Revolutionizing Road Transportation with Artificial Intelligence Empowered Technologies

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for
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Road Transportation Is Important

Unexpected drop in August retail sales as supply chain problems weigh on stores

Why traffic nightmares is now normal in Nov

It’s crawl but true, we have worst traffic jams
Road Transportation Challenges

What are the top five challenges in road transportation in the US?

In the United States, road transportation faces several specific challenges that can often be region-specific due to the vast size and diverse geography of the country. Nonetheless, some of the top challenges that are generally acknowledged across the U.S. include:

1. **Aging Infrastructure**: The U.S. has a large network of roads and highways that have been underfunded for years. Many bridges, tunnels, and roadways are in need of repair or replacement. The American Society of Civil Engineers often gives poor grades to the nation's infrastructure in its report cards.

2. **Congestion**: Congestion in U.S. cities and on major highways leads to significant time delays, increased fuel consumption, and higher emissions. Traffic congestion is especially severe in large metropolitan areas and on major arteries across the country.

3. **Safety and Traffic Fatalities**: Road safety continues to be a significant concern in the U.S. Despite advances in vehicle safety, traffic fatalities and serious injuries are a leading cause of death, especially among young people. The challenges include addressing distracted driving, driving under the influence, and the safety of vulnerable road users such as pedestrians and cyclists.

4. **Environmental Concerns**: The U.S. transportation sector is one of the largest contributors to national greenhouse gas emissions. There is a growing challenge to reduce the carbon footprint of road transport by encouraging the use of more fuel-efficient vehicles, developing electric vehicle infrastructure, and promoting alternative transportation options.

5. **Equity and Accessibility**: There's an increasing recognition of the need for equitable transportation that serves diverse populations including low-income neighborhoods, people with disabilities, and those living in rural areas. Access to reliable and affordable transportation is crucial for access to jobs, education, and healthcare.
Road Transportation Challenges

Eight Transformational Technologies

Autonomous Vehicles

Eight Transformational Technologies

Connected Vehicles

Image Source: https://www.volpe.dot.gov/sites/volpe.dot.gov/files
Eight Transformational Technologies

Electric Vehicles

Eight Transformational Technologies

Smart Infrastructure

Image Source: https://www.2025ad.com/latest/computing-and-autonomous-driving/
Eight Transformational Technologies

Crowdsourcing Data and Applications

Eight Transformational Technologies

Bigdata Analytics

Image Source: http://www.uwdrive.net
Eight Transformational Technologies

Ride Resource Sharing

Eight Transformational Technologies

Mobility as a Service (MaaS)

AI Is a Critical Binding Agent

Image source: https://www.xcubelabs.com/blog/how-ai-is-transforming-the-transport-industry/
Power of These Disruptive Technologies

Proof of the Effectiveness

NYC Daily Trips: Taxi, Uber, and Lyft
Based on TLC summary data

Image Source: https://arekskuza.com/the-innovation-blog/uber-business-model/
AI Applications in Transportation

Transportation is likely to be one of the first domains in which the general public will be asked to trust the reliability and safety of an AI system for a critical task.

- One Hundred Year Study on Artificial Intelligence (AI100), Stanford University,
AI can improve performance beyond that provided by other analytics techniques. The top five potential incremental value from AI:

1. **Travel**
2. **Transport & Logistics**
3. **Retail**
4. **Automotive and assemble**
5. **High tech**

### Breakdown of use cases by applicable techniques, %

- **15%**: Full value can be captured using non-AI techniques
- **16%**: AI necessary to capture value ("greenfield")

### Potential incremental value from AI over other analytics techniques, %

<table>
<thead>
<tr>
<th>Industry</th>
<th>Incremental Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel</td>
<td>178</td>
</tr>
<tr>
<td>Transport and logistics</td>
<td>89</td>
</tr>
<tr>
<td>Retail</td>
<td>87</td>
</tr>
<tr>
<td>Automotive and assembly</td>
<td>85</td>
</tr>
<tr>
<td>High tech</td>
<td>85</td>
</tr>
<tr>
<td>Oil and gas</td>
<td>70</td>
</tr>
<tr>
<td>Chemicals</td>
<td>57</td>
</tr>
<tr>
<td>Media and entertainment</td>
<td>57</td>
</tr>
<tr>
<td>Basic materials</td>
<td>55</td>
</tr>
<tr>
<td>Agriculture</td>
<td>66</td>
</tr>
<tr>
<td>Consumer packaged goods</td>
<td>55</td>
</tr>
<tr>
<td>Banking</td>
<td>50</td>
</tr>
<tr>
<td>Healthcare systems and services</td>
<td>44</td>
</tr>
<tr>
<td>Public and social sectors</td>
<td>44</td>
</tr>
<tr>
<td>Telecommunications</td>
<td>44</td>
</tr>
<tr>
<td>Pharmaceuticals and medical products</td>
<td>39</td>
</tr>
<tr>
<td>Insurance</td>
<td>38</td>
</tr>
<tr>
<td>Advanced electronics/semiconductors</td>
<td>36</td>
</tr>
<tr>
<td>Aerospace and defense</td>
<td>30</td>
</tr>
</tbody>
</table>
Published papers on AI research and applications in transportation
Data source: Google Scholar
Hot Topics in AI for Transportation

- Natural Language Processing
- Recommendation System
- Reinforcement Learning
- Graph Neural Network
- Block Chain
- Computer Vision & Edge AI
NLP Method for Truck Parking Prediction

- Cost-effective solution for truck parking using NLP techniques
  
  Sensor-fused detection
  
  Customized Machine Learning

Ride Sharing Recommendation

1. Broadcasting Rider
2. Data Server
3. Characteristics Matching Layer
   ML Content-Based Recommendation
4. Final Rider List
   Complete Trip
5. Save Feedback
   DRIVER
   RIDER 1
   RIDER 2
   RIDER 3
   Compute Classifiers
   Feedback
   Given Classifier
   Feedback
   Received Classifier
   Feed Characteristics,
   Computed Classifiers to Train
   The Machine Learning Module
   Support Vector Machine
   Classifier Module

Find Closest Driver

Uber vs. Lyft
Reinforcement Learning (RL)

AlphaGo Master beat Jie KE 3:0!
AlphaGo Zero 98:11 AlphaGo Master
RL for Autonomous Driving

• Motivations
  - Autonomous driving consists of multiple tasks. For example, higher-level tasks pertain to decision-making based on reasoning of the surrounding environment.
  - Long-term decisions are hard to model in traditional models
  - Uncertainties are interrelated in autonomous driving scenarios.

• Applications
  • Lane changing
  • Car following

Zhu et al., 2020: https://doi.org/10.1016/j.trc.2020.102662
• Motivations
  - Measurements of traffic variables on transportation networks are becoming increasingly common.
  - Two data points might be spatially close in Euclidean space but interact independently. The true distance is roadway driving distance.
  - The need to predict traffic characteristics in a short or long future time horizon for different ITS applications is strong.

• Solutions
  - GNN + recurrent NN variants (vanilla RNN, LSTM, sequence to sequence)

Cui et al., 2020: https://doi.org/10.1016/j.trc.2020.102674
Block Chain for Transportation

- Supply chain
  - Lack of information for consumer about the origin of food products
- Electric vehicle charging
  - Allow customers to query charging stations for the lowest available price
- Smart vehicle
  - Malicious attacks can compromise passengers’ safety
Blockchain + AI for Transportation

A Blockchain-enabled Intelligent IoT Architecture with Artificial Intelligence

• **Edge intelligence:**
  - AI uses analytic tools for reliable data mining (feature extraction, scaling, and representation) of big unstructured data from IoT devices.
  - Blockchain technology provided peer to peer connection to unstructured IoT devices in networks for security and privacy.

• **Fog intelligence:**
  - AI technologies are deployed to train machine learning models and make decisions as rapidly as possible at fog intelligence.
  - Blockchain technology provides a distributed repository in which every device has its copy of the whole ledger.

• **Cloud intelligence:**
  - Intelligent agents of AI are used in cloud intelligence to collect, select, analyze the data from ambient environments using centralized methods.
  - Blockchain provides the distributed pattern for secure big data analysis in IoT.

Edge-AI for Traffic Sensing

Traditional Sensing Tech

OR

AI empowered Sensing Tech

Cooperative Sensing
Computer Vision
Sensor Fusion
Edge Computing
ALL IN ONE
Human-Machine Interaction
Sample Applications
- Various Speed Limit Volume by 13 Classes
- Adaptive Control
- Hazard Warning
- Traffic Environment Sensing

Detection Thread
- Vehicle Localization
- Vehicle Classification

Tracking Thread
- Vehicle Counting
- Point-based Speed

Environment Thread
- Visibility Detection
- Road Surface Condition

Transportation Agencies
- Traffic Volume by Type
- Traffic Congestion
- Delinquent Zone Control

Road Users
- Speeding Warning
- Low Visibility Warning
- Road Surface Condition Warning

SPaT Plan
- GPS Record
- Radar Data
- Video Stream
- Humidity
- Temperature

Signal Controller
- Mobile Phone
- Radar
- Camera
- DHT22

Mobile Unit for Sensing Traffic (MUST)
Edge Computing

- Computational processing of sensor data away from the centralized nodes and close to the logical edge of the network (where the data is generated)

- Empowered by AI technologies, data can be processed by an IoT device itself or by a local computer, rather than being transmitted to a cloud data center.
Mobile Unit for Sensing Traffic (MUST)

-40°C ~ 70°C
10% ~ 90%
IP 65
12VDC
<35Watts
ARM1176JZF-S 700 MHz
3G/4G/5G, Ethernet
Linux
Micro Secure Digital (SD) Card
10 pounds
170 mm (length), 170 mm (width), 300 mm (height)
Edge-AI for Traffic Sensing

Object Detection and Classification
Edge-AI for Traffic Sensing

- Traffic volume detection and vehicle classification
  - Transfer learning
  - MobileNet pretrained on ImageNet and finetuned on MIO-TCD

<table>
<thead>
<tr>
<th></th>
<th>Car</th>
<th>Truck</th>
<th>Bus</th>
<th>Cyclist</th>
<th>Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>91%</td>
<td>5%</td>
<td>2%</td>
<td>2%</td>
<td>0</td>
</tr>
<tr>
<td>Truck</td>
<td>6%</td>
<td>87%</td>
<td>4%</td>
<td>3%</td>
<td>0</td>
</tr>
<tr>
<td>Bus</td>
<td>1%</td>
<td>2%</td>
<td>96%</td>
<td>1%</td>
<td>0</td>
</tr>
<tr>
<td>Cyclist</td>
<td>2%</td>
<td>2%</td>
<td>1%</td>
<td>95%</td>
<td>0</td>
</tr>
<tr>
<td>Background</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100%</td>
</tr>
</tbody>
</table>
## Road Surface Conditions Monitoring

<table>
<thead>
<tr>
<th></th>
<th>Dry</th>
<th>Snowy</th>
<th>Icy</th>
<th>Wet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td>97.5%</td>
<td>0.4%</td>
<td>0.7%</td>
<td>1.4%</td>
</tr>
<tr>
<td>Snowy</td>
<td>0.2%</td>
<td>97.9%</td>
<td>1.8%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Icy</td>
<td>1.6%</td>
<td>1.6%</td>
<td>93.6%</td>
<td>3.2%</td>
</tr>
<tr>
<td>Wet</td>
<td>0.6%</td>
<td>1.7%</td>
<td>2.4%</td>
<td>95.3%</td>
</tr>
</tbody>
</table>
Camera View Dehaze for Visibility Detection

Original Image  Scattering Map  De-hazed Image
# Edge-AI for Environment Sensing

## Visibility Detection

<table>
<thead>
<tr>
<th>Visibility</th>
<th>Threshold</th>
<th>±5%</th>
<th>±10%</th>
<th>±20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_s &lt; 500$ m</td>
<td>85.29%</td>
<td>89.14%</td>
<td>93.18%</td>
<td></td>
</tr>
<tr>
<td>500 m ≤ $V_s &lt; 1000$ m</td>
<td>88.17%</td>
<td>90.25%</td>
<td>95.42%</td>
<td></td>
</tr>
<tr>
<td>1000 m ≤ $V_s &lt; 2000$ m</td>
<td>90.36%</td>
<td>93.22%</td>
<td>97.03%</td>
<td></td>
</tr>
<tr>
<td>$V_s ≥ 2000$ m</td>
<td>91.23%</td>
<td>95.78%</td>
<td>98.75%</td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>89.27%</td>
<td>92.15%</td>
<td>96.61%</td>
<td></td>
</tr>
</tbody>
</table>
Edge AI for Highway Monitoring

Mobile App for device management, real-time data collection, event detection & warning.
This pilot project received the FHWA 2023 Build a Better Mousetrap Innovative Project Award!
Highway Safety Improvement

Technologies are available to help prevent crashes and reduce the severity of such tragedies!

AI Applications in Transportation

- Successful AI applications need domain knowledge

At some point in the day, everyone is a pedestrian. Walking accounts for about 11% of all trips. Unfortunately, pedestrian injuries and fatalities remain high. In 2021, 7,388 pedestrians were killed – a 13% increase from 2020 – and more than 60,000 pedestrians were injured nationwide (source: NHTSA).
Pedestrian Detection + Tracking
Diverse Pedestrian Groups Sensing

YOLO V4 Object Detection Model

Our Pedestrian Sensing Method
(Object Detection + Density Detection)
System Design:

• Encoder-decoder (ED)

• Density Map Segmentation & Clustering (DMSC)

• Local Patch Refinement (LPR)
People’s Opinions Are Different
President Joe Biden issued an executive order on AI that many experts say is a significant step forward on Nov. 2, 2023

- Civil Rights
- Data Usage and Privacy
- Regulation on AI-Generated Products
- Etc.
Huge Potential for AI & Transportation

AI JOB POSTINGS (% of ALL JOB POSTINGS) in the UNITED STATES by SECTOR, 2021

Source: Emi Burning Glass, 2021 | Chart: 2022 AI Index Report

- Information: 3.30%
- Professional, Scientific, and Technical Services: 2.59%
- Manufacturing: 2.02%
- Finance and Insurance: 1.81%
- Agriculture, Forestry, Fishing and Hunting: 0.95%
- Public Administration: 0.95%
- Educational Services: 0.84%
- Utilities: 0.78%
- Mining, Quarrying, and Oil and Gas Extraction: 0.69%
- Management of Companies and Enterprises: 0.67%
- Wholesale Trade: 0.63%
- Retail Trade: 0.54%
- Real Estate and Rental and Leasing: 0.40%
- Transportation and Warehousing: 0.33%
- Waste Management and Remediation Services: 0.28%
Huge Potential for AI & Transportation

TOP CONTRACT SPENDING on AI by U.S. GOVERNMENT DEPARTMENT and AGENCY, 2000–21 (SUM)


- Department of Defense (DOD): 5.20
- National Aeronautics and Space Administration (NASA): 1.41
- Department of Health and Human Services (HHS): 0.70
- Department of Homeland Security (DHS): 0.45
- Department of the Treasury (TREAS): 0.32
- Department of Veterans Affairs (VA): 0.15
- Department of Commerce (DOC): 0.15
- Department of Agriculture (USDA): 0.07
- Department of Energy (DOE): 0.06
- Securities and Exchange Commission (SEC): 0.06
- General Services Administration (GSA): 0.06
- Department of State (DOS): 0.06
- Social Security Administration (SSA): 0.05

Department of Transportation (DOT): 0.05

Huge Potential for AI & Transportation

**TOP CONTRACT SPENDING on AI by U.S. GOVERNMENT DEPARTMENT and AGENCY, 2021**


- Department of Defense (DOD): 1,138
- Department of Health and Human Services (HHS): 234
- National Aeronautics and Space Administration (NASA): 169
- Department of Homeland Security (DHS): 81
- Department of Commerce (DOC): 49
- Department of the Treasury (TREAS): 34
- Department of Veterans Affairs (VA): 25
- Department of Transportation (DOT): 12
- Securities and Exchange Commission (SEC): 12
- Department of Agriculture (USDA): 8
- Department of Energy (DOE): 8
- Agency for International Development (USAID): 6
- Department of Justice (DOJ): 4
- Department of State (DOS): 3
- National Science Foundation (NSF): 2

Thanks for Your Attention!

Let us work together for a safer, greener, more efficient, and more equitable future transportation system!

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