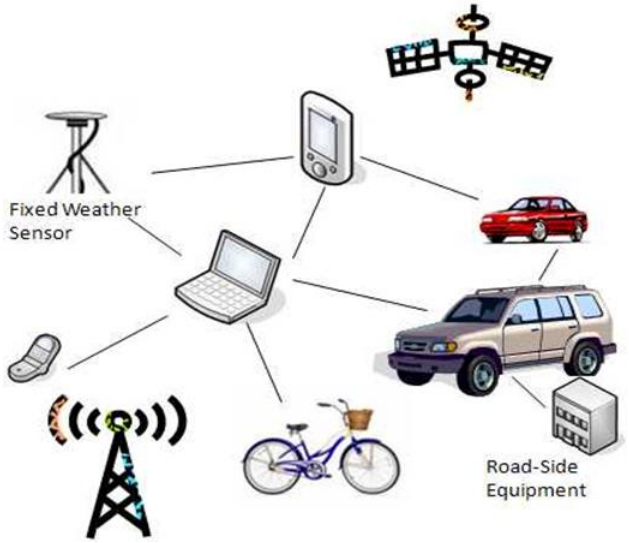



Analytical Models

Theory-based Models




"Data-driven" Models – A "real-time" weather-integrated travel time forecasting models using machine learning




Thakuriah, P. and N. Tilahun (2013). Incorporating Weather Information into Real-Time Speed Estimates: Comparison of Alternative Models. In Journal of Transportation Engineering, Vol. 139, No. 4, pp. 379-389.

# Opportunity: educated workforce

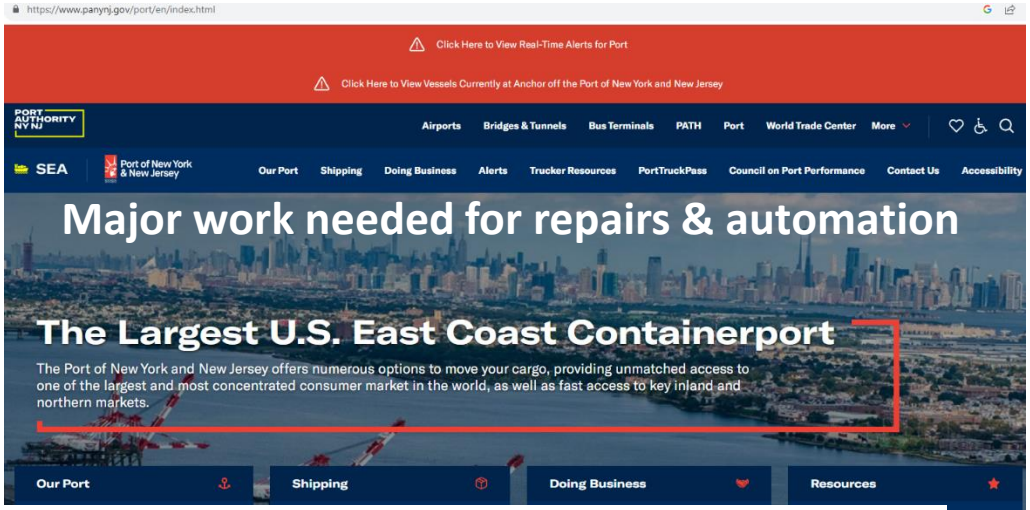
- Specialist transportation planning and engineering knowledge on modeling and simulations of transportation systems
- Data gathering: science of sensors, remote sensing, survey methods, core understanding of new forms of data and how they work
- Data analytics: machine learning, advanced statistical analysis, urban and transport modelling and simulations, GIS, spatial analysis, visualisation
- Information management: systems, databases, programming skills, machine learning, data structures, algorithms
- Information governance: legal and economic aspects of data management, privacy and security
- Business management: project management, business case development, monetisation and ROI analysis

# Skills - Team Composition

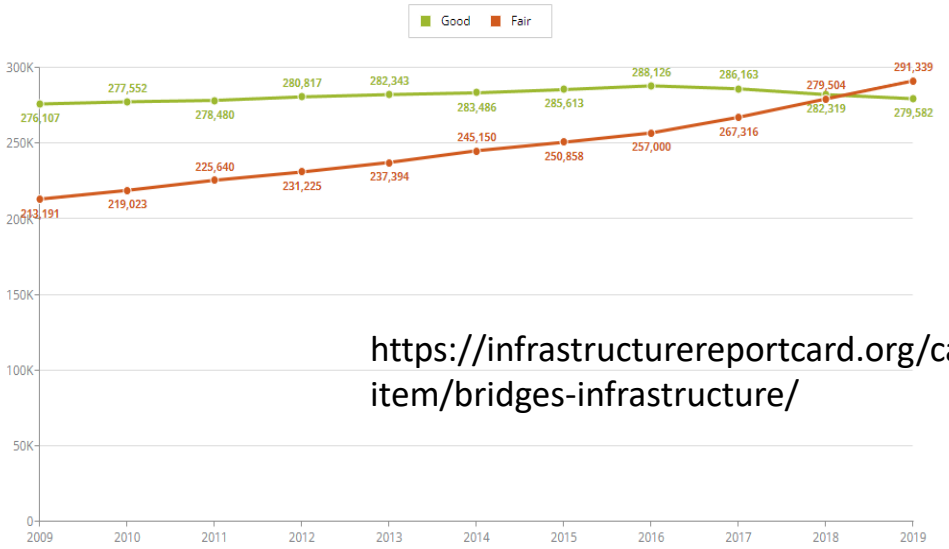
- Domain experts in transportation
- Information management
- Data science analysts
- Experts on data acquisition, sharing, standards
- Experts in governance, ethics, privacy
- Consumer analysts – people who assess and understand users needs and market
- Communications and outreach
- Experts in commercialisation, business case development

**Successful teams learn from each other, listen to needs, are open to new ideas, and are constantly seeking to collaborate.**

# Infrastructure Needs




US Bridges by condition by year




https://infrastructurereportcard.org/cat-item/bridges-infrastructure/

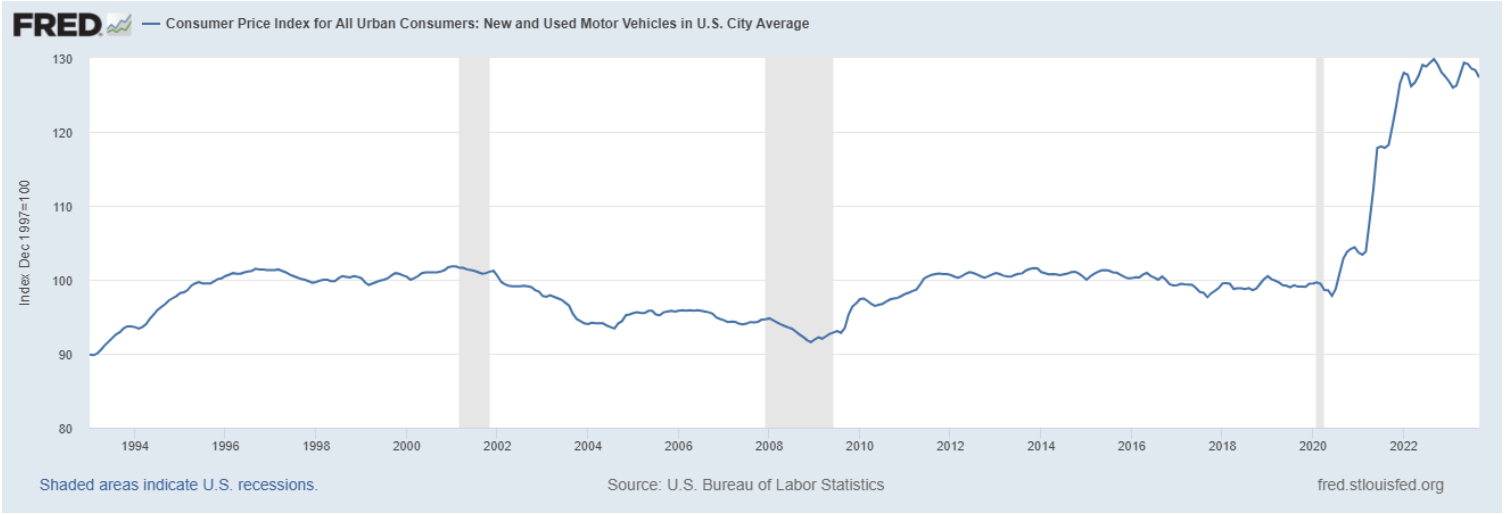
**Repair, expansion and automation needed in bridges, roads, tunnels, public transportation, ports and airports as they reach the end of their design lifecycle**

Infrastructure Investment and Jobs Act (2021) - approximately $1.2 trillion in spending – optimistic estimates are that it will add 1.5million jobs per year for next 10 years

## Volatility in prices & uncertainty in transportation consumption


Global Energy Price Index (1993-2023)

Source: Federal Reserve Economic Data (FRED)




US New and Used Car Consumer Price Index (1993-2023)

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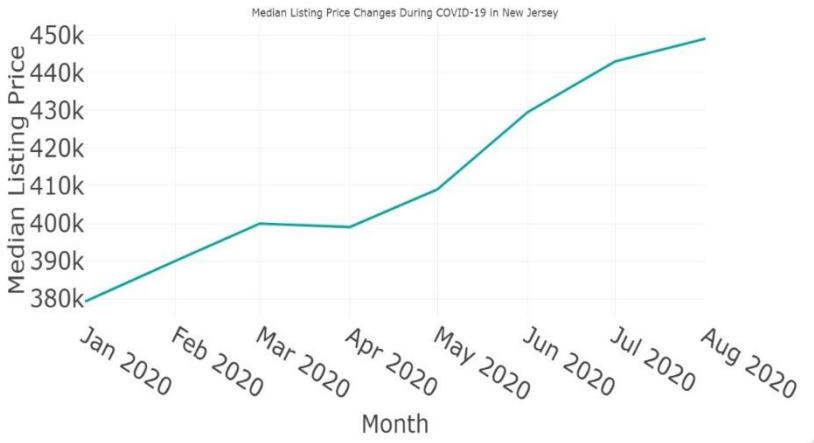
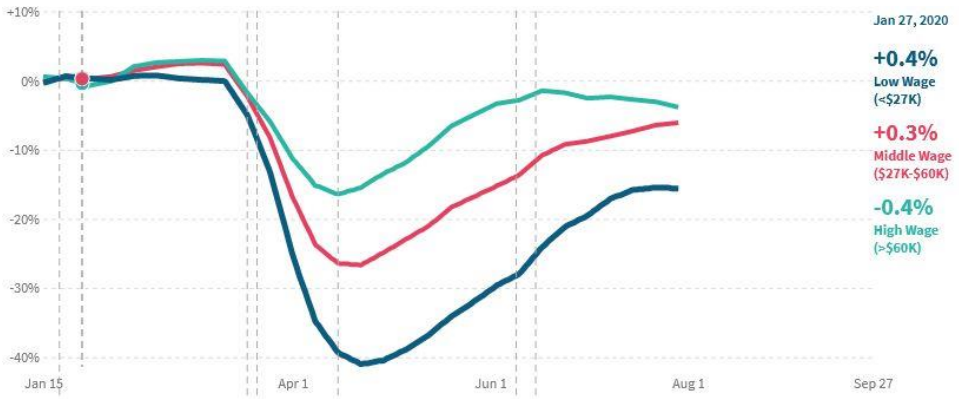
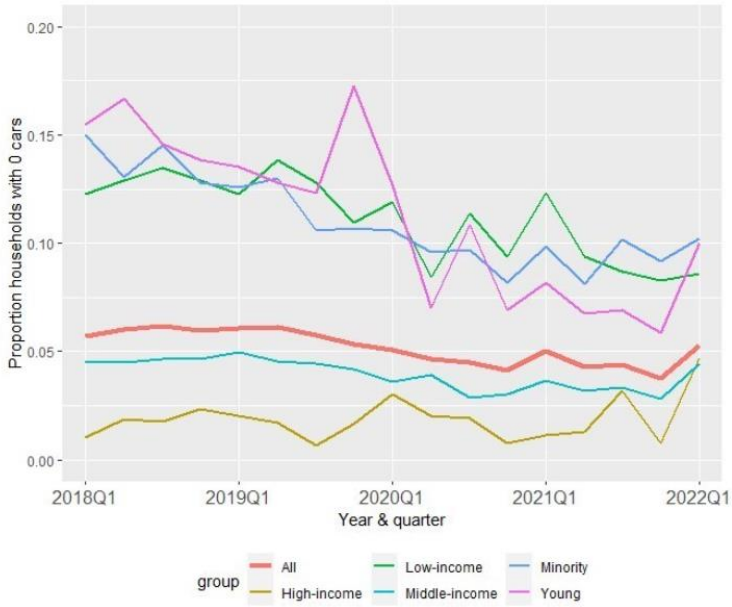
## New Jersey Property Sale Prices (2020)




## New Jersey Employment Rates (2020)




**Predictive analytics of these broader trends will be foundational to strategic planning for future mobility systems**


Thakuriah, P. (2023). Exploring Car-Ownership and Declining Carlessness in the United States during the COVID-19 Pandemic. Transport Findings. https://doi.org/10.32866/001c.72773

# Non-transportation & broader trends affecting future urban mobility

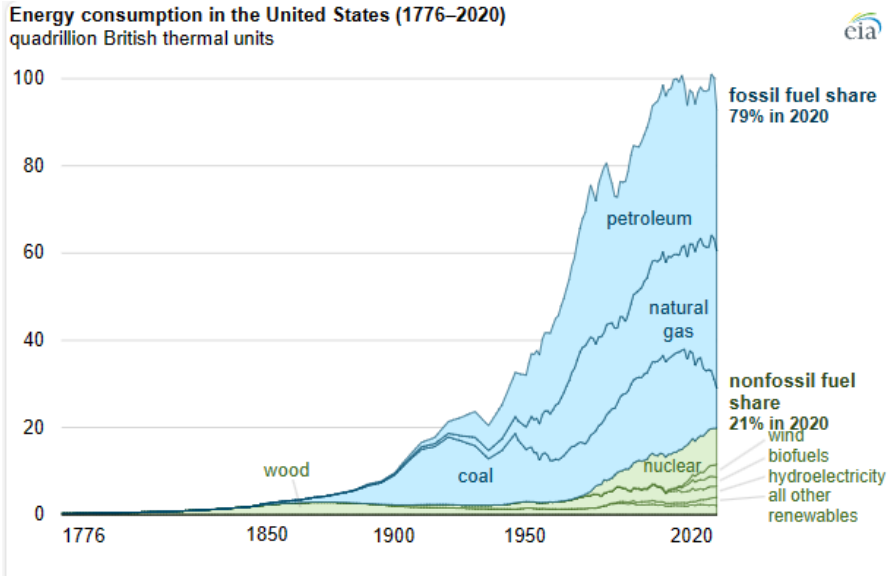
# Climate change & electric vehicles

Dependence on fossil fuels continue to be a major concern.

EV sales now representing 8.6% of the total new-vehicle retail market

USA's "next great public works project" (after the interstate highway system) is underway: an electric vehicle (EV) charging network that will reach the farthest corners of the nation

**Elsewhere emissions? – In the US, nationally, 79% of total energy consumption comes from fossil fuels – petroleum, natural gas, coal. Many other price, behavioral and strategy changes needed.**

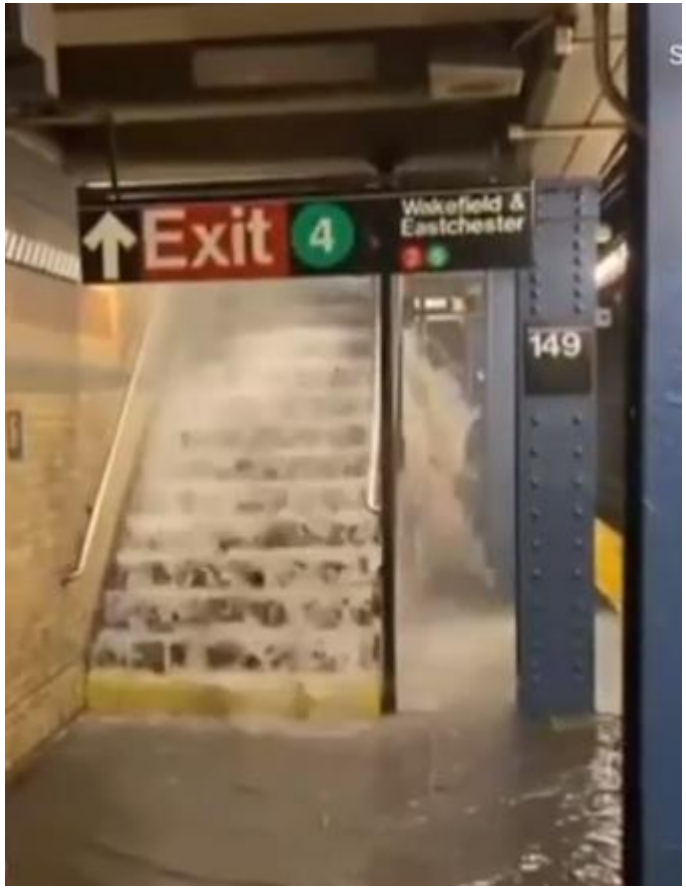



Energy Information Administration (2020)

# Climate change & Disaster Preparation

Impact of climate change on extreme weather events and implications for future mobility systems:

- Resilience planning: fortify infrastructure to protect from storm surges, flood, fires, tornadoes
- Preparedness : preparedness plans, emergency exercises/training
- Responses: emergency evacuation and other operations
- Recovery: repair and recover lost or damaged infrastructure
- Mitigation: vulnerability assessment, public education




**Increase in frequency, intensity, duration of extreme weather events are a game-changer in urban transportation resilience and will play a key role in future urban mobility systems**

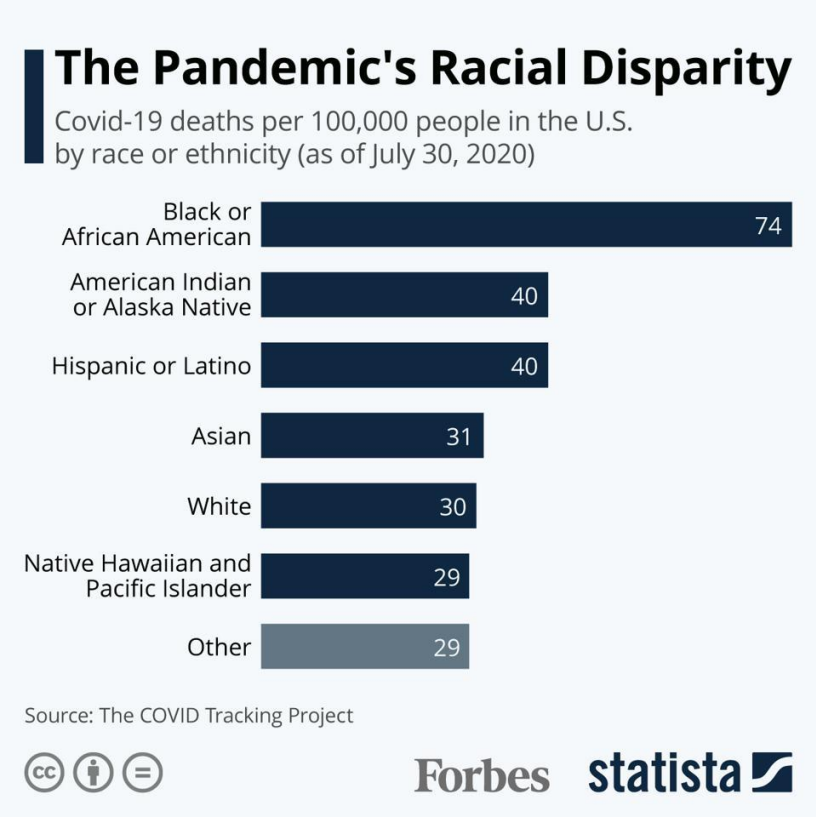
# Social Determinants of Health

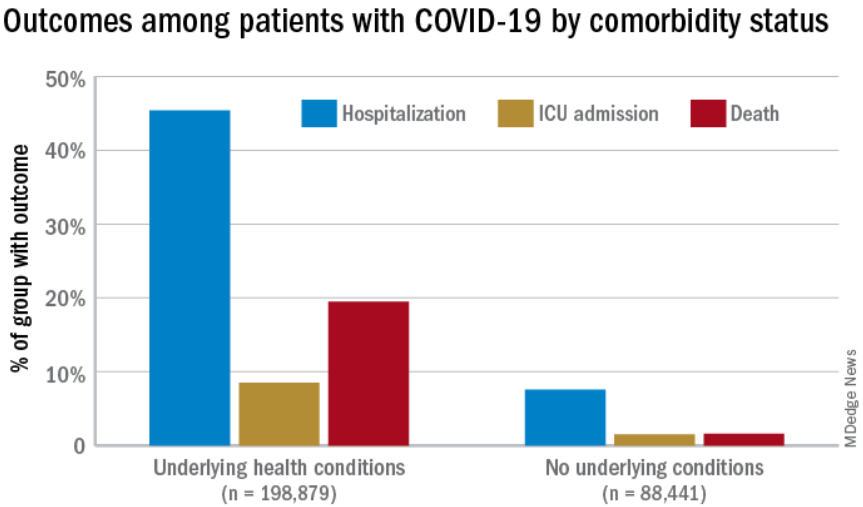
- Social determinants of health (SDOH) refer to the conditions in which people are born, grow, live, work, and age, and how these conditions influence their overall health and well-being.
- Years of research has shown that transportation plays a key role in safety, stress and livability.

**Understanding and addressing social determinants of health, and the role of transportation within that context, is crucial for achieving health equity and improving the overall health of populations.**


https://www.cdc.gov/visionhealth/determinants/index.html

# Health Disparities and Social Determinants of Health



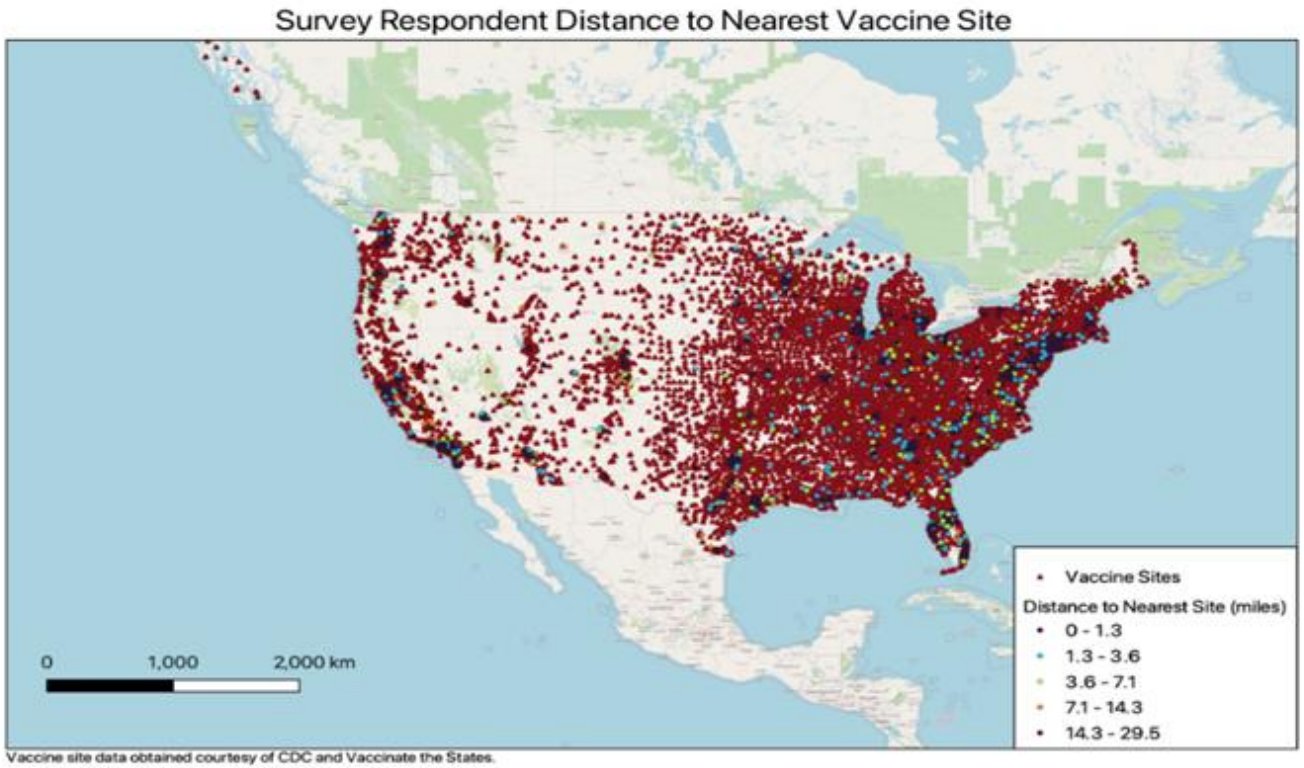




Notes: 1,761,503 cases were reported in the United States as of May 30, 2020. Outcome and underlying-condition status are unknown for the majority of those patients.

Source: MMWR. 2020 Jun 15;69(early release):1-7

# Using Big Data Technology to Map Vaccination Centers in the early days of the US COVID vaccination program

https://rucilab.rutgers.edu/visualizing-the-spread-of-covid-19-in-the-united-states/



# Active travel & Health & mHealth

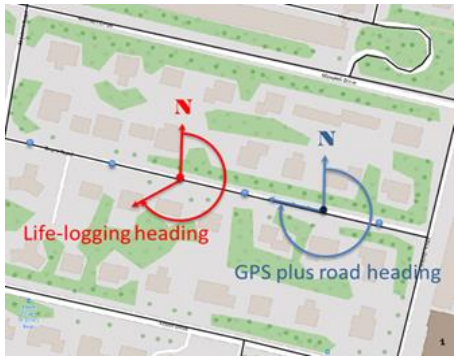
Recent increases in the use of wearable technology allows the recording of mobility patterns, fitness and other leisure activities, monitor personal health and safety, and for travel and navigation.

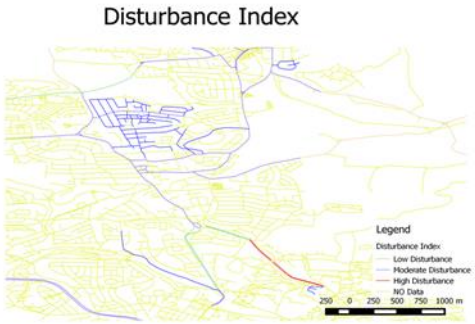
Examples include smartphones with their increasingly greater number of integrated sensors, such as GPS or motion sensors such as accelerometers, gyroscopes and magnetometers.

More specialized devices such as wearable cameras, or others that monitor eye-tracking, galvanic skin response, and facial expressions allow the detection of stressors in the transportation system.


The usability of these devices to evaluate mobility patterns and related physiological processes or behaviors opens up new ways of designing and operating healthy transportation systems

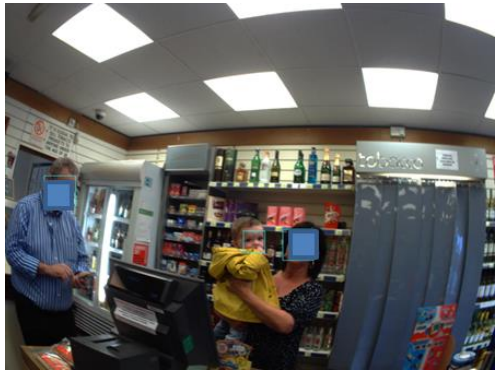
## Urban Health 1 - A traffic hazard "disturbance" index from wearable sensors




Using multiple sources of personal sensor information, index the street network with the degree of uncertainty and perceived conflict – ***usable to measure degree of social distancing on sidewalks and public spaces***.

## Urban Health 2 - Insights into physical distancing in non-emergency conditions



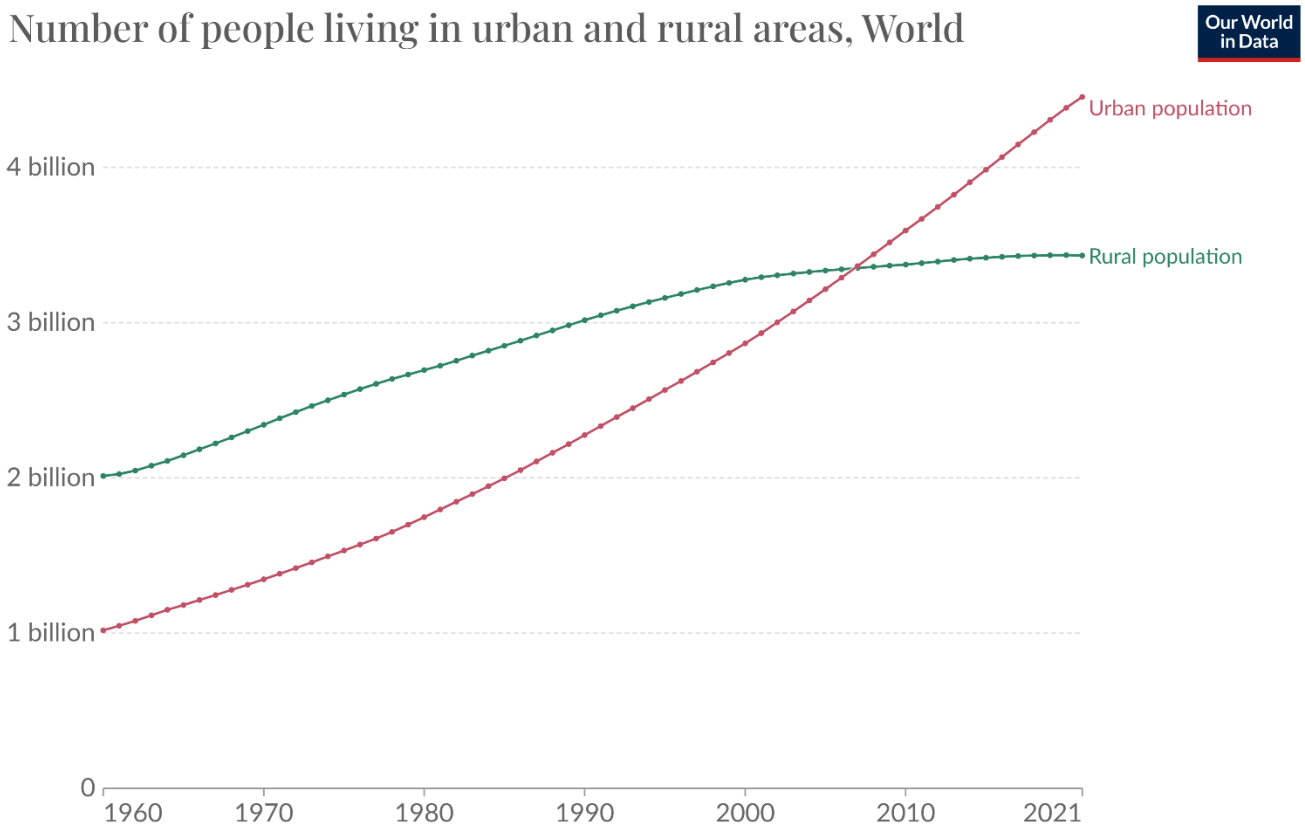
On a slightly different note - when and how much time do we spend socially-distanced from others? Data from wearable cameras can tell us.

Thakuriah, P., C. Boididou and J. Hong. *Physical distancing and its association with travel behavior in daily pre-pandemic urban life: An analysis utilizing lifelogging images and composite survey and mobility data*. Under review in Environment and Planning B: Urban Analytics and City Science.

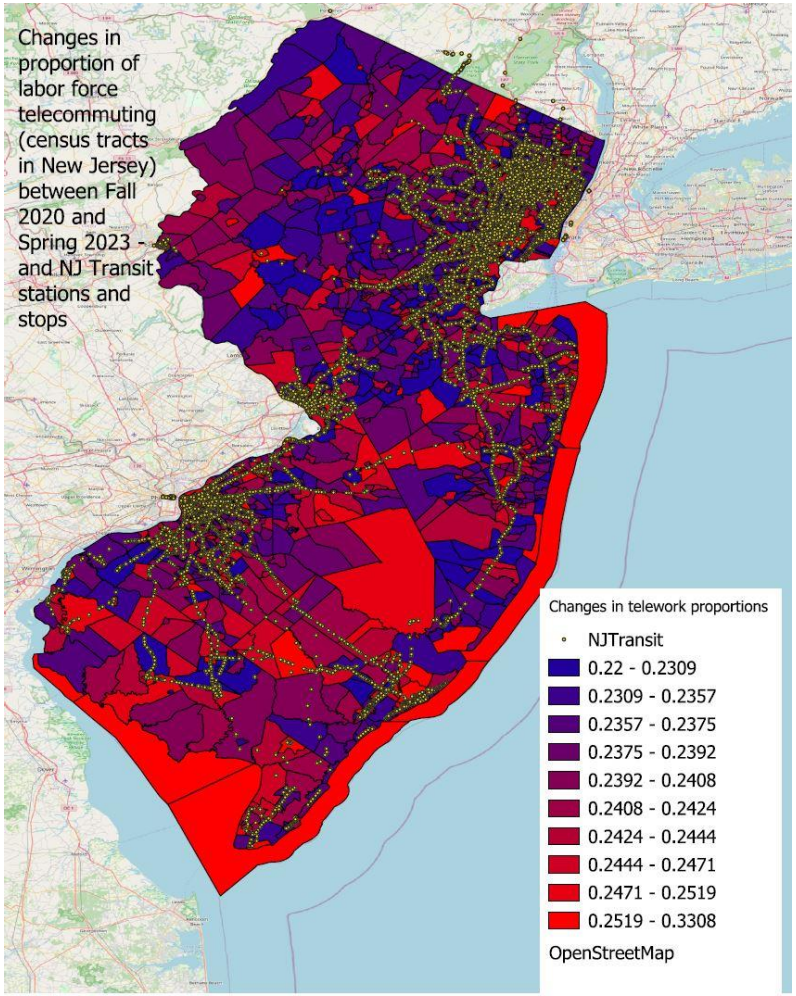
Thakuriah, P., K. Sila-Nowicka, J. Hong, C. Boididou, M. Osborne, C. Lido, A. McHugh (2020). *Integrated Multimedia City Data (iMCD): A Composite Survey and Sensing Approach to Understanding Urban Living and Mobility*. In Computers, Environment and Urban Systems. Early online: https://doi.org/10.1016/j.compenvurbsys.2019.101427

Sila-Nowicka, K. and P. Thakuriah (2019). *Multi-sensor movement analysis for transport safety and health applications*. In PLoSONE https://doi.org/10.1371/journal.pone.0210090

# The future is urban!



## Telecommuting & remote work




**A major consideration for transportation, particularly public transportation going forward is telecommuting and remote work.**

Bureau of Labor Statistics found that around 27% of the US workforce was working remotely part of the time in September 2022.

We put together multiple sources of data including **small-area estimation via machine learning model** to estimate census tract-level telecommuting levels at multiple time periods post-2020

In New Jersey, telecommuting levels in 2022-2023 remained closer to pandemic highs of 2020 in census tracts where transit best serves the population

Telecommuting levels have reduced in areas with less transit service

# Future of work in the transportation sector

- Labor shortage in trucking, public transportation, construction and related industries and increasing reliance on automated technology
- Reduction in human error and safety improvements for workers
- Job losses may occur
- New occupations and job categories may arise in the transportation sector

**Strategic planning needed to:**

- **Identify major re-skilling with job displacement**
- **Regulatory framework to resolve major ethical dilemmas**
- **New business, engineering and legal models involving human-robotic co-work**

# Changes in household demographics and diversity, equity and inclusion implications for future mobility

- Falling household sizes: Households are at the center of consumption-related decisions. Worldwide, household size is becoming smaller – with a increase in the proportion of households with 1 or 2 persons.
- Women's labor force participation has remained around 50% over last few decades worldwide. OECD rate at 62.5% women.

- About 9.2% of the world, or 719 million people, live on less than $2.15 a day.
- The share of older persons (65+) is also increasing – share is projected to rise from 10% in 2022 to 16% in 2050.
- An estimated 1.3 billion people (16% of the global population) experience significant disability today.

- Implications for increases in individual trip-making and ride-sharing could be highly consequential
  - Specialized transportation (e.g. volunteer driver services, subsidized services to jobs) are tremendous
  - Mobility literacy
  - Advances in assistive technology

**A litmus test for the success of future mobility is that no one is left behind in terms of mobility and accessibility due to their gender, age, disability status, income, or race.**

Technologically advanced, societally responsive, environmentally efficient, socially just, humane, and affordable transportation in smart, healthy and livable cities

## Opportunities for future mobility

## Conclusions & Opportunities

- **Better integration** of infrastructure development strategies and transportation service delivery with smart cities initiatives with through integrated city-wide platforms and user-side applications
- **Development of city data infrastructure** that can stimulate an innovative ecosystem in mobility and transportation
- **Encouragement of MaaS operations** for ride-hailing and micromobility
- **Integrating advances in data science** with deep domain knowledge of transportation planning and operations – and developing a workforce to carry out such work
- Tighter coupling of city transportation with **urban design, complete streets, programmable/multi-use streets, public spaces and livability**
- **Public policy** that supports public participation and community engagement in designing transportation services and equity and inclusion principles in delivery of services
- Collaboration with **disaster response and human services communities**
- **Regulatory framework** to attract new service providers but to provide guardrails for transparency and privacy in mobility data collection and in resolving ethical dilemmas and biases regarding automation

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Many thanks to the following collaborators:

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**Thank you!**

## Master of Public Informatics

"Society is awash in data. We need trained, public-minded professionals that can think critically about how to use that data efficiently and ethically."

*Frank A. Felder, Ph.D., Research Professor and Director, Program in Public Informatics*

### About the Program

The Bloustein School's Master of Public Informatics program provides the vehicle for educating professional student cohorts in the competencies needed in public informatics: statistics, programming, data management, data analytics, visualization, spatial analysis, applications and the integration of these skills. Graduates of the program will bring a critical voice and a deep understanding of context to an emerging field.

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