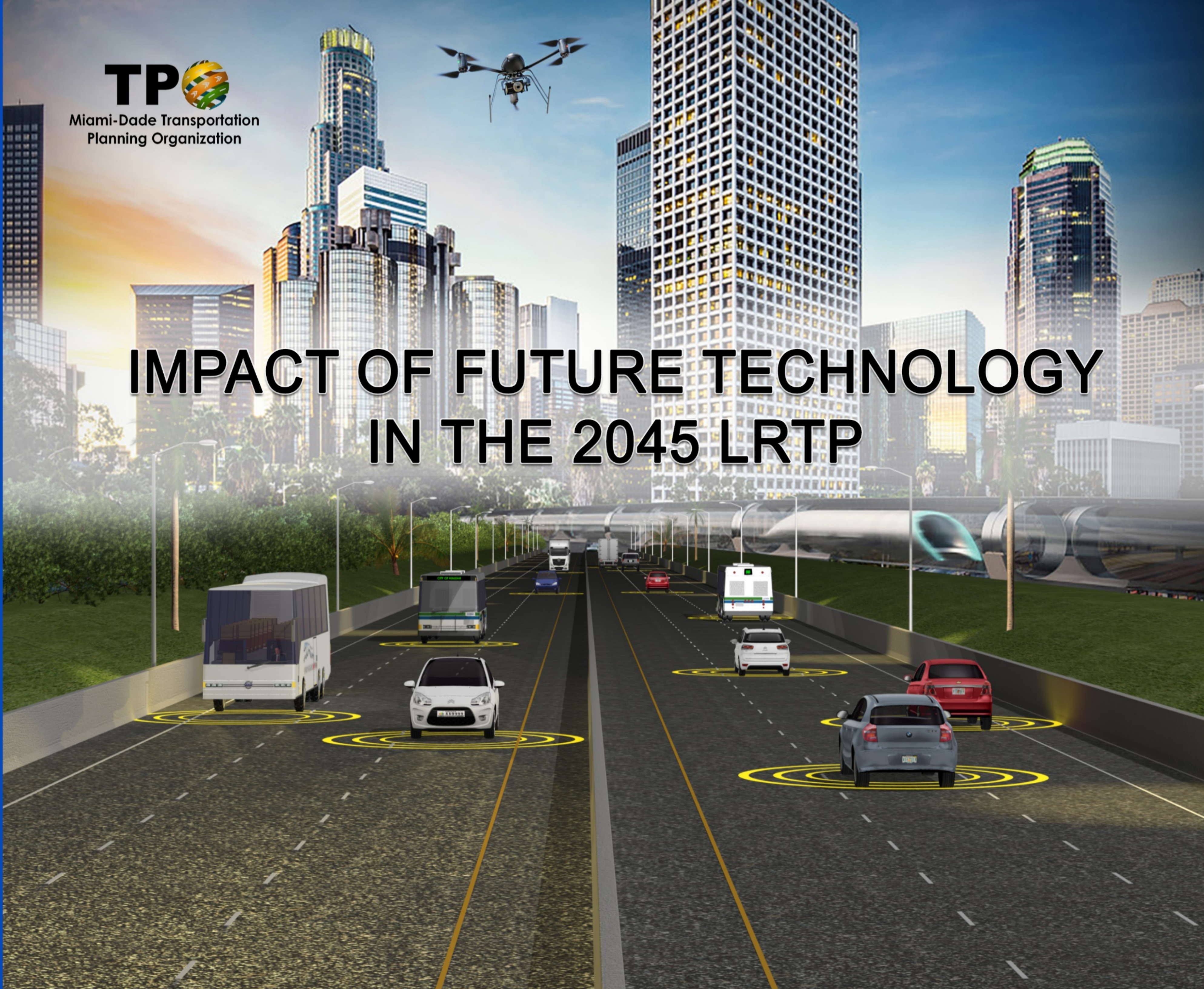
Miami-Dade Transportation Planning Organization

IMPACT OF FUTURE TECHNOLOGY IN THE 2045 LRTP



FINAL REPORT – June, 2017

THE CORRADINO GROUP

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Miami-Dade Transportation Planning Organization

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Summary

S.1 INTRODUCTION

The purpose of this project is to evaluate existing and future technologies that will impact and transform the transportation planning process. It will offer the steps to incorporate technologies in the 2045 Long Range Transportation Plan (LRTP). The project's deliverables address the question: ***"What will our community look like in 20–25 years?"***

Technology advancements are causing a shift in the way automotive vehicles are manufactured, as well as the way we will plan, design, and construct our infrastructure (roads, bridges, and transit systems) to accommodate them in the future. Traditional modes of transportation are being inundated with technology, and, as with everything else technology-driven, the future of transportation is evolving at a rapid pace with auto companies, alone, each spending billions of dollars each year. The limitations are, in fact, not technology, as much as the regulations to be put into place.

By adding computers, or on-board units (OBU), with Wi-Fi connections, sensors, cameras, and detectors, vehicles will: communicate, calculate, process data, optimize route planning, avoid crashes, and provide other driver-assist functions. As technology further evolves, vehicles will become fully autonomous. Eventually, the computers will perform all of these tasks simultaneously and as quick as, or quicker than the human brain. This will change the transportation infrastructure of the future.

The U.S. Department of Transportation issued on September 20, 2016, Federal policy for automated vehicles, laying a path for the safe testing and deployment of new auto technologies that have potential to improve safety and mobility on the road. The U.S. Transportation Department indicated: *"This policy is an unprecedented step by the federal government to harness the benefits of transformative technology by providing a framework for how to do it safely."*

S.2 LITERATURE REVIEW

This project goes beyond just driverless cars. The full list of categories for which a literature review was conducted, as part of **Task 2** is:

- **A.** Autonomous Vehicles (AV)/Connected Autonomous Vehicles (CAV)/Mobility
  - **A.1** Cars
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  - **A.5** Emergency vehicles
  - **A.6** Freight
  - **A.7** Marine
  - **A.8** Ridesharing
  - **A.9** Air
  - **A.10** Railroad
- **B.** Smart Cities
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- **E.** BRT (Bus Rapid Transit)
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- **G.** Energy
- **H.** 3D Printing
- **I.** Parking
- **J.** Bikes
- **K.** Drones
- **L.** IoT/Data Management
- **M.** Banking
- **N.** Rain Channels

- **O.** Electric Vehicles/Alternative Fuels
- **P.** Cost/Financing
- **Q.** Dashboards
- **R.** Traffic Control Systems
- **S.** Be in/Be Out
- **T.** ADAs (Adv. Driver Assist. Sys.)
- **U.** Traveler Information Systems
- **V.** Communication Technology

A *Glossary of Terms* is provided in **Appendix A**, included under separate cover.

In total, more than 200 sources were reviewed and 100+ abstracts prepared, a sample of which is provided in **Table S-1**. The abstracts are in **Appendix B**. Both appendices are included under separate cover. Each abstract includes the following information:

- Topic;
- Category (listed above);
- Date;
- Source;
- Abstract of literature;
- Potential for Pilot Project;
- Cost to implement;
- Cost implications.

Figure S-1 provides an example. This body of information was used to determine the technologies that are the most practicable so that Smart City solutions (**Task 3** of the work order), and elements of the 2045 LRTP can be developed (**Tasks 4 and 5**).

Table S-1: Sample of Literature Review Results

CATEGORY	SUB-CATEGORY	TOPIC	SOURCE
A. AV/CAV	A.1 Cars	1. Big Carmakers Merge, Cautiously, Into the Self-Driving Lane	http://www.nytimes.com/2016/09/02/automobiles/big-carmakers-merge-cautiously-into-the-self-driving-lane.html
A. AV/CAV	A.1 Cars	2. Surveys of Consumers about AV Ownership/Use	http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/TTI-2016-8.pdf http://newsroom.aaa.com/2016/03/three-quarters-of-americans-afraid-to-ride-in-a-self-driving-vehicle/
A. AV/CAV	A.1 Cars	3. "Autonomous Vehicle Implementation Predictions: Implications for Transport Planning"	www.vtpi.org/AVIP_TTI_Jan2014.pdf
A. AV/CAV	A.1 Cars	4. Autonomous Vehicle Technology—A Guide for Policy Makers	http://www.rand.org/pubs/research_reports/RR443-2.html
A. AV/CAV	A.1 Cars	5. Smart Mobility: Reducing Congestion and Fostering Faster, Greener, and Cheaper Transportation Options	http://dupress.com/articles/smart-mobility-trends/#sup-2
A. AV/CAV	A.1 Cars	6. INTELLIGENT TRANSPORTATION SYSTEMS Vehicle-to-Infrastructure (V2I) Technologies -- a V2I-equipped intersection	http://www.gao.gov/assets/680/672548.pdf
A. AV/CAV	A.1 Cars	7. AUTONOMOUS | SELF-DRIVING VEHICLES LEGISLATION ENABLED IN STATES	http://www.ncsl.org/research/transportation/autonomous-vehicles-legislation.aspx
A. AV/CAV	A.1 Cars	8. Federal Automated Vehicles Policy	https://www.transportation.gov/sites/dot.gov/files/docs/AV%20policy%20guidance%20PDF.pdf
A. AV/CAV	A.1 Cars	9. Dual-Mode Vehicle and Infrastructure Alternatives Analysis	http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/0-5827-1.pdf http://faculty.washington.edu/jbs/itrans/dualmode.htm http://www.overlandats.com/
A. AV/CAV	A.1 Cars	10. Cheap Lidar: The Key to Making Self-Driving Cars Affordable	http://spectrum.ieee.org/transportation/advanced-cars/cheap-lidar-the-key-to-making-selfdriving-cars-affordable
A. AV/CAV	A.1 Cars	11. Autonomous vehicles could cost America 5 million jobs.	http://www.latimes.com/opinion/op-ed/la-oe-greenhouse-driverless-job-loss-20160922-snap-story.html
A. AV/CAV	A.2 PoDs	12. MDC MPO Aerial Cable Transit Feasibility Study	http://miamidadetpo.org/library/studies/aerial-cable-transit-feasbility-study-final-report-2016-02.pdf
A. AV/CAV	A.2 PoDs	13. Maglev Pod Transit-skyTran	http://fortune.com/2015/11/24/skytran-maglev-pod-system-tel-aviv https://en.wikipedia.org/wiki/SkyTrann
A. AV/CAV	A.3 Transit	14. AV Transit in MDC	http://www.huffingtonpost.com/entry/ibm-local-motors-olli_us_5762975be4b05e4be860f03c
A. AV/CAV	A.3 Transit	15. Self-driving buses take to roads alongside commuter traffic in Helsinki	https://www.theguardian.com/technology/2016/aug/18/self-driving-buses-helsinki
A. AV/CAV	A.3 Transit	16. Forecast of How The IoT Will Affect Mass Transit	IoT - Examining How IoT Will Affect
A. AV/CAV	A.4 Car Sharing	17. Car giants see road to riches in sharing	https://www.yahoo.com/news/car-giants-see-road-riches-sharing-062326758.html

Source: The Corradino Group

Figure S-1: Example Abstract

Miami-Dade County TPO Technology Literature Summary Sheet

Topic: #28 The future of freight: More shipping, fewer emissions?

Category: Freight – Sea CATEGORY I// #82 on list

Author(s)/Sponsoring Agency: Nate Berg, *Green Biz*

Date: January 16, 2016

Source: https://www.greenbiz.com/article/future-freight-more-shipping-less-emissions
http://www.europarl.europa.eu/RegData/etudes/STUD/2015/569964/IPOL_STU(2015)569964_EN.pdf
http://www.worldshipping.org/about-the-industry/how-liner-shipping-works
http://www.worldshipping.org/about-the-industry/how-liner-shipping-works/the-step-by-step-process
https://www3.epa.gov/otaq/oceanvessels.htm

Abstract: Much of what we consume embarks on a seaborne journey from another part of the world. Ships handle roughly 90 percent of global trade, nearly 11 billion tons of goods per year. Maritime vessels and ports are only a part of the picture. Airlines, railroads, trucks, warehouses, refrigerators, delivery people — the international system of goods movement -- is integral to the way we live. It also is a huge source of opportunity to reduce humans' environmental footprint. International aviation and maritime transport are constantly growing despite considerable efficiency improvements. In 2012, both sectors together accounted for about 3% to 4% of global emissions (PDF). A recent report (PDF) from the European Parliament estimated that number could rise as high as 17 percent by 2050 due to growth of global transport demand and if the shipping industry does not keep pace with other economic sectors in addressing emissions.

Efficiency gains and developments in automation may have the biggest influence on how the environmental footprint of the global system of goods movement evolves in the coming years. Maritime ports are getting more automated. Ships essentially can plug into the ports where they dock, tapping into local power instead of idling their huge engines and burning hundreds of tons of fuel to sit still. Automated cranes can quickly unload and reload ships to reduce their time in port. And the same systems can quickly move those thousands of containers onto the trucks and trains that carry them to distant locations.

The issue of getting to/from the port is another dominant conversation in goods-movement. Companies, such as FedEx, are investing in hybrid or all-electric delivery vehicles.. Amazon is investigating delivery by battery-powered drones, which could reduce the reliance on traditional vehicles and their emissions. As the economic efficiency of shipping increases on sea and land, there will be more factories in more locations, with the parts and raw materials moving between them at lower cost and with more energy efficiency than today.

Potential for Pilot Project[1]

Near-term[2]: Ports and their "last-mile" infrastructure, like at the Port of Miami, must be modernized in order to match new and improved shipping processes.

Mid-term[3]: Once ports are modernized to handle these new and improved shipping processes, the industry will need to prepare to accommodate continued improvements in shipping technology.

Long-term[4]: Same as above.

Cost to Implement

Near-term: Port upgrades cost millions if not billions of dollars

Mid-term: Same as above

Long-term: Same as above

Cost Implications

Near-tern: It is expected that reduction in future costs will help make-up for initial spending

Mid-term: Same as above

Long-term: Long-term cost reductions will have far reaching impacts throughout the entire global economy.

1: Considered an on-the ground application; 2:2020-2025; 3: 2026-2035; 4:2036-2045

Source: The Corradino Group

S.3 EVALUATION

Over the next few decades, technology will continue to revolutionize our way of life. The phenomenon of connecting "everything" through technology is termed the "Internet of Things" or "IoT."

The key to planning for this future is to establish a network of technology infrastructure that is capable of supporting human needs. This network must be upgraded quickly and efficiently. With the infrastructure in place, any city, town, rural place, or area along any roadway/corridor can build out the Internet of Things. The impacts, the potential benefits, and the disruptive changes to everyday life as we know it, are just beginning.

By reviewing hundreds of sources of information, the consultant has been able to assess the potential to implement various technologies, from autonomous vehicles to Maglev/fast trains to fossil fuel energy alternatives. Two assessments of implementation potential have been conducted: 1); in various phases of the *LRTP* and, 2) for a *pilot/demonstration project*. **Table S-2** is an example of the evaluation form.

Table S-2: Sample Preliminary Evaluation of Technologies

CATEGORY	SUBCATEGORY	TOPIC	Possible in Pilot Program	Possible in 2045 LRTP		
				2020-2025	2026-2035	2036-2045
A. AV/CAV	A.1 Cars	1. Big Carmakers Merge, Cautiously, Into the Self-Driving Lane	◔	○	◔	◑
A. AV/CAV	A.1 Cars	2. Surveys of Consumers about AV Ownership/Use	◔	○	◔	◑
A. AV/CAV	A.1 Cars	3. "Autonomous Vehicle Implementation Predictions: Implications for Transport Planning"	◔	○	◔	◑
A. AV/CAV	A.1 Cars	4. Autonomous Vehicle Technology—A Guide for Policy Makers	◔	○	◔	◑
A. AV/CAV	A.1 Cars	5. Smart Mobility: Reducing Congestion and Fostering Faster, Greener, and Cheaper Transportation Options	◔	○	◔	◑
A. AV/CAV	A.1 Cars	6. INTELLIGENT TRANSPORTATION SYSTEMS Vehicle-to-Infrastructure (V2I) Technologies -- a V2I-equipped intersection	◔	○	◔	◑
A. AV/CAV	A.1 Cars	7. AUTONOMOUS | SELF-DRIVING VEHICLES LEGISLATION ENABLED IN STATES	●	○	◔	◑
A. AV/CAV	A.1 Cars	8. Federal Automated Vehicles Policy	●	●	●	●
A. AV/CAV	A.1 Cars	9. Dual-Mode Vehicle and Infrastructure Alternatives Analysis	○	○	○	○
A. AV/CAV	A.1 Cars	10. Cheap Lidar: The Key to Making Self-Driving Cars Affordable	◑	○	◑	●
A. AV/CAV	A.1 Cars	11. Autonomous vehicles could cost America 5 million jobs.	◔	◔	◑	●
A. AV/CAV	A.2 PoDs	12. MDC MPO Aerial Cable Transit Feasibility Study	◔	◔	◔	◑

LEGEND				
○ HIGHLY UNLIKELY	◔ POSSIBLE, BUT UNLIKELY	◑ POSSIBLE	◕ LIKELY	● HIGHLY LIKELY
○ HIGHLY UNLIKELY	◔ POSSIBLE, BUT UNLIKELY	◑ POSSIBLE	◕ LIKELY	● HIGHLY LIKELY

Source: The Corradino Group

S.4 ELEMENTS OF THE LRTP

The following are developments expected to occur in each of the following time periods.

THE PERIOD 2020–2025

- **Infrastructure** that is capable of supporting future technology needs;
- **Freight:** The Port of Miami will move further into the next generation IoT;
- **Transit:** Planning for BRT;
- **Logistics:** IoT devices that will save logistics businesses billions by helping move goods and assets through their supply chains and warehouses faster and more cheaply; and,
- **Smart Cities:** It is expected that progress will be made on all of these elements: Energy, Water, Waste, Transit (BIBO), Retailing, Utilities, Wellness/Healthcare, Banking, Buildings, and Manufacturing.

THE PERIOD 2026–2035

- **Autonomous Vehicles/Cars:** It is expected that the penetration of privately-owned AV cars will be about 25 percent during the period 2026–2035. This will cause some job losses in the transportation sector. Nonetheless, while AVs will have limited personal ownership, their impact cannot be ignored. Therefore, updating the Travel Demand Model suite, discussed in the full report, should begin as soon as possible.
- **Autonomous Vehicles/Buses:** It is possible that AV buses will have a significant place in MDC transit. The job impact here will be complicated by union relations/negotiations. In this area, there will be a need for increased skills, with higher pay, and, likely, increased numbers of maintenance personnel to service the new AV technology.
- **Autonomous Vehicles/Trucks:** The use of self-driving, heavy-duty trucks will be limited but growing during the period 2026–2035. Acceptance of AV trucks by the unions is an issue. So is the willingness of fleet owners to accept completely driverless vehicles—ones that are hands off the wheel as well as foot off the accelerator and brake. Rather, there is more of a focus on "semi-autonomous" truck capability, perhaps for short durations on the highway but more applicable in low-speed environments, such as at truck stops or at warehouse docks.
- **Autonomous Vehicles/Ambulances:** AV ambulances will still be considered experimental in 2026–2035 because fully autonomous ambulances will need to achieve the highest level of automation (Level 4) before allowing the EMT ambulance driver to assist the other EMT with patient care while the ambulance is in motion. On the other hand, there will be increased use of ambulance drones (or AirMules) by hospitals and, to a lesser degree, by government.
- **AV Infrastructure:** Vehicle-to-Infrastructure (V2I) technologies are not likely to be extensively deployed in the United States in the period 2026–2035 as existing infrastructure systems are replaced or upgraded.

- **AV Ridesharing vs. Car-sharing:** It is expected that ridesharing will widely expand in 2026–2035, much of which will be in autonomous vehicles. Uber expects its entire fleet will be fully autonomous by 2030. That, too, will have a job impact, albeit relatively small, both for Uber drivers and those in the taxi business.

- **Car-sharing** will be more limited than ridesharing. Still, it will place a number of AV cars on the road.

- **Electric Vehicles (EVs):** There are many limitations that prevent suddenly swapping out large numbers of current vehicles for electric ones. Not everybody has access to a charging station. Nonetheless, with the sale by General Motors of the Chevy Bolt at a reasonable price, and the federal commitment of $4.5 billion to support development and use of EVs, their presence will grow in the period 2026–2035.

- **Bus Rapid Transit:** The first of three new BRT lines is expected to be in operation during the 2026–2035 period.

- **Gondola:** An MDC TPO study examined a number of options for a gondola and concluded a 1.2-mile, two-station Marlins Park (Little Havana)-to-Downtown alignment was preferred. Nonetheless, it is not expected this will be part of the LRTP in the 2026–2035 timeframe.

- **Rail Freight:** By becoming more digitally focused by way of machine-to-machine communications and mobile devices, rail operations will accelerate the transformation to a more interconnected, transparent, and agile form between 2026 and 2035.

- **Marine Freight:** Automating a container terminal is expensive, so ports are holding off on buying into the technology until absolutely necessary. Even so, it is expected that the Port of Miami will, in the 2026–2035 period, begin to make the substantial investment needed in automated cranes and other robotics in order to continue its position as a leading world port.

- **Logistics:** Creating the optimum logistics system requires strong collaboration and investment by all segments of the supply chain. The MDC TPO should facilitate that participation/cooperation, beginning as soon as possible.

- **3D Printing:** 3D printing will begin to affect manufacturing and shipping in the 2026–2035 timeframe. Remote production overseas in lower-cost locations could be replaced by manufacturing facilities located at home closer to the consumer, allowing for a more responsive manufacturing process and greater quality control.

- **Drones:** Between 2026 and 2035, drone use will grow extending beyond aerial photography, real estate, various inspections, agriculture, and filmmaking, to department stores and food stores plus firefighting, search-and-rescue, and conservation.

- **Roadway Traveler Information Systems:** These systems, already widely in use, will continue to expand.

- **Traffic Management Technology:** By 2026, Miami-Dade County will be increasing the installation of pole-mounted wireless technologies (cameras, sensors of environmental conditions) to manage everything from traffic/pedestrian activities to flooding to ozone/pollution problems. The investment will need to be steady and significant.

- **Pedestrian Safety Technology:** MDC will advance in installing solar-powered in-road light systems which detect the presence of a pedestrian crossing or preparing to cross the street, plus safety reflectors which feature sensors, LED lights, wireless charging, and communications made to blink and alert vehicle drivers to pedestrian movements.

- **Bikes:** MDC has done extensive study and implementation of bicycle facilities and programs. It is expected to continue that work over the next generation to provide a truly multimodal transportation system.

- **Parking:** In the period 2026–2035, vehicle self-parking will be more prevalent. But its effects on parking facilities will have to wait until the number of AVs in the vehicle population reaches more than a majority.

- **Energy:** The smart grid is one of the most well-developed and widely recognized IoT systems. Smart grids rely on smart meters, which relay information about a system's energy usage to a central management system to efficiently allocate resources. In the period 2026–2035, MDC will push forward in this area of energy efficiency.

- **Solar Roadways:** While possible, it is unlikely that solar roadways will play a significant role in MDC by 2036. The technology is years away from being proven.

- **Energy from Road Friction:** This technology is not likely to be widely applicable for some time because it needs to be proven.

- **Smart Cities:** It is expected Smart Cities technologies that are expected to be engaged starting in the 2020–2025 period will be aggressively moving forward in the 2026–2035 period of the LRTP.

THE PERIOD 2036–2045

The key elements in this period will build upon the work of the two previous phases and will include in the LRTP the following. Details are elaborated upon in the full report.

- Autonomous Vehicles
  - ✓ Cars
  - ✓ Buses
  - ✓ Trucks
  - ✓ Emergency Equipment
- AV Infrastructure
  - ✓ Roadway Traveler Information Systems
- Electric Vehicles
- Bus Rapid Transit (BRT)
- Gondola
- Freight
  - ✓ Rail
  - ✓ Marine
- Logistics
- 3D Printing
- Drones
- Traffic Management Technology
- Pedestrian Facility Technology
- Bikes
- Parking
- Energy
- Solar Roadway
- Smart Cities
  - ✓ Environmental Conditions
  - ✓ Water
  - ✓ Waste
  - ✓ Transit
  - ✓ Wellness/Healthcare

  - ✓ Retailing
  - ✓ Utilities
  - ✓ Banking
  - ✓ Buildings
  - ✓ Manufacturing
- Digital Dashboards

A general overview of how these innovations mesh together can be seen by viewing:

https://vimeo.com/209590464
https://vimeo.com/209590865

S.5 PILOT PROJECT PROPOSAL

For purposes of this work, a pilot/demonstration project is proposed on a "Smart City" basis. The pilot is conceived as being conducted: 1) in a compact area, i.e., a smaller incorporated area of Miami-Dade County; 2) starting by 2020 and continuing for three to five years; and, 3) in cooperation with a local university already engaged in technology research.

IMPLEMENTATION

A comprehensive plan for the pilot project needs to be developed by all stakeholders—MDC and TPO, governments of the pilot project area, a local university, FDOT, private partners, and others. Once the plan is developed, private and public funding needs to be gathered. This includes the local government of the pilot project area, the MDC Commission, and FDOT. Eventually, once the pilot project demonstrates success, it should be presented as an attractive addition to the USDOT Smart City program.

Details are provided later in the main report.

S.6 SYSTEMS ARCHITECTURE

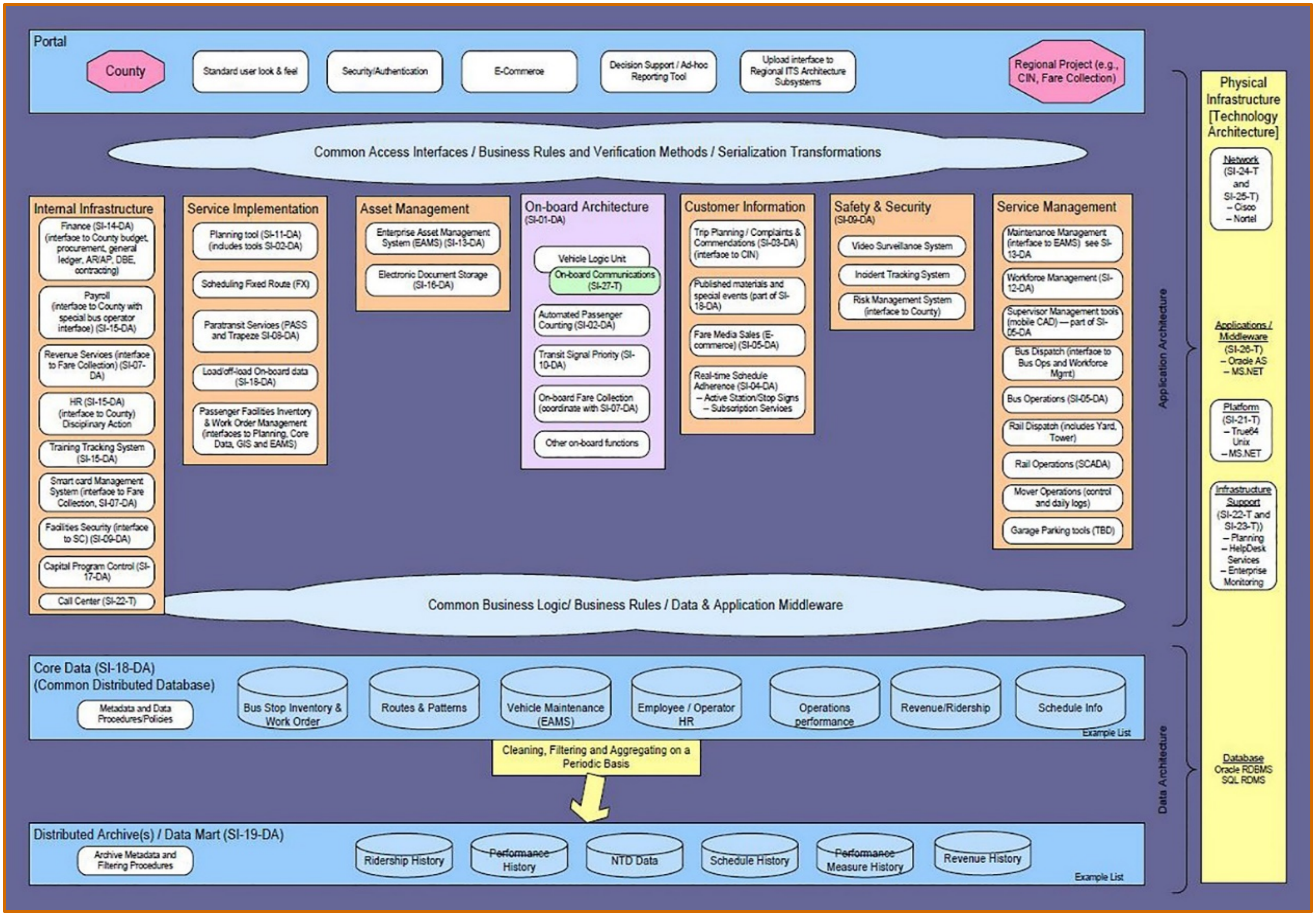
The chart on the next page illustrates the Miami-Dade County systems architecture for just one segment of the county's transportation operation—transit. There are equally intricate designs to manage roadway traffic, data/devices of all kinds, water and sewer information/facilities, and on and on. Therefore, to address the IoT architecture of the future takes a crystal ball, which is not available, at least not to this consultant. As a result, the approach to this task is to "borrow" examples of basic concepts developed by researchers/scientists at IBM, Symantec, The Reason Foundation, and Universities like Carnegie Mellon, Florida, and Michigan, to illustrate current thinking, which will quickly evolve as more technological developments become available.

It is noteworthy that Miami-Dade County's progress toward becoming an IoT SMART Community is aided by being the first municipality to launch an AT&T Smart Cities Operation Center. The program aims to give governments visibility into their communities' conditions using an integrated visualization dashboard placed in the County Mayor's office.

In Miami-Dade, AT&T is now working to apply solutions that address intelligent lighting and smart transportation as part of its Smart Cities initiative. In collaboration with its alliance member Hitachi, AT&T will soon be deploying public safety solutions, including:

- Remote monitoring and more efficient operations solutions for police and public safety officials;
- Upgrades to the county's existing infrastructure with smart LED lighting;
- Reliable data to help inform decision making around urban transportation planning; and,
- A traffic intersection network solution to help improve traffic flow.

Miami-Dade County Transit System IoT Architecture



Source: Miami-Dade County

S.7 DTPW AND ITS PARTNERS' EFFORTS RELATED TO SMART CITIES AND CAV TECHNOLOGIES

ONGOING EFFORTS

Following is a summary of the ongoing efforts at the Miami-Dade County Department of Transportation and Public Works (DTPW).

- Adaptive Signal Control Technology (ASCT) Deployment;
- Advanced Transit Management System and AV Technology;
- Smart Streetlighting;
- Mobile Apps:
  - ✓ MDT Tracker;
  - ✓ MDT Transit Watch;
  - ✓ Upgrade of DTPW's Fare Collection System and Infrastructure;
  - ✓ All-inclusive Trip Planner and Payment App;
  - ✓ On-Demand, Flexible Transit Program; and,
  - ✓ CIVIQ Mobility Experience (CME).
- Other ongoing projects/efforts include implementing:
  - ✓ PayByPhone, mobile parking payment applications for Metrorail parking garages and parking-and-ride facilities;
  - ✓ WAZE partnership for data exchange;
  - ✓ Bikesharing program for Metrorail stations and other transit facilities, dynamic carpooling application (RideFlag);
  - ✓ Sidewalk Labs' Smart Parking App to help drivers find available parking in real time through Google maps;
  - ✓ RideFlag/SFCS Partnership for dynamic carpooling app;
  - ✓ Reversible traffic flow lanes;
  - ✓ Transit Signal Priority for buses; and,
  - ✓ EV Infrastructure network plan to increase availability of charging stations across the county, particularly at transit facilities to increase access to transit.

FDOT AND MDX CAV-RELATED EFFORTS

- FDOT's Freight Signal Priority (FSP) pilot; and,
- MDX's SMART 836:
  - ✓ SMART 836 CV Technology Deployment;
  - ✓ V2I Mobility Applications Deployment;
  - ✓ DSRC-Based Application for Pavement Surface Analysis; and,
  - ✓ Bluetooth and Wi-Fi Readers Technology Deployment.

WHAT CAN BE SEEN/EXPECTED IN 2020 AND BEYOND

- Autonomous shared vehicle transportation services;
- Implementation of Mobility as a Service (MaaS); and,
- Mobility Platform.

S.8 IMPLEMENTATION

Beginning immediately, the TPO should update its Travel Demand Model, consistent with the proposal presented in this report. Likewise, research on funding mechanisms is key to developing a cost-affordable plan. New funding concepts should be explored, such as: Vehicle Mile Charge in place of fuel tax; Rental Car Passenger Facility Charge; Value Capture/Tax Increment Financing with tax districts around stations or along segments of the route. The TPO should engage a Study Advisory Committee with members from the public and private sectors to test/brainstorm the schedule/viability of items in the time periods for implementation. Then—with the LRTP consultant engaged—the full analysis will begin, including public involvement. Coordination with SMART Plan developments will be essential. New technology, and high-type transit, in combination with possible and significant land use changes will affect the future of the TPO region more than at any time in the past.

S.9 CONCLUSION

The “IoT Revolution” is changing the world faster than ever with impacts greater than past “economic” revolutions. Over the next few decades, technology will continue to revolutionize our way of life.

The transformations are, in many ways, unfathomable. Residential neighborhoods, public utilities, education, healthcare, manufacturing, and public safety will transform in ways that will change the entire world. Over the next 50 years, vehicles will no longer have a driver’s seat, steering wheel, or pedals. The shipping industry will become further automated and autonomous, where the need for drivers of semi-trucks, cargo ships, and trains could disappear.

The key to participating in the *Internet of Things* revolution is to establish a network of technology infrastructure that is capable of supporting human needs. This network must provide for the technology infrastructure to be upgraded quickly and efficiently. With the infrastructure in place, any city, town, rural place, or area along any roadway/corridor can build out the Internet of Things. The impacts, the potential benefits, and the disruptive changes to everyday life as we know it, are just beginning.

Miami-Dade County will be at the forefront of this technology revolution as will other world-class cities.

1. Purpose

The purpose of this project is to evaluate existing and future technologies that will inform and transform the transportation planning process. It offers steps to incorporate technologies in the 2045 Long Range Transportation Plan (LRTP). The project addresses the question: ***"What will our infrastructure and community look like in 20-25 years?"***

Technology advancements are causing a shift in the way automotive vehicles are manufactured, as well as the way we will plan, design, and construct our infrastructure (roads, bridges, and transit systems) to accommodate them in the future. Traditional modes of transportation are being inundated with technology, and, as with everything else technology-driven, the future of transportation is evolving at a rapid pace with auto companies, alone, each spending billions of dollars each year. The limitations are, in fact, not technology, as much as the regulations to be put into place.

By adding computers, or on-board units (OBU), with Wi-Fi connections, sensors, cameras, and detectors, vehicles will: communicate, calculate, process data, optimize route planning, avoid crashes, and provide other driver-assist functions. As technology further evolves, vehicles will become fully autonomous. Eventually, the computers will perform all of these tasks simultaneously and as quick as, or quicker than the human brain. This will change the transportation infrastructure of the future.

The U.S. Department of Transportation issued on September 20, 2016, Federal policy for automated vehicles, laying a path for the safe testing and deployment of new auto technologies that have potential to improve safety and mobility on the road. The U.S. Transportation Department indicated: *"This policy is an unprecedented step by the federal government to harness the benefits of transformative technology by providing a framework for how to do it safely."*

2. Results

2.1 LITERATURE REVIEW

This project goes beyond just driverless cars. The full list of categories for which a literature review was conducted, as part of **Task 2** is:

A. Autonomous Vehicles (AV)/Connected Autonomous Vehicles (CAV)/Mobility

- **A.1** Cars
- **A.2** PoDs
- **A.3** Transit
- **A.4** Car Sharing
- **A.5** Emergency vehicles
- **A.6** Freight
- **A.7** Marine
- **A.8** Ridesharing
- **A.9** Air
- **A.10** Railroad

B. Smart Cities
C. TDM (Travel Demand Modeling)
D. Maglev/Hyperloop

E. BRT (Bus Rapid Transit)
F. Solar
G. Energy
H. 3D Printing
I. Parking
J. Bikes
K. Drones
L. IoT/Data Management
M. Banking
N. Rain Channels
O. Electric Vehicles/Alternative Fuels
P. Cost/Financing
Q. Dashboards
R. Traffic Control Systems
S. Be in/Be Out
T. ADAs (Adv. Driver Assist. Sys.)
U. Traveler Information Systems
V. Communication Technology

A *Glossary of Terms* is provided in **Appendix A**, included under separate cover.

In total, more than 200 sources were reviewed and 100+ abstracts prepared (**Table 1**). The abstracts, in the order presented in Table 1, are in **Appendix B**, also included under separate cover. This body of information was used to determine which are the most practicable so that Smart City solutions (**Task 3** of the work order), and elements of the 2045 LRTP can be developed (**Tasks 4 and 5**).

Table 1: Literature Review Results

CATEGORY	SUB-CATEGORY	TOPIC	SOURCE
A. AV/CAV	A.1 Cars	1. Big Carmakers Merge, Cautiously, Into the Self-Driving Lane	http://www.nytimes.com/2016/09/02/automobiles/big-carmakers-merge-cautiously-into-the-self-driving-lane.html
A. AV/CAV	A.1 Cars	2. Surveys of Consumers about AV Ownership/Use	http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/TTI-2016-8.pdf http://newsroom.aaa.com/2016/03/three-quarters-of-americans-afraid-to-ride-in-a-self-driving-vehicle/
A. AV/CAV	A.1 Cars	3. "Autonomous Vehicle Implementation Predictions: Implications for Transport Planning"	www.vtpi.org/AVIP_TTI_Jan2014.pdf
A. AV/CAV	A.1 Cars	4. Autonomous Vehicle Technology—A Guide for Policy Makers	http://www.rand.org/pubs/research_reports/RR443-2.html
A. AV/CAV	A.1 Cars	5. Smart Mobility: Reducing Congestion and Fostering Faster, Greener, and Cheaper Transportation Options	http://dupress.com/articles/smart-mobility-trends/#sup-2
A. AV/CAV	A.1 Cars	6. INTELLIGENT TRANSPORTATION SYSTEMS Vehicle-to-Infrastructure (V2I) Technologies -- a V2I-equipped intersection	http://www.gao.gov/assets/680/672548.pdf
A. AV/CAV	A.1 Cars	7. AUTONOMOUS | SELF-DRIVING VEHICLES LEGISLATION ENABLED IN STATES	http://www.ncsl.org/research/transportation/autonomous-vehicles-legislation.aspx
A. AV/CAV	A.1 Cars	8. Federal Automated Vehicles Policy	https://www.transportation.gov/sites/dot.gov/files/docs/AV%20policy%20guidance%20PDF.pdf
A. AV/CAV	A.1 Cars	9. Dual-Mode Vehicle and Infrastructure Alternatives Analysis	http://d2dtl5nnlpfr0r.cloudfront.net/tti.tamu.edu/documents/0-5827-1.pdf http://faculty.washington.edu/jbs/itrans/dualmode.htm http://www.overlandats.com/
A. AV/CAV	A.1 Cars	10. Cheap Lidar: The Key to Making Self-Driving Cars Affordable	http://spectrum.ieee.org/transportation/advanced-cars/cheap-lidar-the-key-to-making-selfdriving-cars-affordable
A. AV/CAV	A.1 Cars	11. Autonomous vehicles could cost America 5 million jobs.	http://www.latimes.com/opinion/op-ed/la-oe-greenhouse-driverless-job-loss-20160922-snap-story.html
A. AV/CAV	A.2 PoDs	12. MDC MPO Aerial Cable Transit Feasibility Study	http://miamidadetpo.org/library/studies/aerial-cable-transit-feasbility-study-final-report-2016-02.pdf
A. AV/CAV	A.2 PoDs	13. Maglev Pod Transit-skyTran	http://fortune.com/2015/11/24/skytran-maglev-pod-system-tel-aviv https://en.wikipedia.org/wiki/SkyTrann
A. AV/CAV	A.3 Transit	14. AV Transit in MDC	http://www.huffingtonpost.com/entry/ibm-local-motors-olli_us_5762975be4b05e4be860f03c
A. AV/CAV	A.3 Transit	15. Self-driving buses take to roads alongside commuter traffic in Helsinki	https://www.theguardian.com/technology/2016/aug/18/self-driving-buses-helsinki
A. AV/CAV	A.3 Transit	16. Forecast of How The IoT Will Affect Mass Transit	PDF IoT - Examining How IoT Will Affect '
A. AV/CAV	A.4 Car Sharing	17. Car giants see road to riches in sharing	https://www.yahoo.com/news/car-giants-see-road-riches-sharing-062326758.html

Table 1: Literature Review Results (continued)

CATEGORY	SUB-CATEGORY	TOPIC	SOURCE
A. AV/CAV	A.4 Car Sharing	18. General Motors' Maven is all about car sharing, not ride sharing	https://www.cnet.com/roadshow/news/general-motors-maven-car-sharing/
A. AV/CAV	A.5 Emergency Vehicles	19. Driverless Technology and the Ambulance of the Future	http://www.fisdap.net/blog/driverless_technology_and_ambulance_future https://designmind.frogdesign.com/2015/11/the-future-of-autonomous-emergency-response/ http://www.express.co.uk/life-style/science-technology/568243/Driverless-NHS-Ambulances-Red-Light-Green-Newcastle http://www.autoblog.com/2016/09/12/google-autonomous-car-emergency-lights/ https://herox.com/news/189-the-evolution-of-uavs-the-ambulance-drone https://www.theguardian.com/technology/2016/jan/13/airmule-first-autonomous-ambulance-drone-takes-flight
A. AV/CAV	A.6 Freight	20. Daimler Tests Self-Driving Truck Platoon in Live	https://www.trucks.com/2016/03/21/daimler-tests-self-driving-truck-platoon-in-live-traffic/
A. AV/CAV	A.6 Freight	21. Autonomous Vehicles: What Fleets Want	http://www.alertdriving.com/home/fleet-alert-magazine/north-america/autonomous-vehicles-what-fleets-want
A. AV/CAV	A.6 Freight	22. Otto Moving with 'Urgency' to Introduce Autonomous Truck Tech and Uber Acquires Otto Self-Driving Truck Startup, Signs Volvo Deal	https://www.trucks.com/2016/08/16/otto-autonomous-truck-tech/ https://www.trucks.com/2016/08/18/uber-acquires-otto-self-driving-truck-startup/
A. AV/CAV	A.6 Freight	23. TRUCK DRIVER SHORTAGE ANALYSIS 2015	http://www.trucking.org/ATA%20Docs/News%20and%20Information/Re-ports%20Trends%20and%20Statistics/10%206%2015%20ATAs%20Driver%20Shortage%20Re-port%202015.pdf
A. AV/CAV	A.6 Freight	24. Forecast of How The IoT Will Affect Logistics	PDF IoT - Examining How IoT Will Affect '
A. AV/CAV	A.6 Freight	25. Could autonomous trucks be the next weapon for terrorists?	https://www.fueloyal.com/self-driving-trucks-tehnology-and-consequences/ http://www.cnbc.com/2016/07/21/could-autonomous-trucks-be-the-next-weapon-for-terrorists.html https://www.theguardian.com/technology/2015/sep/07/hackers-trick-self-driving-cars-lidar-sensor https://www.theguardian.com/technology/2016/mar/13/autonomous-cars-self-driving-hack-mikko-hypponen-sxsw http://www.autoinsurancecenter.com/top-20-pros-and-cons-associated-with-self-driving-cars.htm
A. AV/CAV	A.6 Freight	26. Shippers setting sail via Internet of (Floating) Things and Op-timizing Port Ecosystems with IoT Analytics	http://industrialinternetnow.com/shippers-setting-sail-via-internet-of-floating-things/ https://www.agtinternational.com/wp-content/uploads/2014/10/AGT_AAG_SmartPrt-2.pdf

Table 1: Literature Review Results (continued)

CATEGORY	SUB-CATEGORY	TOPIC	SOURCE
A. AV/CAV	A.6 Freight	27. The Future of Freight Transport and the Implications of Self-Driving Trucks	http://www.pennlease.com/2015/08/the-future-of-freight-transport-and-the-implications-of-self-driving-trucks/ https://www.thestreet.com/story/13177664/1/self-driving-trucks-to-revolutionize-industry-juice-us-economy.html http://www.dbschenkerusa.com/file/hoen/2199346/1PYoNJBRO5juVvLV36HUM-qPgJnI/7923390/data/Visions_of_the_Future_2030.pdf http://truckofthefuture.eu/ http://www.ccjdigital.com/future/ https://www.bloomberg.com/view/articles/2015-05-27/when-will-self-driving-trucks-destroy-america http://www.orionsystems.com/ http://www.orionsystems.com/solutions/fleet-solutions/
A. AV/CAV	A.6 Freight	28. The future of freight: More shipping, less emissions?	https://www.greenbiz.com/article/future-freight-more-shipping-less-emissions http://www.europarl.europa.eu/RegData/etudes/STUD/2015/569964/IPOL_STU(2015)569964_EN.pdf http://www.worldshipping.org/about-the-industry/how-liner-shipping-works http://www.worldshipping.org/about-the-industry/how-liner-shipping-works/the-step-by-step-process https://www3.epa.gov/otaq/oceanvessels.htm
A. AV/CAV	A.7 Marine	29. Supersize Ships Prompt More Automation at Ports and Massive Robots Keep Docks Shipshape	http://www.wsj.com/articles/supersize-ships-prompt-more-automation-at-ports-1459202549 http://www.wsj.com/articles/massive-robots-keep-docks-shipshape-1459104327
A. AV/CAV	A.7 Marine	30. Marine Port Technology and Emissions Reductions	https://en.wikipedia.org/wiki/Rubber_tyred_gantry_crane https://www.porttechnology.org/news/konecranes_launches_worlds_first_hybrid_reachstacker/ "Remote monitoring Konecranes-style, March 02, 2013"
A. AV/CAV	A.7 Marine	31. Forecast of How The IoT Will Affect Logistics – Tagging freight	IoT - Examining How IoT Will Affect ' http://www.dhl.com/content/dam/Local_Images/g0/New_aboutus/innovation/DHLTrendReport_Internet_of_things.Pdf
A. AV/CAV	A.8 Ride-sharing	32. General Motors/Lyft AV Taxis	http://www.wsj.com/articles/gm-lyft-to-test-self-driving-electric-taxis-1462460094
A. AV/CAV	A.8 Ride-sharing	33. Uber AV Taxi	http://www.bloomberg.com/news/features/2016-08-18/uber-s-first-self-driving-fleet-arrives-in-pittsburgh-this-month-is06r7on
A. AV/CAV	A.8 Ride-sharing	34. AV Taxi in Singapore	http://www.bbc.co.uk/news/business-37181956

Table 1: Literature Review Results (continued)

CATEGORY	SUB-CATEGORY	TOPIC	SOURCE
A. AV/CAV	A.9 Air	35. The Future of Air Cargo: How to Adapt	http://www.citylab.com/work/2014/10/a-complete-guide-to-the-future-of-us-freight-movement/381012/ http://www.inboundlogistics.com/cms/article/air-cargos-future-ready-for-anything/ http://aircargoworld.com/airfreight-has-bright-future-despite-technology-lag/ http://www.wsj.com/articles/are-drones-the-future-of-air-freight-1436468089 http://www.orionsystems.com/ http://www.orionsystems.com/solutions/fleet-solutions/
A. AV/CAV	A.10 Railroads	36. Think beyond the rails: Leading in 2025	http://www-935.ibm.com/industries/traveltransportation/think-beyond-the-rails.html http://www.progressiverailroading.com/ http://www.progressiverailroading.com/rail_industry_trends/article/Drones-mobility-and-more-Supplier-perspectives-on-next-level-rail-technology--49386
B. Smart Cities		37. Why Santa Monica Is a Smart City Trailblazer	http://www.ioti.com/smart-cities/why-santa-monica-smart-city-trailblazer
B. Smart Cities		38. Surveying Innovations Across City Systems— “Becoming Smart”	http://datasmart.ash.harvard.edu/news/article/the-urban-internet-of-things-727
B. Smart Cities		39. Surveying Innovations Across City Systems—Some Challenges	http://datasmart.ash.harvard.edu/news/article/the-urban-internet-of-things-727
C. TDM (Travel Demand Modeling)		40. "Using an Activity-Based Model to Explore Possible Impacts of Automated Vehicles"	https://www.google.com/webhp?sourceid=chrome-instant&ion=1&espv=2&ie=UTF-8#q=29.+Using+an+Activity-Based+Model+to+Explore+Possible+Impacts+of+Automated+Vehicles%E2%80%9D
C. TDM (Travel Demand Modeling)		41. "Modeling Autonomous Vehicles"	http://www.fsutmsonline.net/images/uploads/mtf-files/Modeling_Autonomous_Vehicles_by_Jerry_Graham_and_Dan_Macmurphy.pdf
C. TDM (Travel Demand Modeling)		42. "Effects of Next-Generation Vehicles on Travel Demand and Highway Capacity"	www.fehrandpeers.com/fpthink/nextgenerationvehicles/
D. Maglev/ Hyperloop		43. Hyperloop	http://www.usatoday.com/story/tech/news/2016/05/09/la-sf-30-min-hyperloop-wars/84137224/ http://www.usatoday.com/story/tech/news/2016/06/25/hyperloop-may-be-transportation-leap-too-far/86284444/
D. Maglev/ Hyperloop		44. Maglev in Other Countries	http://usa.chinadaily.com.cn/epaper/2014-02/19/content_17291903.htm http://www.koreatimes.co.kr/www/news/nation/2016/02/116_197061.html http://www.digitaltrends.com/cool-tech/hyperloop-india/#ixzz4HVgrAtku
D. Maglev/ Hyperloop		45. Dallas to Houston High Speed Rail	http://www.yourhoustonnews.com/pasadena/news/multi-billion-dollar-bullet-train-connecting-houston-to-dallas-expected/article_df2448e8-30a3-11e6-91e3-837610fb3cb6.html

Table 1: Literature Review Results (continued)

CATEGORY	SUB-CATEGORY	TOPIC	SOURCE
D. Maglev/ Hyperloop		46. Maglev in U.S.	http://www.californiaprogressreport.com/site/conventional-high-speed-rail-vs-magnetically-levitated-trains-was-maglev-ever-contention http://ilikemike.me/report-orlando-maglev-train-dead/ http://www.maglev2000.com/assets/FRAsum.pdf http://northeastmaglev.com/about-tnem http://www.miamidade.gov/transit/corridor-plans.asp http://www.miamidade.gov/transit/library/mpo-douglasroad-transit-corridor.pdf
D. Maglev/ Hyperloop		47. Fast Trains Outside the U.S.	http://www.railway-technology.com/projects/arlanda/ http://www.fluor.com/projects/high-speed-rail-line-design-build
E. BRT (Bus Rapid Transit)		48. US 36 Bus Rapid Transit, CO	http://www.riderta.com/healthline/about
E. BRT (Bus Rapid Transit)		49. Cape Town, South Africa BRT (BRT)	http://www.rtd-fastracks.com/us36_1
E. BRT (Bus Rapid Transit)		50. Healthline serving the Euclid Corridor	http://www.riderta.com/healthline/about
F. Solar		51. Solar Roadways – Missouri DOT Pilot Project on Route 66	http://www.upworthy.com/one-of-americas-most-famous-highways-is-about-to-become-an-awesome-science-experiment http://www.solarroadways.com/ http://www.ky3.com/content/news/Solar-pilot-project-could-pave-way-to-roadways-of-the-future-383470771.html http://www.riverfronttimes.com/newsblog/2016/06/27/route-66-will-get-a-dose-of-solar-power-in-southwest-missouri https://www.youtube.com/watch?v=qlTA3rnpgzU https://www.youtube.com/watch?v=YQba3ENhlKA
F. Solar		52. Solar Energy Present and Future	http://energy.gov/eere/sunshot/photovoltaics-research-and-development https://books.askvenkat.com/2013/01/wireless-power-transmission-via-solar.html http://www.sciencealert.com/engineers-just-created-the-most-efficient-solar-cells-everver http://www.sciencealert.com/india-says-the-cost-of-solar-power-is-now-cheaper-than-coal http://www.sciencealert.com/world-s-largest-solar-power-station-planned-for-india http://www.sciencealert.com/india-establishes-world-s-first-100-percent-solar-powered-airport

Table 1: Literature Review Results (continued)

CATEGORY	SUB-CATEGORY	TOPIC	SOURCE
G. Energy		53. Energy	http://www.eia.gov/Energyexplained/?page=us_energy_transportation https://www.eia.gov/electricity/state/florida/index.cfm http://www.miamidade.gov/green/energy.asp http://www.fsec.ucf.edu/en/consumer/solar_electricity/rebates.htm http://www.caranddriver.com/features/how-tesla-and-elon-musk-are-building-an-ev-infrastructure-feature http://www.solarroadways.com/ http://www.fhwa.dot.gov/environment/climate_change/mitigation/publications/row/index.cfm http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_TPK/FDOT-BDV24-977-01-rpt.pdf
H. 3D Printing		54. The Future Impact of 3D Printing on the Freight Transportation Industry and Retailers	https://blog.integracore.com/freight/the-future-impact-of-3d-printing-on-the-transportation-industry/ http://www.strategy-business.com/article/00219?pg=all https://3dprint.com/119885/wake-forest-3d-printed-tissue/
I. Parking		55. How Driverless Cars Spell the End of Parking as We Know It	http://www.pcmag.com/commentary/346952/how-driverless-cars-spell-the-end-of-parking-as-we-know-it http://auto.howstuffworks.com/car-driving-safety/safety-regulatory-devices/self-parking-car.htm http://www.treehugger.com/cars/tesla-showcases-3-self-driving-features-summon-autopilot-and-autopark-video.html
J. Bikes		56. Bikes	https://en.wikipedia.org/wiki/Bicycle-sharing_system http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.599.5656&rep=rep1&type=pdf http://miamidadetpo.org/library/studies/rail-convertibility-study-final-2004-11.pdf http://miamidadetpo.org/library/studies/csx-corridor-evaluation-study-final-2009-08.pdf
K. Drones		57. FAA Expects 600,000 Commercial Drones in the Air (by 2017)	http://www.npr.org/sections/thetwo-way/2016/08/29/491818988/faa-expects-600-000-commercial-drones-in-the-air-within-a-year
K. Drones		58. Drone Use for Transportation Purposes	http://www.michigan.gov/mdot/0,4616,7-151-9622_11045_24249_52176-353767--,00.html
L. IoT/Data Management		59. What is the Internet of Things (IoT)?	http://www.businessinsider.com/what-is-the-internet-of-things-definition-2016-8?IR=T
L. IoT/Data Management		60. Internet of Things in Healthcare: Information Technology in Health	http://www.businessinsider.com/internet-of-things-in-healthcare-2016-8
L. IoT/Data Management		61. IoT Forecast: Examining How The IoT Will Affect The World	PDF IoT - Examining How IoT Will Affect '

Table 1: Literature Review Results (continued)

CATEGORY	SUB-CATEGORY	TOPIC	SOURCE
L. IoT/Data Management		62. Forecast of How The IoT Will Affect Healthcare	IoT - Examining How IoT Will Affect '
L. IoT/Data Management		63. Forecast of How The IoT Will Affect Infrastructure	IoT - Examining How IoT Will Affect '
L. IoT/Data Management		64. Forecast of How The IoT Will Affect Manufacturing	IoT - Examining How IoT Will Affect '
L. IoT/Data Management		65. Forecast of How The IoT Will Affect Buildings	IoT - Examining How IoT Will Affect '
L. IoT/Data Management		66. Forecast of How The IoT Will Affect Utilities	IoT - Examining How IoT Will Affect '
L. IoT/Data Management		67. Forecast of How The IoT Will Affect Retailing	IoT - Examining How IoT Will Affect '
L. IoT/Data Management		68. Safeguarding the Internet of Things: Being secure, vigilant, and resilient in the connected age	http://dupress.deloitte.com/dup-us-en/deloitte-review/issue-17/internet-of-things-data-security-and-privacy.html
L. IoT/Data Management		69. Securing the Internet of Things (IoT)	http://hpe-enterpriseforward.com/eiu-securing-iot/ http://www.ctiasupermobility2016.com/events/eventdetails.cfm/2856 http://hpe-enterpriseforward.com/risks-dont-take-secrets-secured-environment/ http://www.computerweekly.com/opinion/How-to-mitigate-security-risks-associated-with-IoT https://erm.ncsu.edu/library/article/risk-management-in-the-internet-of-things
L. IoT/Data Management		70. Managing Risk for the Internet of Things (IoT)	160217_Lewis_ManagingRiskIoT_Web_I
L. IoT/Data Management		71. IoT in Wellness/Healthcare	http://www.dhl.com/content/dam/Local_Images/g0/New_aboutus/innovation/DHLTrendReport_Internet_of_things.pdf

Table 1: Literature Review Results (continued)

CATEGORY	SUB-CATEGORY	TOPIC	SOURCE
L. IoT/Data Management		72. Clustered regularly interspaced short palindromic repeats (CRISPR)	https://www.sciencenews.org/article/crispr-inspires-new-tricks-edit-genes
M. Banking		73. Automation of Banking	http://www.americanbanker.com/issues/179_21/community-banks-opening-up-to-closing-branches-1065326-1.html http://www.digitaltrends.com/mobile/square-vs-intuit-gopayment-vs-paypal-here-mobile-credit-card-processors/
M. Banking		74. Forecast of How The IoT Will Affect Banking	IoT - Examining How IoT Will Affect '
N. Rain Channels		75. Rain Channels Double as Roadways	http://ask.metafilter.com/225360/Where-do-I-go-to-drive-through-the-LA-River-andOr-Glendale-Narrows https://www.kcet.org/confluence/whats-taking-los-angeles-river-revitalization-so-long
O. Electric Vehicles/Alternative Fuels		76. 87 percent of drivers could switch to electric car with little hassle	http://www.newser.com/story/229799/87-of-drivers-could-switch-to-electric-car-with-little-hassle.html
O. Electric Vehicles/Alternative Fuels		77. Growing momentum for electric cars	http://www.dw.com/en/growing-momentum-for-electric-cars/a-19447582
O. Electric Vehicles/Alternative Fuels		78. NanoFlowcell thinks you'd rather refuel your battery, instead of recharging	http://www.autoblog.com/2016/08/02/nanoflowcell-refuel-battery-charging/
O. Electric Vehicles/Alternative Fuels		79. Obama's plan to line the country's roads with electric vehicle chargers	https://www.washingtonpost.com/news/energy-environment/wp/2016/07/21/this-is-obamas-plan-to-fill-the-countrys-roads-with-electric-vehicle-chargers/?tid=a_inl&utm_term=.fe8b33d5691d
O. Electric Vehicles/Alternative Fuels		80. Power from the Friction Contact of the Road	http://www.popsci.com/new-goodyear-tires-could-help-power-your-car
O. Electric Vehicles/Alternative Fuels		81. Tokyo Hopes to Make Hydrogen Power the Star of the 2020 Olympics	http://www.wsj.com/articles/tokyo-hopes-to-make-hydrogen-power-the-star-of-the-2020-olympics-1442174267
O. Electric Vehicles/Alternative Fuels		82. China's Electric Car production	http://fortune.com/2016/09/07/vw-electric-car-venture-jac-motor/

Table 1: Literature Review Results (continued)

CATEGORY	SUB-CATEGORY	TOPIC	SOURCE
O. Electric Vehicles/Alternative Fuels		83. The Increased power of electric cars and buses	http://www.freep.com/story/money/cars/mark-phelan/2016/09/13/chevrolet-bolt-electric-cars-main-stream-tesla-nissan-leaf-toyota-prius/90108614/ http://insideevs.com/proterra-catalyst-e2-bus-debuts-travels-600-miles-charge/
P. Cost/ Financing		84. Oregon tries taxing drivers by the mile	http://thehill.com/policy/transportation/243610-oregon-to-tax-drivers-by-the-mile-for-roads https://www.oregon.gov/ODOT/HWY/RUFPP/docs/RUCPP%20Final%20Report%20-%20May%202014.pdf
P. Cost/ Financing		85 Alternatives to the VMT transportation taxing system	https://www.oregon.gov/ODOT/HWY/RUFPP/docs/RUCPP%20Final%20Report%20-%20May%202014.pdf
P. Cost/ Financing		86. “On the Move: State Strategies for 21st Century Transportation Solutions"	http://www.ncsl.org/research/transportati on/state-so1utions-for-21st-century-transportation
P. Cost/ Financing		87. State and Local Funding	http://www.dot.state.fl.us/officeofcomptroller/pdf/GAO/RevManagement/Tax%20Primer.pdf http://edr.state.fl.us/Content/local-government/reports/lgfih15.pdf
P. Cost/ Financing		88. Federal Funding	https://www.fhwa.dot.gov/policy/olsp/financingfederalaid/fund.cfm https://www.cbo.gov/sites/default/files/51300-2016-03-HighwayTrustFund.pdf
Q. Dashboards		89. Dashboards	https://en.wikipedia.org/wiki/Dashboard
R. Traffic Control Systems		90. The Economic and Societal Impact of Motor Vehicle Crashes, 2010 (Revised)	https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812013
R. Traffic Control Systems		91. Safety reflector for pedestrians gets connected to IoT C151	http://www.smart2zero.com/news/safety-reflector-pedestrians-gets-connected-iot
R. Traffic Control Systems		92. Solar Pedestrian Crossings	https://www.google.com/webhp?sourceid=chrome-instant&ion=1&espv=2&ie=UTF-8#q=solar%20pedestrian%20crossing%20pavement
R. Traffic Control Systems		93. Smart IP Cameras Can Read Traffic, Identify Pedestrians	http://www.intelfreepress.com/news/smart-ip-traffic-cameras/8915/
R. Traffic Control Systems		94. Chicago deploys computers with eyes, ears and noses	http://www.computerworld.com/article/3115224/internet-of-things/chicago-deploys-computers-with-eyes-ears-and-noses.html
S. BIBO/One Inclusive App		95. Integrated Transit Mobility Application	https://charliecard.mbta.com https://www.taptogo.net https://transitstore.miamidade.gov http://www.miamidade.gov/transit/easy-card.asp https://smartrip.wmata.com/storefront
S. BIBO/One Inclusive App		96. Ticketless Transit	https://www.virgin.com/travel/ticketless-transit-getting-around-the-city-with-just-your-phone http://www.passengertransport.co.uk/2016/02/cubics-multi-modal-check-in-be-out-trial/

Table 1: Literature Review Results (continued)

CATEGORY	SUB-CATEGORY	TOPIC	SOURCE
S. BIBO/One Inclusive App		97. Be-In/Be-Out Systems (BIBO)	http://www.thelocal.ch/20160229/sbb-caves-in-over-rail-pass-customer-data http://www.thelocal.ch/20160307/swiss-trains-pilot-ticketless-fare-system http://webarchive.nationalarchives.gov.uk/20091203214536/http:/www.dft.gov.uk/pgr/scienceresearch/orresearch/paymentsystems.pdf http://www.mobility.siemens.com/mobility/global/en/integrated-Mobility/eticketing/pages/eticketing.aspx#BiBo_System_20_Be_in_Be_out_
T. ADAs		98. Advanced Driver Assistance System (ADS) for Buses	https://en.wikipedia.org/wiki/Advanced_driver_assistance_systems
U. Traveler Information Systems		99. What Are Highway Traveler Information Systems	https://mobility.tamu.edu/mip/strategies-pdfs/traffic-management/executive-summary/traveler-information-systems-1-pg.pdf
U. Traveler Information Systems		100. What Traveler Information Systems Do	https://en.wikipedia.org/wiki/Advanced_traveller_information_system https://www.waze.com/ http://www.tomtom.com/en_us/
V. Communication Technology		101. "Nextdoor," the social network designed specifically for neighborhoods	http://mashable.com/2013/08/21/nextdoor-android-app/#o27zXQHwvmqp http://well.blogs.nytimes.com/2015/10/13/meet-the-neighbors-theres-an-app-for-that/?_r=1

2.2 TASK 3: EVALUATION

The evolution of modern technology is changing the world faster than ever with impacts greater than the 1st Industrial Revolution (1760–1840) and 2nd Industrial Revolution of the late 19th and early 20th centuries.

Over the next few decades, technology will continue to revolutionize our way of life. The phenomenon of connecting "everything" through technology is termed "the Internet of Things" or "IoT."

The technological revolution we are currently experiencing will accelerate over the next several decades, and the transformations are, in many ways, unfathomable. Residential neighborhoods, public utilities, education, healthcare, manufacturing, and public safety will transform in ways that will change the entire world. Over the next 50 years, vehicles will no longer have a driver's seat, steering wheel, or pedals. The shipping industry will become further automated and autonomous, where the need for drivers of semi-trucks, cargo ships, and trains will likely disappear.

The key to participating in the *Internet of Things* revolution is to establish a network of technology infrastructure that is capable of supporting human needs. This network must provide for the technology infrastructure to be upgraded quickly and efficiently. With the infrastructure in place, any city, town, rural place, or area along any roadway/corridor can build the Internet of Things. The impacts, the potential benefits, and the disruptive changes to everyday life, as we know it, are just beginning.

By reviewing hundreds of sources of information, the consultant has been able to assess the potential to implement various technologies, from the use of autonomous vehicles to Maglev/fast trains to fossil fuel energy alternatives. Two assessments of implementation potential have been conducted: 1); in various phases of the *LRTP* and, 2) for a *pilot/demonstration project* (**Table 2**).

Table 2: Preliminary Evaluation of Technologies

CATEGORY	SUBCATEGORY	TOPIC	Possible in Pilot Program	Possible in 2045 LRTP		
				2020-2025	2026-2035	2036-2045
A. AV/CAV	A.1 Cars	1. Big Carmakers Merge, Cautiously, Into the Self-Driving Lane	Possible, but unlikely	Highly unlikely	Possible, but unlikely	Possible
A. AV/CAV	A.1 Cars	2. Surveys of Consumers about AV Ownership/Use	Possible, but unlikely	Highly unlikely	Possible, but unlikely	Possible
A. AV/CAV	A.1 Cars	3. "Autonomous Vehicle Implementation Predictions: Implications for Transport Planning"	Possible, but unlikely	Highly unlikely	Possible, but unlikely	Possible
A. AV/CAV	A.1 Cars	4. Autonomous Vehicle Technology—A Guide for Policy Makers	Possible, but unlikely	Highly unlikely	Possible, but unlikely	Possible
A. AV/CAV	A.1 Cars	5. Smart Mobility: Reducing Congestion and Fostering Faster, Greener, and Cheaper Transportation Options	Possible, but unlikely	Highly unlikely	Possible, but unlikely	Possible
A. AV/CAV	A.1 Cars	6. INTELLIGENT TRANSPORTATION SYSTEMS Vehicle-to-Infrastructure (V2I) Technologies -- a V2I-equipped intersection	Possible, but unlikely	Highly unlikely	Possible, but unlikely	Possible
A. AV/CAV	A.1 Cars	7. AUTONOMOUS | SELF-DRIVING VEHICLES LEGISLATION ENABLED IN STATES	Highly likely	Highly unlikely	Possible, but unlikely	Possible
A. AV/CAV	A.1 Cars	8. Federal Automated Vehicles Policy	Highly likely	Highly likely	Highly likely	Highly likely
A. AV/CAV	A.1 Cars	9. Dual-Mode Vehicle and Infrastructure Alternatives Analysis	Highly unlikely	Highly unlikely	Highly unlikely	Highly unlikely
A. AV/CAV	A.1 Cars	10. Cheap Lidar: The Key to Making Self-Driving Cars Affordable	Possible	Highly unlikely	Possible	Highly likely
A. AV/CAV	A.1 Cars	11. Autonomous vehicles could cost America 5 million jobs.	Possible, but unlikely	Possible, but unlikely	Possible	Highly likely
A. AV/CAV	A.2 PoDs	12. MDC MPO Aerial Cable Transit Feasibility Study	Possible, but unlikely	Possible, but unlikely	Possible, but unlikely	Possible

LEGEND				
HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY	POSSIBLE	LIKELY	HIGHLY LIKELY
HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY	POSSIBLE	LIKELY	HIGHLY LIKELY

Table 2: Preliminary Evaluation of Technologies (continued)

CATEGORY	SUBCATEGORY	TOPIC	Possible in Pilot Program	Possible in 2045 LRTP 2020-2025	2026-2035	2036-2045
A. AV/CAV	A.2 PoDs	13. Maglev Pod Transit-skyTran	○	○	○	◔
A. AV/CAV	A.3 Transit	14. AV Transit in MDC	●	◔	◑	●
A. AV/CAV	A.3 Transit	15. Self-driving buses take to roads alongside commuter traffic in Helsinki	●	◔	◑	●
A. AV/CAV	A.3 Transit	16. Forecast of How The IoT Will Affect Mass Transit	●	●	●	●
A. AV/CAV	A.4 Car Sharing	17. Car giants see road to riches in sharing	●	◔	◑	◕
A. AV/CAV	A.4 Car Sharing	18. General Motors' Maven is all about car sharing, not ride sharing	●	◔	◑	◕
A. AV/CAV	A.5 Emergency Vehicles	19. Driverless Technology and the Ambulance of the Future	◔	○	◔	◕
A. AV/CAV	A.6 Freight	20. Daimler Tests Self-Driving Truck Platoon in Live	◔	○	◔	◕
A. AV/CAV	A.6 Freight	21. Autonomous Vehicles: What Fleets Want	◔	○	◔	◕
A. AV/CAV	A.6 Freight	22. Otto Moving with 'Urgency' to Introduce Autonomous Truck Tech and Uber Acquires Otto Self-Driving Truck Startup, Signs Volvo Deal	◔	○	◔	◕
A. AV/CAV	A.6 Freight	23. TRUCK DRIVER SHORTAGE ANALYSIS 2015	N/A	N/A	N/A	N/A
A. AV/CAV	A.6 Freight	24. Forecast of How The IoT Will Affect Logistics	●	●	●	●

LEGEND				
○ HIGHLY UNLIKELY	◔ POSSIBLE, BUT UNLIKELY	◑ POSSIBLE	◕ LIKELY	● HIGHLY LIKELY
○ HIGHLY UNLIKELY	◔ POSSIBLE, BUT UNLIKELY	◑ POSSIBLE	◕ LIKELY	● HIGHLY LIKELY

Table 2: Preliminary Evaluation of Technologies (continued)

CATEGORY	SUBCATEGORY	TOPIC	Possible in Pilot Program	Possible in 2045 LRTP		
				2020-2025	2026-2035	2036-2045
A. AV/CAV	A.6 Freight	25. Could autonomous trucks be the next weapon for terrorists?	N/A	N/A	N/A	N/A
A. AV/CAV	A.6 Freight	26. Shippers setting sail via Internet of (Floating) Things and Optimizing Port Ecosystems with IoT Analytics	Possible	Highly Unlikely	Possible, but unlikely	Likely
A. AV/CAV	A.6 Freight	27. The Future of Freight Transport and the Implications of Self-Driving Trucks	Possible	Possible	Possible	Highly Likely
A. AV/CAV	A.6 Freight	28. The future of freight: More shipping, less emissions?	Possible	Possible, but unlikely	Possible	Highly Likely
A. AV/CAV	A.7 Marine	29. Supersize Ships Prompt More Automation at Ports and Massive Robots Keep Docks Shipshape	Possible	Possible	Likely	Highly Likely
A. AV/CAV	A.7 Marine	30. Marine Port Technology and Emissions Reductions	Possible	Possible	Likely	Highly Likely
A. AV/CAV	A.7 Marine	31. Forecast of How The IoT Will Affect Logistics -- Tagging freight	Likely	Likely	Highly Likely	Highly Likely
A. AV/CAV	A.8 Ridesharing	32. General Motors/Lyft AV Taxis	Possible	Possible	Likely	Highly Likely
A. AV/CAV	A.8 Ridesharing	33. Uber AV Taxi	Possible	Possible	Likely	Highly Likely
A. AV/CAV	A.8 Ridesharing	34. AV Taxi in Singapore	Possible	Possible	Likely	Highly Likely
A. AV/CAV	A.9 Air	35. The Future of Air Cargo: How to Adapt	Possible	Possible	Highly Likely	Highly Likely
A. AV/CAV	A.10 Railroads	36. Think beyond the rails: Leading in 2025	Possible, but unlikely	Highly Unlikely	Possible, but unlikely	Possible

LEGEND				
HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY	POSSIBLE	LIKELY	HIGHLY LIKELY
HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY	POSSIBLE	LIKELY	HIGHLY LIKELY

Table 2: Preliminary Evaluation of Technologies (continued)

CATEGORY	SUBCATEGORY	TOPIC	Possible in Pilot Program	Possible in 2045 LRTP 2020-2025	2026-2035	2036-2045
B. Smart Cities		37. Why Santa Monica Is a Smart City Trailblazer	POSSIBLE	POSSIBLE, BUT UNLIKELY	LIKELY	HIGHLY LIKELY
B. Smart Cities		38. Surveying Innovations Across City Systems— "Becoming Smart"	POSSIBLE	POSSIBLE, BUT UNLIKELY	POSSIBLE	LIKELY
B. Smart Cities		39. Surveying Innovations Across City Systems—Some Challenges	POSSIBLE	POSSIBLE, BUT UNLIKELY	POSSIBLE	LIKELY
C. TDM (Travel Demand Modeling)		40. "Using an Activity-Based Model to Explore Possible Impacts of Automated Vehicles"	HIGHLY LIKELY	HIGHLY LIKELY	HIGHLY LIKELY	HIGHLY LIKELY
C. TDM (Travel Demand Modeling)		41. "Modeling Autonomous Vehicles"	HIGHLY LIKELY	HIGHLY LIKELY	HIGHLY LIKELY	HIGHLY LIKELY
C. TDM (Travel Demand Modeling)		42. "Effects of Next-Generation Vehicles on Travel Demand and Highway Capacity"	HIGHLY LIKELY	HIGHLY LIKELY	HIGHLY LIKELY	HIGHLY LIKELY
D. Maglev/Hyperloop		43. Hyperloop	HIGHLY UNLIKELY	HIGHLY UNLIKELY	HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY
D. Maglev/Hyperloop		44. Maglev in Other Countries	HIGHLY UNLIKELY	HIGHLY UNLIKELY	HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY
D. Maglev/Hyperloop		45. Dallas to Houston High Speed Rail	HIGHLY UNLIKELY	HIGHLY UNLIKELY	HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY
D. Maglev/Hyperloop		46. Maglev in U.S.	HIGHLY UNLIKELY	HIGHLY UNLIKELY	HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY
D. Maglev/Hyperloop		47. Fast Trains Outside the U.S.	HIGHLY UNLIKELY	HIGHLY UNLIKELY	HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY
E. BRT (Bus Rapid Transit)		48. US 36 Bus Rapid Transit, CO	HIGHLY LIKELY	HIGHLY LIKELY	HIGHLY LIKELY	HIGHLY LIKELY

LEGEND				
HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY	POSSIBLE	LIKELY	HIGHLY LIKELY
HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY	POSSIBLE	LIKELY	HIGHLY LIKELY

Table 2: Preliminary Evaluation of Technologies (continued)

CATEGORY	SUBCATEGORY	TOPIC	Possible in Pilot Program	Possible in 2045 LRTP		
				2020-2025	2026-2035	2036-2045
E. BRT (Bus Rapid Transit)		49. Cape Town, South Africa BRT (BRT)	●	●	●	●
E. BRT (Bus Rapid Transit)		50. Healthline serving the Euclid Corridor	●	●	●	●
F. Solar		51. Solar Roadways – Missouri DOT Pilot Project on Route 66	◔	○	◔	◑
F. Solar		52. Solar Energy Present and Future	◑	◔	◑	●
G. Energy		53. Energy	◑	◔	◑	●
H. 3D Printing		54. The Future Impact of 3D Printing on the Freight Transportation Industry and Retailers	◔	◔	◑	●
I. Parking		55. How Driverless Cars Spell the End of Parking as We Know It	○	○	◔	◕
J. Bikes		56. Bikes	●	●	●	●
K. Drones		57. FAA Expects 600,000 Commercial Drones in the Air (by 2017)	●	◕	●	●
K. Drones		58. Drone Use for Transportation Purposes	●	◕	●	●
L. IoT/Data Management		59. What is the Internet of Things (IoT)?	●	◔	◕	●
L. IoT/Data Management		60. Internet of Things in Healthcare: Information Technology in Health	●	◔	◕	●

LEGEND				
○ HIGHLY UNLIKELY	◔ POSSIBLE, BUT UNLIKELY	◑ POSSIBLE	◕ LIKELY	● HIGHLY LIKELY
○ HIGHLY UNLIKELY	◔ POSSIBLE, BUT UNLIKELY	◑ POSSIBLE	◕ LIKELY	● HIGHLY LIKELY

Table 2: Preliminary Evaluation of Technologies (continued)

CATEGORY	SUBCATEGORY	TOPIC	Possible in Pilot Program	Possible in 2045 LRTP		
				2020-2025	2026-2035	2036-2045
L. IoT/Data Management		61. IoT Forecast: Examining How The IoT Will Affect The World	Highly Likely	Possible, But Unlikely	Likely	Highly Likely
L. IoT/Data Management		62. Forecast of How The IoT Will Affect Healthcare	Highly Likely	Possible, But Unlikely	Likely	Highly Likely
L. IoT/Data Management		63. Forecast of How The IoT Will Affect Infrastructure	Highly Likely	Possible, But Unlikely	Likely	Highly Likely
L. IoT/Data Management		64. Forecast of How The IoT Will Affect Manufacturing	Highly Likely	Possible, But Unlikely	Likely	Highly Likely
L. IoT/Data Management		65. Forecast of How The IoT Will Affect Buildings	Highly Likely	Possible, But Unlikely	Likely	Highly Likely
L. IoT/Data Management		66. Forecast of How The IoT Will Affect Utilities	Highly Likely	Possible, But Unlikely	Likely	Highly Likely
L. IoT/Data Management		67. Forecast of How The IoT Will Affect Retailing	Highly Likely	Possible, But Unlikely	Likely	Highly Likely
L. IoT/Data Management		68. Safeguarding the Internet of Things: Being secure, vigilant, and resilient in the connected age	Highly Likely	Possible, But Unlikely	Likely	Highly Likely
L. IoT/Data Management		69. Securing the Internet of Things (IoT)	Highly Likely	Possible, But Unlikely	Likely	Highly Likely
L. IoT/Data Management		70. Managing Risk for the Internet of Things (IoT)	Highly Likely	Possible, But Unlikely	Likely	Highly Likely
L. IoT/Data Management		71. Iot in Wellness/Healthcare	Highly Likely	Possible, But Unlikely	Likely	Highly Likely
L. IoT/Data Management		72. Clustered regularly interspaced short palindromic repeats (CRISPR)	Highly Unlikely	Highly Unlikely	Highly Unlikely	Highly Unlikely

LEGEND				
HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY	POSSIBLE	LIKELY	HIGHLY LIKELY
HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY	POSSIBLE	LIKELY	HIGHLY LIKELY

Table 2: Preliminary Evaluation of Technologies (continued)

CATEGORY	SUBCATEGORY	TOPIC	Possible in Pilot Program	Possible in 2045 LRTP		
				2020-2025	2026-2035	2036-2045
M. Banking		73. Automation of Banking	HIGHLY LIKELY	HIGHLY LIKELY	HIGHLY LIKELY	HIGHLY LIKELY
M. Banking		74. Forecast of How The IoT Will Affect Banking	HIGHLY LIKELY	HIGHLY LIKELY	HIGHLY LIKELY	HIGHLY LIKELY
N. Rain Channels		75. Rain Channels Double as Roadways	HIGHLY UNLIKELY	HIGHLY UNLIKELY	HIGHLY UNLIKELY	HIGHLY UNLIKELY
O. Electric Vehicles/Alternative Fuels		76. 87 percent of drivers could switch to electric car with little hassle	POSSIBLE	POSSIBLE, BUT UNLIKELY	POSSIBLE	LIKELY
O. Electric Vehicles/Alternative Fuels		77. Growing momentum for electric cars	POSSIBLE	POSSIBLE, BUT UNLIKELY	POSSIBLE	LIKELY
O. Electric Vehicles/Alternative Fuels		78. NanoFlowcell thinks you'd rather refuel your battery, instead of recharging	HIGHLY UNLIKELY	HIGHLY UNLIKELY	HIGHLY UNLIKELY	HIGHLY UNLIKELY
O. Electric Vehicles/Alternative Fuels		79. Obama's plan to line the country's roads with electric vehicle chargers	HIGHLY UNLIKELY	HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY	LIKELY
O. Electric Vehicles/Alternative Fuels		80. Power from the Friction Contact of the Road	HIGHLY UNLIKELY	HIGHLY UNLIKELY	HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY
O. Electric Vehicles/Alternative Fuels		81. Tokyo Hopes to Make Hydrogen Power the Star of the 2020 Olympics	HIGHLY UNLIKELY	HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY	POSSIBLE
O. Electric Vehicles/Alternative Fuels		82. China's Electric Car production	POSSIBLE	POSSIBLE, BUT UNLIKELY	POSSIBLE	LIKELY
O. Electric Vehicles/Alternative Fuels		83. The Increased power of electric cars and buses	POSSIBLE	POSSIBLE, BUT UNLIKELY	POSSIBLE	LIKELY
P. Cost/Finacing		84. Oregon tries taxing drivers by the mile	LIKELY	POSSIBLE, BUT UNLIKELY	LIKELY	HIGHLY LIKELY

LEGEND				
HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY	POSSIBLE	LIKELY	HIGHLY LIKELY
HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY	POSSIBLE	LIKELY	HIGHLY LIKELY

Table 2: Preliminary Evaluation of Technologies (continued)

CATEGORY	SUBCATEGORY	TOPIC	Possible in Pilot Program	Possible in 2045 LRTP		
				2020-2025	2026-2035	2036-2045
P. Cost/Finacing		85 Alternatives to the VMT transportation taxing system	Likely	Possible, but unlikely	Likely	Highly likely
P. Cost/Finacing		86. "On the Move: State Strategies for 21st Century Transportation Solutions"	Likely	Possible, but unlikely	Likely	Highly likely
P. Cost/Finacing		87. State and Local Funding	Possible	Possible	Highly likely	Highly likely
P. Cost/Finacing		88. Federal Funding	Likely	Likely	Highly likely	Highly likely
Q. Dashboards		89. Dashboards	Highly likely	Highly likely	Highly likely	Highly likely
R. Traffic Control Systems		90. The Economic and Societal Impact of Motor Vehicle Crashes, 2010 (Revised)	Highly likely	Highly likely	Highly likely	Highly likely
R. Traffic Control Systems		91. Safety reflector for pedestrians gets connected to IoT C151	Possible	Possible, but unlikely	Likely	Highly likely
R. Traffic Control Systems		92. Solar Pedestrian Crossings	Highly likely	Highly likely	Highly likely	Highly likely
R. Traffic Control Systems		93. Smart IP Cameras Can Read Traffic, Identify Pedestrians	Highly likely	Highly likely	Highly likely	Highly likely
R. Traffic Control Systems		94. Chicago deploys computers with eyes, ears and noses	Highly likely	Likely	Highly likely	Highly likely
S. BIBO/One Inclusive App		95. Integrated Transit Mobility Application	Highly likely	Highly likely	Highly likely	Highly likely
S. BIBO/One Inclusive App		96. Ticketless Transit	Highly likely	Highly likely	Highly likely	Highly likely

LEGEND				
HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY	POSSIBLE	LIKELY	HIGHLY LIKELY
HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY	POSSIBLE	LIKELY	HIGHLY LIKELY

Table 2: Preliminary Evaluation of Technologies (continued)

CATEGORY	SUBCATEGORY	TOPIC	Possible in Pilot Program	Possible in 2045 LRTP 2020-2025	Possible in 2045 LRTP 2026-2035	Possible in 2045 LRTP 2036-2045
S. BIBO/One Inclusive App		97. Be-In/Be-Out Systems (BIBO)	Possible	Possible, but unlikely	Possible	Highly likely
T. ADAs		98. Advanced Driver Assistance System (ADS) for Buses	Likely	Likely	Highly likely	Highly likely
U. Traveler Information Systems		99. What Are Highway Traveler Information Systems	Highly likely	Highly likely	Highly likely	Highly likely
U. Traveler Information Systems		100. What Traveler Information Systems Do	Highly likely	Highly likely	Highly likely	Highly likely
V. Communication Technology		101. "Nextdoor," the social network designed specifically for neighborhoods	Highly likely	Highly likely	Highly likely	Highly likely

LEGEND				
HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY	POSSIBLE	LIKELY	HIGHLY LIKELY
HIGHLY UNLIKELY	POSSIBLE, BUT UNLIKELY	POSSIBLE	LIKELY	HIGHLY LIKELY

LONG RANGE TRANSPORTATION PLAN

Turning to **Table 2**, preliminary assessments have been made about the potential to implement "new technologies of the future" in three distinct periods (2020–2025, 2026–2035, and 2036–2045) of the LRTP. The first phase focused on is 2036–2045. The key elements of the LRTP in that period are listed and elaborated upon below. First, it cannot be stressed enough that a new suite of travel demand models (TDM) must be in place to develop the 2045 LRTP to address the impact of autonomous/connected vehicles.

Suggested TDM Approach

A reasonable approach to update the TDM would be to construct a number of alternative futures, make assumptions on expected behaviors and consequences, and conduct travel demand model sensitivity tests. The tests could show what issues are important, and would reveal how well the forecasting tools can deal with autonomous/connected vehicles. Adjustments to the model and assumptions could be made after reviewing sensitivity results. As experience with autonomous/connected vehicles increases, models would be improved, as is the case with new travel modes and facilities.

Alternatives and Expected Model Changes Needed for Sensitivity Testing

Before conducting sensitivity tests, the following characteristics must be defined for each alternative:

- Alternative policies for driverless vehicles;
- Assumptions on the degree of market penetration at various future years;
- Highway networks which identify roads that would be restricted to autonomous/connected vehicles;
- Links where the number of lanes on restricted facilities could be recoded to make use of narrower lanes;
- Speed, capacity, and volume/delay functions for restricted roadways;
- Ways of representing increased safety and higher reliability;
- Investigating whether speed, capacity, and volume/delay functions are needed for roadways that are not restricted to autonomous/connected vehicles;
- New zonal data files for land use patterns based on increased speeds and reduced delays; and,
- Estimates of how the SERPM 7 CTRAMP ABM (Activity-Based Model) could be modified to reflect more unaccompanied travelers under the age of 16 and more elderly travelers.

To start, a single scenario for a 2045 "most likely" case would be defined to frame the needs and issues. The scenario could then be tested using an enhanced version of SERPM 7.

Improvements to the current SERPM 7 ABM would be required to test the autonomous/connected vehicle alternatives. While the current model is an advanced activity-based model, changes would be required because SERPM 7 was not designed to test autonomous/connected vehicles. When extending the use of a model beyond its original intent, it is important to assess all facets of the model to verify that its assumptions are still valid. The following summary is presented in terms of the more familiar four-step model, but also would apply to the ABM.

- ***Network Representation:*** Network models are common to both four-step and ABM models. Network changes include:
  - ✓ Adding a link attribute designating whether it is available to conventional vehicles only, autonomous/connected vehicles only, or both;
  - ✓ Revising speed limits for links restricted to autonomous/connected vehicles;
  - ✓ Implementing changes in intersection delay assumptions for roadways and links restricted to autonomous/connected vehicles; and,
  - ✓ Revising transit network coding to use restricted links, as appropriate.
- ***Trip Generation:*** The SERPM 7 ABM does not use a conventional trip generation model; instead, it estimates the daily activity pattern for each person, depending on issues like work and school status, age, income, and family characteristics. Other models estimate the number of trips made by each person for each activity. These models would need to be modified to produce more trips by persons over age 65 and persons under the age of 16, if vehicles no longer require licensed drivers. Vehicle availability, and how vehicles might be shared would also need to be defined. Zonal data should be reviewed to determine whether adjustments to development patterns are required in response to higher travel speeds. Tests should also be made to measure the model's response to faster travel times.
- ***Trip Distribution***: SERPM 7 uses destination choice models to distribute individual trips. These models should create longer trips in response to higher speeds. Sensitivity tests should be conducted to verify that the model's response is reasonable because it was not designed to consider the range of speed changes that might arise with autonomous/connected vehicles.
- ***Mode Choice:*** Transit mode shares might suffer from increased highway speeds. But, depending on network details, transit vehicles running in mixed traffic might see similar speed increases. Also, a term should be added to the highway-mode utility to account for at least part of the increased cost of automated/connected vehicles, as the cost associated with the higher speeds would dampen highway mode gains. Perhaps the most complex required model change would be to split highway trips among manually operated vehicles and autonomous/connected vehicles, if market penetration is significant, and it is confirmed that autonomous/connected vehicles can travel faster. The best way to do this would be to add manual and autonomous/connected modes (manual/automated nest) to the trip and tour mode choice models.

Funding: Federal

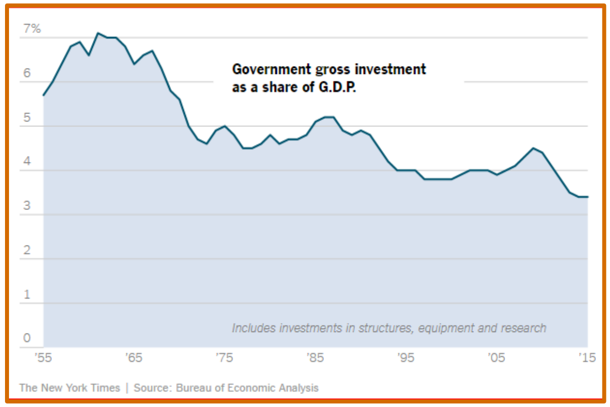
A second major issue to address in establishing a "new technology future" is financing.

The Highway Trust Fund (HTF) was established in 1956 to finance the Interstate Highway System and certain other roads. The Mass Transit Fund, as a subset of the HTF, was created in

1982. Most all federal funding for transportation now comes through the HTF formula and grant funding process. The HTF relies principally on fuel taxes collected on the basis of gallons sold. Roughly one-quarter of public funds spent on highways and mass transit is provided by the federal government.

As vehicle mile-per-gallon rates increased, based on federal mandate, taxes per mile of travel decreased. Meanwhile, the gas tax has not been increased since 1993, so inflation reduced by a third the real value of the revenue generated. The recession beginning in 2008 reduced out-of-pocket discretionary spending, which discouraged travel. At the same time, the proportion of alternatively-fueled vehicles has increased.

Since 2008, the HTF has run a deficit; the Congressional Budget Office (CBO) forecasts that the deficits will continue.[1] These conditions have led to the fact that, today, federal, state, and local governments are spending half as much on the nation's public infrastructure, as they were in the 1950s and 1960s.



Raising the per-gallon gas tax is a logical way to recover, insofar as it acts like a carbon tax and encourages economy of travel, use of alternatives to fossil fuels, reduced dependency on foreign oil, and it taxes heavier vehicles that have a greater impact on roads at a higher level. And gas taxes could be indexed to inflation. But, dealing with changes to taxes does not always follow logic. So, as an option that looks less like a tax increase, a VMT-based fee has gained some support. This approach may have importance in that the rise in autonomous vehicles will increase and so will vehicle miles of travel.[2]

Discussion of such a tax became more evident after a Congressional Budget Office (CBO) report was requested by Senate Budget Committee Chairman Kent Conrad (D-N.D.) in 2011.[3] It surfaced the proposal to create an FHWA office of Surface Transportation Revenue Alternatives, tasked with creating a "study framework that defines the functionality of a mileage-based user fee system and other systems." But, while there appears to be widespread agreement that the nation’s infrastructure needs to be better maintained and improved, the anti-tax sentiment has prevented most proposals at the federal level from moving forward. The need is such that the new federal administration has indicated it will act. If so, this will significantly affect the MDC 2045 LRTP.

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[1] CBO estimated the status of the Highway Trust Fund using the revenue and spending projections contained in CBO’s August 2015 baseline, which reflects the enactment of *the Surface Transportation and Veterans Health Care Choice Improvement Act of 2015* (Public Law 114-41). That law transferred $8.1 billion from the general fund of the Treasury to the Highway Trust Fund. Other than accounting for that transfer, compared to the March 2015 estimates, CBO’s estimate of the status of the Highway Trust Fund in August 2015 reflects small increases in projections of revenues credited to the fund and minor changes in spending.

During fiscal year 2016, CBO projects revenues credited to the highway and transit accounts of the Highway Trust Fund will be insufficient to meet the fund’s obligations. Under current law, the trust fund cannot incur negative balances, nor is it permitted to borrow to cover unmet obligations presented to the fund. CBO projects that the highway account will have a shortfall of $1 billion in 2016; by 2025, the cumulative shortfall will grow to $108 billion. CBO also projects that the transit account will have a shortfall of less than $1 billion in 2016, growing to a cumulative shortfall of $40 billion by 2025.

[2] Bryant Walker Smith, Santa Clara Law Review, Volume 52 | Number 4, Article 8, 12-19-2012, “Managing Autonomous Transportation Demand”

[3] http://thehill.com/blogs/floor-action/house/159397-obama-floats-plan-to-tax-cars-by-the-mile

Funding: State and Local

In the face of this federal reluctance to date, Utah, New Jersey, and Tennessee have just raised the per-gallon gasoline tax to provide more dollars for transportation. On the other hand, Oregon is testing a system that would tax drivers by the mile. It is known as MyOReGO, and is the first statewide "vehicle miles traveled" program in the nation. The program is voluntary and has promised drivers' personal information will be protected. Participation is now limited to 5,000 cars.

Drivers who join the program are charged 1.5 cents per mile. Participants are given the option of using a GPS to record their miles or using a non-GPS option that will track usage based on the mileage counters on cars. In return for participating, the drivers are offered a tax credit reimbursing them for the 31-cent-per-gallon Oregon gas tax. The cost of the program is estimated at about 0.5 percent of revenue.

A summary of fuel taxes levied in Florida, as provided in FDOT's *Florida's Transportation Tax Sources, A Primer*, is presented in **Table 3**.

Table 3: Quick Reference to 2016 Fuel Taxes

LEVEL/TAX	AMOUNT	USE
Federal		
Fuel Excise Tax	Gasohol = 18.4¢/gal Gasoline = 18.4¢/gal Diesel = 24.4¢/gal	2.86¢ for mass transit 0.1¢ for leaking tanks Remainder for roads and bridges
State (Distributed to DOT)*		
Fuel Sales Tax	All fuels = 13.3 ¢/gal	At least 15.0% of DOT receipts** dedicated for public transportation. Remainder for any legitimate state transportation purpose.
SCETS* Tax	Gas/Gasohol = 6.1¢ – 7.4¢/gal Diesel = 7.4¢/gal	Net receipts must be spent in the district where generated.
State (Distributed to Local Governments)*		
Constitutional Fuel Tax	All fuels = 2¢/gal	Acquisition, construction, and maintenance of roads
County Fuel Tax	All fuels = 1¢/gal	Any legitimate county transportation purpose
Municipal Fuel Tax	All fuels = 1¢/gal	Any legitimate municipal transportation purpose
Local*		
Ninth-cent Fuel Tax	Gas/Gasohol = 0¢ – 1¢/gal Diesel = 1¢/gal	Any legitimate county or municipal transportation purpose
Local Option Fuel Tax	Gas/Gasohol = 5¢–11¢/gal Diesel = 6¢/gal	Local transportation; small counties may also use funds for other infrastructure needs.

For Florida's counties, the average state tax per gallon is $0.3658 for gasoline and $0.3377 for diesel. These rates are substantially higher than the national averages of $0.2072 for gasoline and $0.2045 for diesel. Florida's state fuel tax is indexed to the Consumer Price Index and adjusted every January.

In terms of the taxes designed to go to local governments (see above table), the Constitutional and County Fuel taxes are distributed by formula.[4] The Municipal Fuel Tax is also distributed by formula. Quoting from the 2015 *Local Government Financial Information Handbook*:

> *"Effective January 1, 2014, the trust fund no longer receives 12.5 percent of the state alternative fuel user decal fee collections due to the repeal of the annual decal fee program for motor vehicles powered by alternative fuels. However, beginning January 1, 2019, 25 percent of the 4 cents of excise tax levied upon each motor fuel equivalent gallon of natural gas fuel, pursuant to s. 206.9955(2)(a), F.S, shall be transferred to the trust fund. An allocation formula serves as the basis for revenue distribution."*

The opportunity for increased local funding for transportation appears to rest on an increase to the *Charter County and Regional Transportation System Surtax* (s. 212.055 (1), F.S. Miami-Dade is collecting half of the allowed 1.0 percent.[5] So, there is potential for additional transportation revenue there. The Florida Department of Revenue summarizes the Ninth-cent Fuel Tax and Local Option Fuel Tax as follows.[6]

Local Option Fuel Taxes

> Sections 206.41(1)(d)-(e), 206.87(1)(b)-(c), 336.021, and 336.025, Florida Statutes
>
> *County governments are authorized to levy up to 12 cents of local option fuel taxes in three separate levies [see the three separate bullets below] on fuel sold within the county. The funds are used for transportation expenditures.*
>
> - *The ninth-cent fuel tax is a tax of 1 cent on every net gallon of motor and diesel fuel sold within a county.*
> - *A tax of 1 to 6 cents on every net gallon of motor and diesel fuel sold within a county.*
> - *A tax of 1 to 5 cents on every net gallon of motor fuel sold within a county. Diesel fuel is not subject to this tax. The funds may also be used to meet the requirements of the capital improvements element of an adopted local government comprehensive plan.*
>
> ***Note:** The Florida Legislature has authorized the statewide equalization of local option tax rates on diesel fuel. It requires that the full 6 cents of the 1-to-6-cents fuel tax as well as the 1-cent ninth-cent fuel tax be levied on diesel fuel in every county, even though the county government may not have imposed either tax on motor fuel or may not be levying the tax on motor fuel at the maximum rate. As a result, 7 cents' worth of local option tax revenue on diesel fuel are distributed to local governments, regardless of whether the county is levying these two taxes on motor fuel.*

About 75 percent of Miami-Dade County's overall $7.1 billion budget (proposed 2016–17) goes to schools, municipal governments, and other taxing authorities. The remainder is allocated to services, including transportation.

[4] http://edr.state.fl.us/Content/local-government/reports/lgfih15.pdf

[5] http://edr.state.fl.us/Content/local-government/reports/lgfih15.pdf, page 158, *2016 Local Discretionary Sales Surtax Rates in Florida's Counties*

[6] http://dor.myflorida.com/dor/taxes/local_option.html#fuel

The fuel tax makes up only one percent of the county's operating budget. Miami-Dade County's principle form of revenue, especially revenue that is available for discretionary spending, is provided by property taxes.

Miami-Dade's transit sales tax, approved in a 2002 referendum, increased the tax on purchased goods in the county a half-penny per dollar, from 6.5 percent to seven percent. The extra revenue is to subsidize free rides for senior citizens and all Metromover passengers. Importantly, it was also to build a new Metrorail line to the western suburbs and one running up 27th Avenue, as well as staff new bus lines and Metrorail routes. But only the 2.5 mile Metrorail extension to Miami International Airport has been completed. However, it is important to understand the Miami-Dade Transit Authority pays for its transit system using the transit sales tax (28%), but also general fund revenue (30%), fares (19%), and government grants (19%).

According to a March 31, 2015, *Miami Herald* article, in 2015, about 37 percent of the transit sales tax is slated for debt payments for $1.5 billion in bonds sold to build the MIA line, plus purchase of new Metromover cars, and some improved bus and rail facilities. Another 38 percent subsidizes daily transit operations. Twenty percent goes to local municipalities for transit services.

The conclusion is that many factors affect transit and transportation funding. With the federal government now providing only about a quarter of public financial support for transportation infrastructure, much depends on how the Florida State Legislature and Miami-Dade County address funding issues.

What is the Internet of Things?

The third major issue to be defined before examining what could be part of the MDC 2045 LRTP is the Internet of Things (IoT).

IoT refers to the connection of devices, beyond computers and smartphones, to the Internet. Cars, kitchen appliances, and even heart monitors can all be connected through the IoT. And as the IoT grows in the next few years, more devices will join that list.

This is being significantly advanced in Miami-Dade County as it is the first municipality in which an AT&T Smart Cities Operation Center has been launched. The program aims to provide visibility into communities' conditions using an integrated visualization dashboard placed in the County Mayor's office.

In Miami-Dade, AT&T is working to apply solutions that address intelligent lighting and smart transportation as part of its Smart Cities initiative. In collaboration with its alliance member Hitachi, AT&T will be deploying public safety solutions, including:

- Remote monitoring and more efficient operations solutions for police and public safety officials;
- Upgrades to the county's existing lighting infrastructure with smart LED lighting;
- Reliable data to help inform decision making around urban transportation planning; and,
- A traffic intersection network solution to help improve traffic flow.

As part of this program, AT&T began in the Spring of 2017:

- Providing, in collaboration with Ericsson, 60 laptops for students and adults in the community to use in the community center, while also equipping the center with Wi-Fi connectivity;

- Installing new 4G LTE wireless-connected cameras at three intersections with the ability to automatically notify traffic management;

- Providing real-time access to existing security cameras at the Arthur Mays Villas and Annie Coleman Gardens public housing complexes; and,

- Retrofitting 48 lights within Annie Coleman Gardens with SMART LED Lighting and connected through AT&T's 4G LTE.

Consistent with this initiative, *Business Insider* forecasts that there will be more than 24 billion IoT devices worldwide by 2020. That's approximately four devices for every human being on the planet. And $6 billion will flow into IoT solutions, including application development, device hardware, system integration, data storage, security, and connectivity. Those investments will generate $13 trillion by 2025.

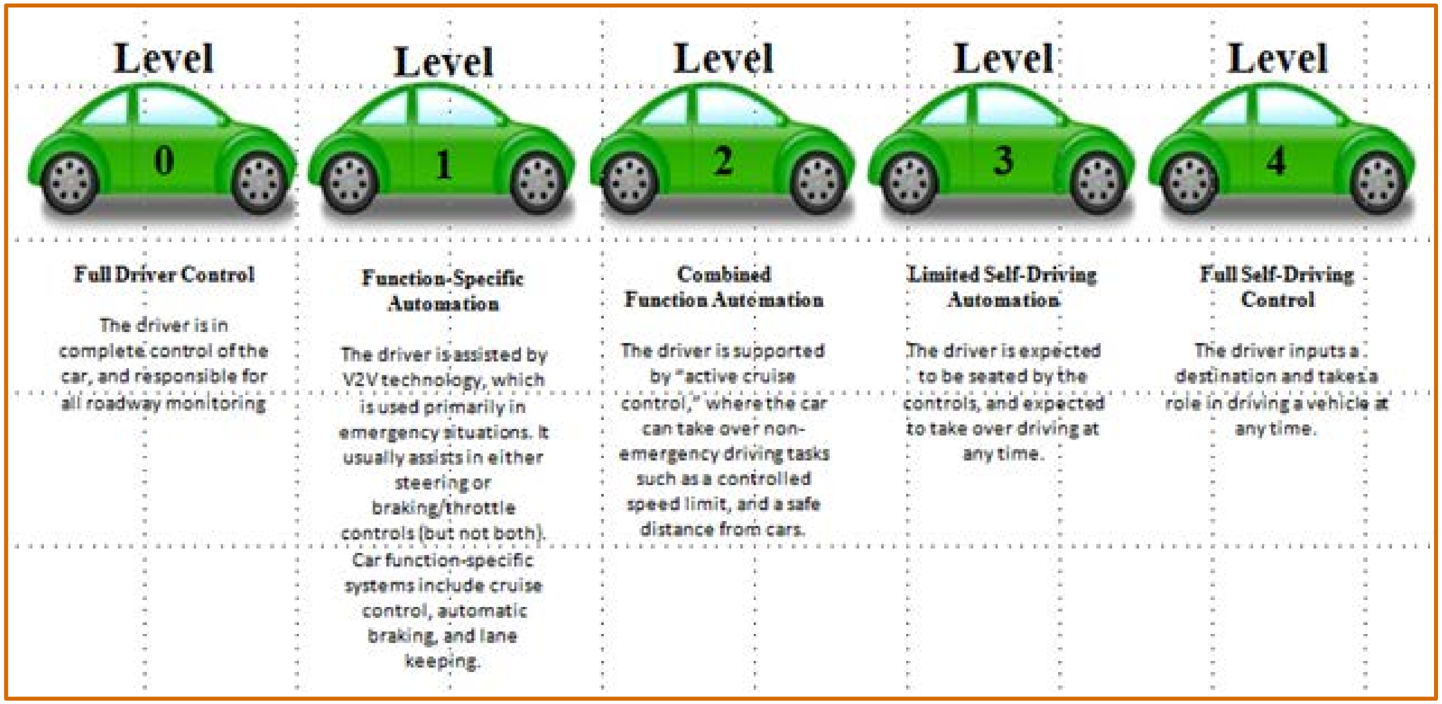
As devices become more connected, security and privacy are the primary concerns among consumers and businesses. In fact, the protection of sensitive data ranked as the top concern (at 36 percent of those polled) among enterprises, according to *the 2016 Vormetric Data Threat Report.* Cyber-attacks are also a growing threat. Hackers could penetrate connected cars, critical infrastructure, and even people's homes. As a result, several tech companies are focusing on cyber security in order to secure the privacy and safety of all these data.

Now, to the 2045 LRTP.

ELEMENTS OF THE 2036–2045 PERIOD OF THE LRTP

The first LRTP phase to be focused on is 2036–2045. The key elements are listed and elaborated upon below.

- Autonomous Vehicles
  - ✓ Cars
  - ✓ Buses
  - ✓ Trucks
  - ✓ Emergency Equipment
- AV Infrastructure
- Electric Vehicles
- Bus Rapid Transit (BRT)
- Gondola
- Freight
  - ✓ Rail
  - ✓ Marine
- Logistics
- 3D Printing
- Drones
- Traffic Management Technology
- Pedestrian Facility Technology
- Bikes
- Parking
- Energy
- Solar Roadway
- Smart Cities



Autonomous Vehicles

Autonomous Vehicle (AV) technology offers the possibility of fundamentally changing transportation. Equipping automotive vehicles of all types with new technology will likely reduce crashes, energy consumption, pollution, and the cost of congestion. This technology is most easily conceptualized using a five-part continuum suggested by the National Highway Traffic Safety Administration (NHTSA), with different benefits of the technology realized at different levels of automation:

- ***Level 0:*** The human driver is in complete control of all functions of the car.
- ***Level 1:*** One function is automated.

- ***Level 2:*** More than one function is automated at the same time (e.g., steering and acceleration), but the driver must remain constantly attentive.
- ***Level 3:*** The driving functions are sufficiently automated that the driver can safely engage in other activities.
- ***Level 4:*** The car can drive itself without a human driver.

Effect on Crashes – The Insurance Institute for Highway Safety (IIHS) estimated that if all vehicles had forward-collision and lane-departure warning systems, side-view (blind spot) assist, and adaptive headlights, nearly a third of crashes and fatalities could be prevented (IIHS, 2010). Level 4 AVs will likely further reduce crashes.

Effect on Mobility – Level 4 AV technology would enable transportation for the blind, disabled, or those too young to drive, providing these groups with independence, reduction in social isolation, and access to essential services.

Effect on Traffic Congestion and Its Costs – Level 3 or higher is likely to substantially reduce the cost of congestion, because occupants of vehicles could undertake other activities.

Effect on Energy and Emissions – The overall effect of AV technology on energy use and pollution is uncertain, but is likely to decrease both. AV technology can improve fuel economy by four to ten percent by accelerating and decelerating more smoothly than a human driver.

Costs – AV technology is likely to decrease the cost of congestion and increase fuel economy, it will also likely decrease the private cost of driving. Because of this decline, and because of the increase in mobility that AVs offer to the elderly or disabled, AV technology may increase total VMT, which in turn may lead to increases in congestion and overall fuel consumption.

Autonomous Vehicles/Cars

No one knows the full scope of the changes to come. But, the auto and technology companies are moving at an aggressive pace to provide the consumer AVs, as illustrated in **Table 4**.

There are widely divergent views on when the AV will deeply penetrate the market—some predict it will be 100 percent penetrated in 15–20 years, while others believe it will take 60 years. In a study conducted by the American Automobile Association, three out of four U.S. drivers reported feeling “afraid” to ride in a self-driving car. Only one-in-five people surveyed said they would trust an autonomous vehicle to drive itself.

Table 4: Predictions of Availability of AV Cars

COMPANY	DRIVERLESS VEHICLE PREDICTION
Baidu	by 2019
BMW	by 2021
Delphi	by 2019
Ford	by 2021
GM	by 2020
NuTonomy	by 2020
Tesla	by 2018
Toyota	in 2020
Uber	Entire fleet by 2030
Volkswagen	by 2019

Source: http://www.driverless-future.com/?page_id=384

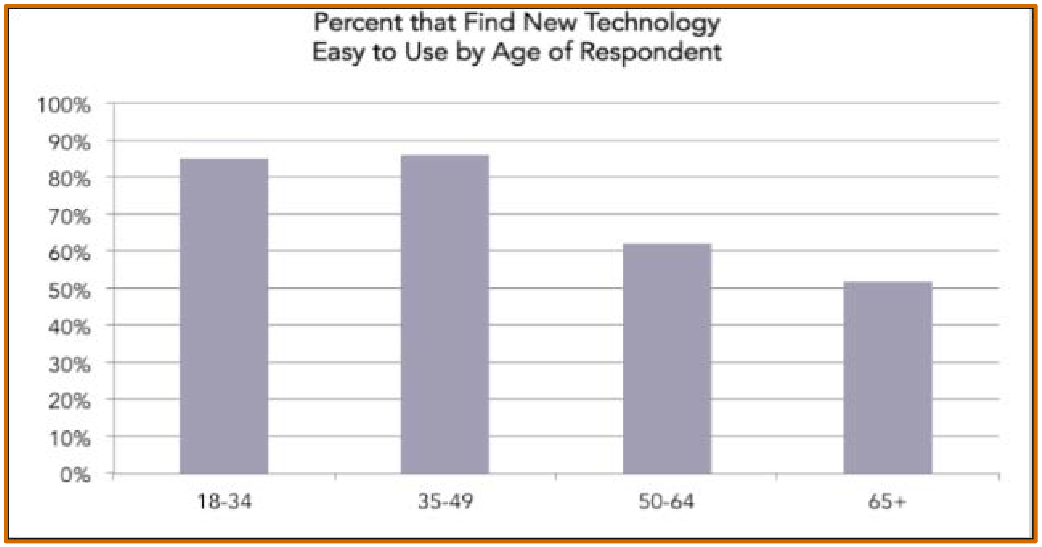
On the other hand, the survey revealed that consumer demand for *semi-autonomous* vehicle technology is high. Nearly two-thirds (61 percent) of drivers reported wanting at least one of the following technologies on their next vehicle: automatic emergency braking, adaptive cruise control, self-parking technology, or lane-keeping assist. Among these drivers, AAA found safety is their primary motivation (84 percent), followed by convenience (64 percent), reducing stress (46 percent), and wanting the latest technology (30 percent). While six-in-ten drivers want semiautonomous technology in their next vehicle, there are still 40 percent of Americans who are either undecided or reluctant to purchase these features.

Education is the key to addressing this consumer sentiment.

These opinions are echoed in a survey conducted in 2015 by a team of researchers at Florida State University (FSU) of Florida residents.[7] The survey asked respondents to indicate how much they agree with the statement: *I generally find new technology easy to use.* **Figure 1** illustrates the percentage of respondents by age group that reported finding new technology easy to use. As expected, younger groups reported higher levels of comfort with new technology than older adults, with a clear break around age 50. Respondents under age 50 reported about 85 percent success in using new technology, whereas for respondents aged 50–64 and 65+, these percentages fell to just above 60 percent and 50 percent, respectively.

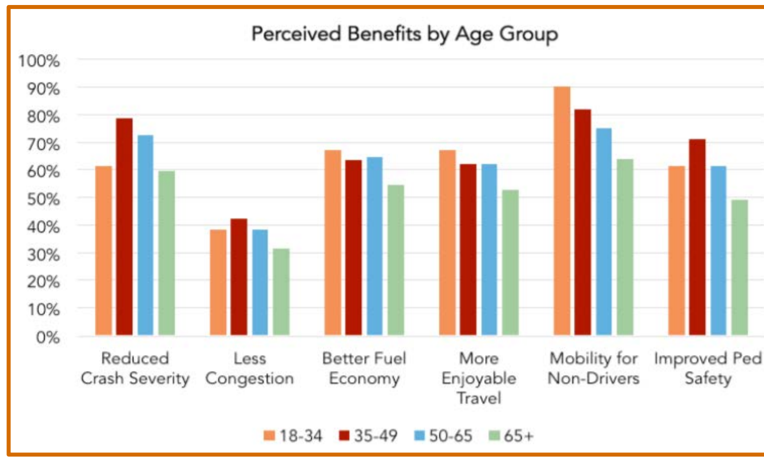
Figures 2 and 3 summarize the level of agreement with key benefits and concerns with AV across four major age groups: 18–34, 35–49, 50–65, and 65+. These results demonstrate that older Floridians (aged 65+) often see fewer benefits and worry about the concerns more than those in other age groups. In contrast, younger people perceive greater benefits flowing from autonomous vehicle technology, and worry less about certain concerns. Specifically, as shown in **Figure 2**, two observations are made. First, almost 70 percent of those 18–34 years of age believed that AV would bring a more enjoyable driving experience, with the hypothesis being that AV will allow users to engage with their personal technology, work, or

Figure 1: New Technology Ease of Use by Age



Source: Florida State University Department of Urban & Regional Planning

Figure 2: Variations in Perceptions of Benefits of Autonomous Vehicle Technology by Major Age Groups



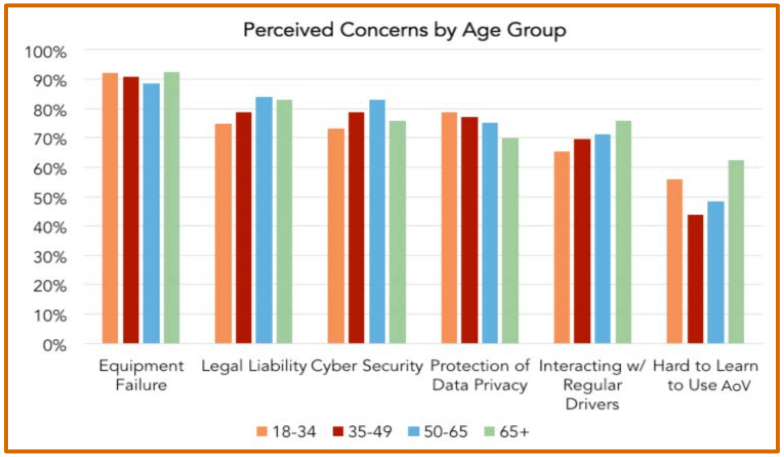
Source: Florida State University Department of Urban & Regional Planning

[7] *Enhanced Mobility of Aging Population Using Automated Vehicles*, Florida State University Department of Urban and Regional Planning, 2015

socialize in ways that human-operated vehicles do not allow. Second, the perception of increased mobility from non-drivers was highest amongst the youngest age group (at over 90%), while only about 60 percent of older adults believed that AV will bring increased mobility to nondrivers. Variations in perceived concerns also vary somewhat by age (shown in **Figure 3**). One finding stands out: older adults had the greatest level of concern about learning to use AV (over 60% indicated this concern), even though more than 55 percent of those 18–34 years of age shared a similar concern. This suggests that there is a role for the AV industry to demonstrate and reinforce to users the ability to use the new technology. The approach for reaching these different groups needs to vary by age cohort. Millennials are much more likely to be reached through social media and online campaigns. Older adults, while more engaged with technology than ever, still require more traditional marketing campaigns with which to be connected.

In summary, older adults are less favorable to technology in general, and see the challenges and costs of AV more than other age groups. However, this group does see some enhanced mobility advantages that might result from AV, which represents an opportunity for building support for the technology among those in this age cohort.

Figure 3: Variations in Perceptions of Concerns of Autonomous Vehicle Technology by Major Age Groups



Source: Florida State University Department of Urban & Regional Planning

To further inform this age group, consistent with the survey results which indicated that even a brief informational brochure on automated vehicles improved respondents' opinion of AVs, the TPO should join FDOT in a comprehensive education/marketing strategy targeting key constituencies, like the aging road user, in a campaign that should:

- Strive to inform the public about what AVs are, how they operate, and what AVs' potential costs and benefits are.
- Target age-specific interests and concerns consistent with survey results which indicate that distinct population subgroups have differing interests and fears concerning AVs. Aging adults typically see the challenges and costs of AVs more than other age groups while younger generations are more favorable toward AVs.
- Tailor media to the age-specific preferences and characteristics recognizing social media and online applications may not be effective with those in the older generations who are less familiar with technology. A multi-media approach would be most effective.

Effect on AVs in Developing the LRTP

To develop the 2045 LRTP, assumptions on AVs are needed. Toward that end, the consultant's personnel and members of the TPO's Study Advisory Committee independently provided their forecast as to when AVs will reach various percentages of vehicles purchased by the American consumer. The results **(Table 5)** are the same for each group, essentially indicating it will be beyond 2045 when AVs will reach 75 percent of all vehicles purchased in the U.S.

This is generally consistent with research pre-

Table 5: Period in which AVs Will Reach Certain % of All Vehicles Purchased in U.S.

PERIOD	CONSULTANT	TPO SAC
2020–2025	NA	NA
2026–2035	25%	25%
2036–2045	50%	50%
> 2045	75%	75%

sented at the 2015 Transportation Research Board Annual Meeting where Todd Litman of the Victoria Policy Institute indicated that some benefits, such as independent mobility for affluent non-drivers, may begin in the 2020s or 2030s; but, most impacts—including reduced traffic and parking congestion, independent mobility for low-income people, increased safety, energy conservation, and pollution reductions—will only be significant when autonomous vehicles become common and affordable, probably in the 2040s to 2060s, and some benefits may require prohibiting human-driven vehicles on certain roadways, which could take longer.

In addition to the "trust" issue cited earlier as an impediment to AV penetration, a key factor is AV affordability. One reason for the current cost of a Level 4 AV is that distinctive spinning device (Lidar) on the roof of a driverless vehicle which helps the vehicle understand the world around it. Lidar, like radar, detects objects with pulses of laser light. Lidar has a shorter range than radar which results in a massive increase in resolution.

Currently, lidar's (light radar) size, complexity, and cost are significant obstacles to the commercialization of any technology that depends on it. But within the next few years, it is expected to become much less expensive.

Many autonomous cars have relied on the HDL-64E lidar sensor from Silicon Valley-based Velodyne, each of which costs $80,000. This year, Velodyne announced a new device with a target cost of $20,000. But, it's still too expensive to be integrated into driverless cars intended for the consumer market.

Another company, Quanergy Systems, projects that its sensor will cost $250 in volume production, and it should be available to automotive original equipment manufacturers in early 2017. Meanwhile, two startups, indicate they will release $100 automotive lidar systems in 2018. Innoviz, in Israel, is promising a "high-definition solid-state lidar" with better resolution and a larger field of view than those in existing sensors. Innoluce, in the Netherlands, is using a system to scan and steer a laser beam instead of the solid-state approach claiming it will outperform optical phased arrays in both range and resolution.

Driverless cars will create some big corporate winners, but they will produce some losers too, notably among the five million people nationwide who drive taxis, buses, vans, trucks, and work for Uber and Lyft. That's almost three percent of the workforce, according to Lawrence Katz, a labor economist at Harvard. Most of these drivers belong to the same demographic as many factory workers—people without college degrees. It's not just the driver jobs that will be impacted—loss of business may affect employment at auto dealerships, car washes, gas stations, and parking lots.

While this forecast is sobering, some say it can be addressed in a win-win situation, particularly because, unlike many previous technologies that took Americans almost by surprise, it is clear that the autonomous vehicle revolution is coming, with time to plan for its job impact.

The solution can be a retraining program so workers are not consigned to a long-term joblessness. Congress could enact a nationwide "green light" for driverless vehicles while, at the same time, establishing a levy on each driverless mile to finance programs for retraining, adjustment assistance, unemployment insurance and, perhaps, government jobs.

And there should be savings attributable to the use of AV technology and improved traffic management technologies to support such programs. Specifically, in 2010, there were 33,000 people killed, 3.9 million injured, and 24 million vehicles damaged in motor vehicle crashes in the U.S. The economic cost of these crashes totaled $242 billion. Included are lost productivity, medical costs, legal and court costs, emergency services costs, EMS insurance administration costs, congestion costs, property damage, and workplace losses. The $242 billion cost of motor vehicle crashes represents the equivalent of nearly $784 for each of the 300+ million people living in the U.S. in 2010, the year of the analysis, and +1.6 percent of the $15 trillion real U.S. gross domestic product in 2010. These figures include both police-reported and unreported crashes.

When quality-of-life valuations are considered, the total value of societal harm from motor vehicle crashes in 2010 was $836 billion. Taxpayer cost to cover crashes was $18 billion in 2010, the equivalent of over $156 for every household in the U.S.

So, even with just a partial elimination of these costs—$242 billion in direct plus another $594 billion in quality-of-life costs (property damage, medical expenses, congestion, excess fuel consumption, pollution)—were to occur through the use of AVs, the economic and societal benefits will be immense.

AV Ridesharing vs. Car-sharing

Ridesharing is the sharing of vehicles by passengers. Types of transportation that are considered ridesharing include carpool, vanpool, and transit.

Real-time ridesharing is conducted by companies like Uber, Sidecar, and Lyft making use of three technologies:

- ***GPS navigation devices*** to determine a driver's route and arrange the shared ride.
- ***Smartphones*** for a traveler to request a ride from wherever they happen to be.
- ***Social networks*** to establish trust and accountability between drivers and passengers.

Car-sharing is not as prevalent but expected to be with the penetration of AVs. For example, General Motors unveiled in January, 2016, its new car-sharing enterprise known as Maven.

Using Maven's app, a potential user searches for a vehicle that fits her/his need. Once the vehicle is secured, the phone acts as the key, unlocking and starting the vehicle.

Maven started its operation at the University of Michigan at Ann Arbor. GM expects to expand to residential neighborhoods in Chicago and

New York. Car-sharing in this way is expected to significantly reduce the cost of owning and operating a vehicle. The initial GM program in Ann Arbor is free to join, and gas and insurance are included for as little as $6 an hour.

One question that arises is: *What will happen to transit/bus systems as AVs penetrate the vehicle fleet?* One answer to that question is found in a study conducted at Florida Atlantic University[8]. It compared two hypothetical scenarios with the current bus transit system of Ann Arbor, Michigan, for a typical fall weekday in 2013. One scenario consisted of an automated car-sharing/taxi system that allows only one rider at a time, and the other consisted of a similar automated system that allows ridesharing for up to four passengers in a "shared-ride" scenario. The two automated car-sharing/taxi scenarios were modeled on simulated transit passenger travel demand data. All three scenarios were then compared for their level of service, cost, greenhouse gas emissions, and congestion impacts. The automated ridesharing service could provide a higher level of service at lower cost and lower carbon emissions than the current bus system. An automated service without ridesharing (i.e., single passenger) would provide high levels of service at lower cost, but with higher levels of carbon emissions than the current bus system. So, ridesharing is essential to obtaining the full cost savings and environmental benefits of a bus system. But, both automated car-sharing/taxi systems would likely increase peak-hour congestion by increasing peak-hour vehicle miles traveled. The best transit system of the future, it would seem, would take advantage of both the flexibility of automated car-sharing/taxis and the capacity management capabilities of large-vehicle transit within a coordinated system.

Autonomous Vehicles/Buses

Two self-driving buses rolled out in August, 2016, on the public roads of Helsinki, Finland, in one of the first trials of its kind. The Easymile EZ-10 electric mini-buses, capable of carrying up to 12 people, will roam the open roads of Helsinki, negotiating traffic for the first time.

The Helsinki experience has its challenges, which it is determined to overcome, leading to the time, surely by 2045, that AV buses will be prevalent, including on the streets of South Florida.

Autonomous Vehicles/Trucks

Across the country, the trucking industry faces a 40,000-person shortage, according to the American Trucking Association. That number is expected to escalate as truckers age out of the workforce, creating supply-chain issues. The average trucker is 49 years old compared to the average U.S. worker, who is 42 years old. Over the next decade, the trucking industry will need to hire a total of 890,000 new drivers. Replacing retiring truck drivers will account for about half of new driver hires. The second largest factor will be industry growth, accounting for 33 percent of new driver hires.

Because trucks account for 69 percent of all tonnage moved in the U.S., it is highly unlikely that the driver shortage could be reduced in any significant manner through modal shift (i.e., shifting a large amount of freight from the highway to the rails or another mode). So,

[8] *Comparing Automated Shared Taxis and Conventional Bus Transit for a Small City*, Dr. Louis A. Merlin, AICP, Florida Atlantic University

there will likely be supply-chain disruptions resulting in shipping delays, higher inventory carrying costs, and, perhaps, shortages at stores.

In light of this situation, a recent survey conducted by Technology & Maintenance Council (TMC) and the American Transportation Research Institute(ATRI) of 32 executives representing 31 fleets found that the majority expect AVs to become reality at some future point. However, completely driverless vehicles—ones that are hands off the wheel as well as foot off the accelerator and brake—are not really what they are talking about. Rather, there is more of a focus on "semi-autonomous" truck capability, perhaps for short durations on the highway.

Research indicates kits that would turn existing trucks into autonomous vehicles cost $30,000. That cost covers sensors, telematics upgrades, human-to-machine interface connections, driveline enhancements, and software algorithms.

It is predicted that early-stage autonomous commercial vehicles will see active use on North American roadways by 2025—largely in platooning operation; the total incremental cost for driverless systems won't decline by more than ten percent to $27,000 by then. This is due to information technology (IT) needs centered around cybersecurity and safety. As a result, it is not expected that fully autonomous trucks will be deployed on U.S. roadways for at least another two decades. Specifically, IHS Automotive estimates annual sales of autonomous, heavy-duty trucks could reach 60,000 annually by 2035. That would amount to 15 percent of sales for trucks in the big, Class 8 weight segment, assuming that the technology is adopted and reaches "appreciable levels" by the end of the next decade, IHS forecasters said. Still, the number of self-driving heavy-duty trucks will be just a fraction of number of autonomous cars expected to be on U.S. roads by 2035.

Nonetheless, Daimler introduced in 2015 its Freightliner Inspiration Truck, two of which were approved for use on Nevada highways in May 2015. The German automaker believes that adding autonomous features to heavy-duty trucks can transform long-haul trucking, relieving driver stress, improving safety and potentially alleviating a chronic industry driver shortage.

Daimler tested three autonomous driving big-rigs in a tight "platoon" formation on an open stretch of highway. The test, in live traffic, demonstrated that such formations can reduce fuel consumption by up to seven percent while also cutting emissions. Connected trucks traveling in a platoon require spacing of about 50 feet instead of the 150 feet required by regular big-rigs. Smaller spacing produces a significant reduction in aerodynamic drag—similar to the slipstream bicycle racers employ in the giant pelotons in the Tour de France. The technology also reduces the trucking industry's labor expenses. Labor typically makes one-third of a firm's cost of operating each truck. While such technology holds promise, issues must be resolved, such as insurance and safety, maintenance, and management of regulatory requirements, among others, before AV trucks gain market penetration.

Regardless of these forecasts, acceptance of AV trucks by the unions is an issue. Kara Deniz, a spokeswoman for the International Brotherhood of Teamsters, indicated that the union has not issued any policy decisions of automation because there are more questions than answers about the impact of self-driving vehicles. She stated that the union believes skilled drivers will be needed well into the future.

Another serious concern is that AV trucks can be used as weapons in terrorist attacks. The concern became widely explored when, on July 14, 2016, a 19-ton cargo truck drove into a crowd in Nice, France, killing 84 people. The driver claimed he carried out the attack on behalf of the Islamic State.

Autonomous trucks operate using Wi-Fi-connected artificial intelligence. Anything that uses Wi-Fi can theoretically be hacked, as revealed last year in St. Louis, Mo., when hackers hijacked a Jeep Cherokee's brakes, dashboard functions, steering, and transmission by remotely hacking into its Wi-Fi-connected entertainment system from a laptop ten miles away. If a truck communicates its location, speed, and fuel level to headquarters, somebody could intercept that message and trick the truck into thinking the person was "fleet headquarters." A malicious actor or group could reprogram a truck and use it as a missile as a way to target innocent people.

Autonomous Vehicles/Ambulances

There are numerous benefits—and some downsides as well—to developing an autonomous emergency vehicle, such as an autonomous ambulance. Currently, an ambulance has room for two EMTs on board. The remainder of the space in or on the vehicle is maximized to provide as much room for the patient, for EMTs to work on/around the patient, and for equipment and storage. One of the two EMTs onboard an ambulance today is responsible for driving the vehicle. However, when an emergency is in progress, having a second EMT available to work on a patient while in commute, can potentially save lives. The potential downside of autonomous ambulances may be a reduction in the number of EMTs needed in the workforce.

Drone ambulances (or AirMules) will also be used to transport patients to a hospital. Drone ambulances can land virtually anywhere, as they occupy about the same space as a small car. An ambulance drone can be deployed with one EMT who can focus solely on the patient, while the drone transports the patient to the hospital autonomously. One ideal candidate to develop AV ambulance drones is the US military.

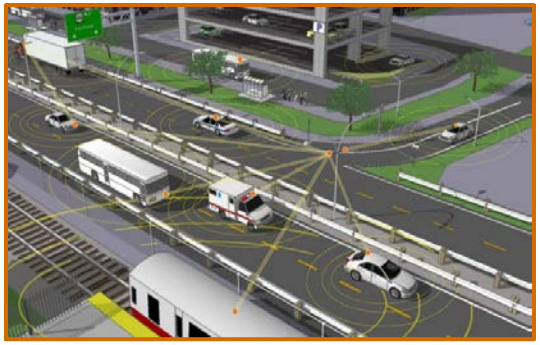
AV Infrastructure

As municipalities face growing population pressures, they will look to connect their public infrastructure to deploy services more efficiently and improve the quality of life. Examples of how IoT devices and networks are already being used by cities include:

- Connected surveillance cameras are helping police monitor areas with high crime rates.
- Connected traffic lights are helping cities adjust traffic patterns to relieve congestion.
- Connected streetlights are helping cities save energy costs.

Vehicle-to-Infrastructure (V2I) equipment may vary depending on the location and the type of application being used. In general, V2I connected components include an array of roadside equipment (RSE) that communicates with vehicles. For example, a V2I-equipped intersection would include:

- Roadside units (RSU) – a device that operates from a fixed position and transmits data to vehicles. This typically refers to a Direct Short-Range Communication (DSRC) radio which is used for safety-critical applications that cannot tolerate interruption, although other technologies may be used for non-safety-critical applications.



- A traffic signal controller that generates the Signal Phase and Timing (SPaT) message, which includes the signal phase (green, yellow, and red) and the minimum and maximum allowable time remaining for the phase for each approach lane to an intersection. The controller transfers that information to the RSU, which broadcasts the message to vehicles.

- A traffic management center that collects and processes aggregated data from the roads and vehicles. These centers may use aggregated data that are collected from vehicles (speed, location, and trajectory) and stripped of identifying information to gain insights into congestion and road conditions as well.

- Communications links (such as fiber optic cables or wireless technologies) between roadside equipment and the traffic management center.

- Support functions, such as underlying technologies and processes to ensure that the data being transmitted are secure.

In a September, 2015, report entitled *Vehicle-to-Infrastructure Technologies Expected to Offer Benefits, but Deployment Challenges Exist,* the U.S. General Accounting Office noted "while early pilot-project deployment of V2I technologies is occurring, V2I technologies **are not likely to be extensively deployed in the United States for the next few decades.** According to U.S. DOT, V2I technologies will likely be slowly deployed in the United States over a 20-year period as existing infrastructure systems are replaced or upgraded."

Roadway Traveler Information Systems

This technology updates drivers on current roadway conditions—including delays, incidents, weather-related messages, travel times, emergency alerts, and alternate routes. Providing this information to drivers before and during trips allows them to make more effective decisions about changing routes, modes, departure times, or even destinations. More-informed drivers result in more efficient use of roadway capacity. This means less gridlock and better traffic flow.

Travel information is generated by sensors reporting to a traffic management center or through private entities using data from in-vehicle location devices, or from smart phones communicating location and speed. This information is then disseminated via traditional broadcast media, internet, mobile devices, or roadside messaging. Personalized travel messages and alerts enable individuals to access trip-specific information on demand, or have it sent to them via text message. Once familiar with these services, nearly 80 percent of drivers use traveler information to make daily decisions about route or departure time.

The same infrastructure that provides traveler information also enables more effective incident management and performance measurement—which can mean a greater return on the investment in the system. For example, Houston TranStar's sensor network collects data and disseminates traveler information to the public, the media, and third-party providers. Each year, nearly two million incident and travel time messages are sent to more than 200 roadside message signs in the region. Benefit-to-cost ratio is estimated to be more than 11 to one.

Maintaining and upgrading these systems to reflect the most up-to-date technology requires implementation and maintenance funding. The good news is that technology and communication advances are driving costs down each year.

Electric Vehicles (EVs)

The present-day market share for electric vehicles is tiny but growing, says the director of the Center of Automotive Management (CAM) at the University of Applied Sciences. But, the caution is that success will not come overnight.

Only 66,000 electric cars were sold in the U.S. in 2016. The market share is about two percent. In Europe, only Norway seems to be accepting of electric vehicles; market share is three percent. For Germany, the sales of purely electric vehicles fell six percent in the first half of 2016. Three issues affect the sales of electric vehicles: price, range, and infrastructure.

Price

Electric cars are still significantly more expensive than comparable vehicles with internal combustion engines.

Nonetheless, electric cars are becoming increasingly important for auto manufacturers because CO_2 limits are increasingly difficult to reach. Manufacturers will not succeed in making their fleets meet ever more stringent air pollution limits without electrification. So, it is expected that by 2025, the global market share of electric vehicles will be ten to 13 percent.

General Motors is now selling the Chevrolet Bolt at a base price of under $30,000, after tax credits. According to GM, data indicate a 200-mile range is the point at which there's a big change in the number of people willing to purchase an electric vehicle. Before the Bolt, people had to pay $60,000 to $200,000 for an EV that could go 200 miles on a charge. The Bolt is also a keystone of GM's strategy for autonomous vehicle and ride-sharing services like Lyft, in which GM has invested $500 million.

Range

Customers expect a minimum range of 250–300 miles from a car. But electric cars now only cover distances of 90–110 miles. If the air conditioning is operating, that range drops to only 60 miles, which is completely insufficient to satisfy customer needs. Electric mobility is out of the question for those who don't have a garage with a power connection. Even for those who do, long trips need a dense network of fast-charging stations along the way.

Infrastructure

While there are 16,000 charging stations in the U.S in 2016 (a 40-fold increase since 2008), many people justifiably fear that they'll run out of charge in an EV and be stranded. To change this, the White House announced in 2016 a new designation of up to $4.5 billion in Energy Department loan guarantees to: 1) support new types of EV charging infrastructure; 2) create plans to designate and develop key electric vehicle "charging corridors" across the country; 3) plan for the government to procure large numbers of electric vehicles; and, 4) support research initiatives at the Department of Energy and its laboratories to improve EV charging technologies. The latter includes technologies that can power an EV with a 200-mile range in the space of ten minutes—far faster than what's currently available.

At the same time, the White House announced that some of the country's largest power companies and automakers—ranging from Duke Energy to the Southern Company, and from Ford to Tesla—had signed a joint statement pledging to "drive the market transformation to electric vehicles by making it easy for consumers to charge their vehicles." The partnership signals that even as Tesla and other automakers build more electric cars, companies like Duke, the country's largest electric utility, are taking steps to create more facilities to accommodate them. Duke recently announced a plan to offer cities in North Carolina $1 million to develop charging facilities, even though there are only about 4,700 EVs in the state.

On a parallel path, the company known as Proterra has developed electric buses with available battery storage capacities from 440–660 kWh, which is up to six times more than the recently announced Tesla Model S/X P100DL. Proterra claims its electric buses have driven more than 2.6 million miles. It also claims 2016 has been "a breakthrough year in the mass transit sector" for the company as 2016 sales in North America reached 312 e-buses by September, which is double the sales in 2015.

Bus Rapid Transit (BRT)

Miami-Dade County has studied three corridors which will likely see BRT service in the next 15 to 25 years: immediate—the SR 836 Corridor; next, the Flagler route; and, later perhaps, along Kendall Drive and Northwest 27th Avenue. Other premium transit services, such as high-speed rail, Maglev, and Hyperloop are not likely options as their grade-separated systems substantially increasing cost compared to BRT in these corridors.

Gondola

The Miami-Dade TPO is interested in understanding the applicability and potential benefits of Aerial Cable Transit (ACT), commonly known as gondolas. ACT offers the potential for reduced right-of-way impacts in that ACT is not a continuous corridor but, instead, is limited to

the footprint of the cable support poles and station areas. This type elevated operation allows ACT systems to bypass obstacles, avoid retrofitting streets, reduce the need for high-value right-of-way acquisition and minimize potentially adverse impacts to valuable public and private assets. As such, some heavily-populated, densely developed urban areas have implemented ACT over other traditional transit infrastructure.

An MDC TPO feasibility study focused on implementing ACT over distances of one to three miles as an extension of the existing rapid transit network to connect to Florida International University (FIU), the Miami Intermodal Center (MIC), Marlins Park/Little Havana, the Health District, Downtown Miami, the Port of Miami, and South Miami Beach. The study considered existing and planned ACT systems throughout the world, evaluating each for their unique characteristics. After examining a number of options, the study chose the 1.2 mile, two-station Marlins Park (Little Havana)-to-Downtown alignment for the preferred ACT route because the short length and two-station arrangement would be economically attractive as a demonstration project with relatively low capital and operating costs. This option serves clearly-established markets related to parking demand, entertainment, and cultural activities tapping into several reliable and substantial sources of passenger demand.

Rail Freight

Freight railways now monitor facilities, assets, systems and shipments in real time. On-time delivery, labor utilization and productivity are all improved. Downtime and delays are minimized.

The transformation of freight railways to an even more interconnected, transparent, and agile form is integral to the future success of the industry. Becoming digitally focused and delivering actionable insights by way of machine-to-machine communications and mobile devices will enable rail operations to run more effectively and efficiently. Mountains of data are generated by customers and partners using digital platforms and mobile devices. Rolling stock, track, sensors, digital video, and transaction systems generate even more data. The challenge is to harness and connect these data to improve business results. Because digital is the new normal, this transformation is not optional if a railway wants to remain competitive and thrive. To achieve results that will power the future of the industry, railways need to:

- Collaborate beyond their comfort zones by partnering with adjacent service providers, creating an ecosystem of value; and,
- Use cognitive computing to harness data both inside and outside their enterprises to drive revenue up, costs down, and win market share.

Marine Freight

Efficiency gains and developments in automation will have the biggest influence on the global system of goods movement in the coming years. Maritime ports are getting more automated. Ships essentially can plug into the ports where they dock, tapping into local power instead of idling their huge engines and burning hundreds of tons of fuel to sit still. Automated cranes can quickly unload and reload ships to reduce their time in port. And the same systems can quickly move those thousands of

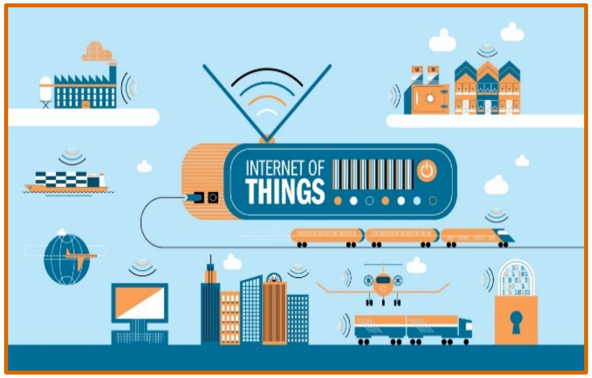
containers onto the trucks and trains. While all this will cost many millions, maybe billions, the Port of Miami is expected to meet this need and be "robotic" by 2045.

Logistics

IoT devices will save logistics businesses billions by helping move goods and assets through their supply chains and warehouses faster and more cheaply because:

- Fleets of connected vehicles will cut travel time and costs by taking the most efficient route possible thanks to real-time traffic updates; and,
- Tracking sensors placed on parcels and shipping containers will help reduce costs associated with lost or damaged goods.

Increased automation will help companies reduce labor costs and increase productivity in warehouses which will be fast adopters of industrial robots. Amazon is already a good example, with nearly 20,000 Kiva robots operating in its warehouses. Each Kiva robot saves more than $500,000 in annual labor costs.



To successfully implement IoT in logistics will require strong collaboration, along with high levels of participation between different players and competitors within the supply chain, and a common willingness to invest. The shared end goal will be to create a thriving IoT ecosystem. To achieve this, there will be some key success factors required:

- Clear and standardized approach for the use of unique identifiers for various types of assets among different industries on a global scale;
- Seamless interoperability for exchanging sensor information in heterogeneous environments;
- Trust and ownership of data and overcoming privacy issues in the IoT-powered supply chain;
- Clear focus on reference architecture for the IoT; and,
- Change in the business mindset to embrace the full potential of the Internet of Things.

3D Printing

The evolution of 3D printing has substantial implications for freight movement. As more parts and products are manufactured in finished form and manufacturing sites locate closer to the end destination, the need to procure parts from multiple sources around the globe could be significantly reduced and, in turn, decrease the need for global transportation.

Although 3D printing is mostly used to create prototypes today, it will likely contribute to the re-shoring trend. Remote production in a lower

-cost market could be replaced by manufacturing facilities located at home closer to the consumer, allowing for a more responsive manufacturing process and greater quality control. As these efforts gain momentum, the need to ship many parts, products, or raw materials to market will be greatly reduced.

A recent analysis found that as much as 41 percent of air cargo and 37 percent of ocean container shipments are threatened by 3D printing.[9] Roughly a quarter of the trucking freight business is also vulnerable, due to the potential decline in goods that start as air cargo or in containers on ships and ultimately need some form of overland transport. Rail companies are the least vulnerable. Footwear, toys, ceramic products, electronics, and plastics have the highest potential for disruption, while sectors, such as perishables and pharmaceuticals, find 3D printing less threatening.

Drones

Advances in unmanned aerial vehicle (UAV) technology have enabled "drones" to become easier to use and afford. In a budget-limited environment, these flexible, remote sensing devices can help address transportation agency needs in operations, maintenance, and asset management while increasing safety and decreasing cost. UAV technologies provide many advantages to help cost-effectively assess, manage, and maintain transportation resources.

So far, the top uses of commercial drones have included aerial photography, real estate promotion, various inspections, agriculture and filmmaking, according to the Association for Unmanned Vehicle Systems International, the industry trade group. Companies like Amazon and Zappos are preparing to use drones for deliveries. Shops, department stores, and food stores will follow over time as the cost of drone use lowers and competition increases. Firefighting, search-and-rescue, conservation, and academic research are seen as additional beneficiaries of drone use. The drone association expects the industry will create more than 100,000 jobs and generate more than $82 billion for the economy in the first ten years of being integrated into the national airspace under recently released federal rules.

Traffic Management Technology

Streetlight and traffic signal poles—NOT telephone/utility poles—are very important to fully deploying "future technologies" or the Internet of Things. With telephone poles, the murky regulatory system is easily used by incumbent telecom companies with a deep and rational interest in maintaining the status quo.

[9] 2015 Commercial Transportation Trends: https://blog.integracore.com/freight/the-future-impact-of-3d-printing-on-the-transportation-industry/U38T; https://www.strategyand.pwc.com/trends/2015-commercial-transportation-trends

Streetlights and traffic signal poles are different. They're part of the public right-of-way; they're assets that are often owned and maintained by local government themselves, or by a local power company. With streetlights and signal poles, a city stands a chance of establishing a competitive and innovative world of Internet of Things through sensors and data transmission as long as it acts decisively to open those street light and signal poles on a fair basis.

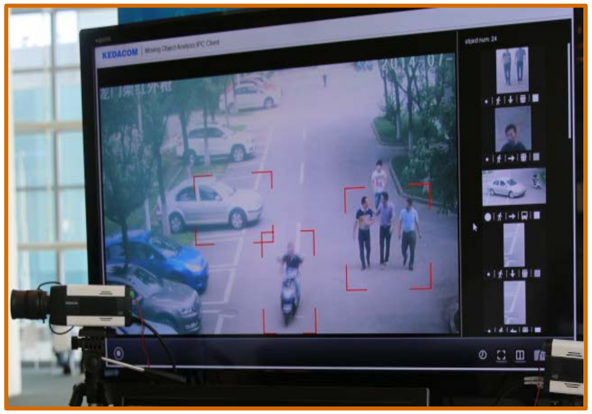
At the risk of getting too technical, advanced wireless transmissions (i.e., whatever is beyond 4G) access to fiber optic cables at frequent geographic intervals is essential. That fiber, in turn, needs to be "dark"—meaning that it's unused and can transmit vast amounts of data. And access to that dark fiber needs to be available at a reasonable price.

The "ideal" pole will be like an electrical outlet in a home: available at a standard, reasonable price to any wireless carrier wanting to connect; connected to a standard wire (in the pole context, dark fiber); and, incorruptible. No one—no vendor of devices or extension cords—should get better access to that outlet than anyone else, or be able to slow down someone else's arrival on that pole. Communities that get control of their streetlight poles and connect them to municipally-overseen, reasonably priced dark fiber can chart their own Internet of Things future, rather than leave their destinies in the hands of vendors whose priorities are driven by the desire to control whole markets and keep share prices and dividends high rather than provide public benefits.

Chicago is deploying sensors on light poles to monitor, photograph, and "listen" to the city. The effort is costing $7 million, and may be the largest urban data collection of its kind once all 500 nodes are in place. The nodes have an array of sensors with enough computing capability to conduct data processing on the device and minimize the amount of bandwidth needed to transmit data. Cameras will track the movement of pedestrians, vehicles, even whether water is pooling on the street. A microphone will monitor noise levels. There will also be temperature, pressure, light, and vibration sensors. Particle sensors will detect pollen. Gas sensors will check air quality, recording carbon monoxide, nitrogen dioxide, sulfur dioxide, and ozone. Even the magnetic field will be monitored. The data will be publicly available through the ***OpenGrid.io*** portal once enough sensors are deployed. The entire installation will be completed in 2018.

New security cameras launched in China, by Intel's Internet of Things Group, provide data to analyze vehicle and pedestrian traffic with real-time results. Using an Intel Atom E3845 processor embedded within a security camera for onboard analysis—a task previously reserved for high-end, back-end servers—unnecessary background footage is automatically ignored or removed while pedestrians, vehicles, and bicycles are extracted and categorized in real time.

Kedacom, a video conference and network surveillance system manufacturer in China, is the first corporation to adopt Intel's design in its smart Internet Protocol camera, to provide car, people and object differentiation. An Internet protocol (IP) camera is a digital video camera attached to a computer network or the Internet allowing it to send and receive data, often used for surveillance. With the hardware and software combination, hour-long videos can be "compressed" into a much shorter length of time, sometimes a few minutes, as well as into a smaller file. This is accomplished with the camera itself actually analyzing the video, identifying and isolating various objects in the scene, and then overlaying these identified objects in a much shorter video. The resulting video, which is delivered to the back-end servers, shows a static background with the objects overlaid in motion.



Intel China's Internet of Things group envisions the smart IP camera technology will be used for traffic monitoring and analysis, within shopping malls, and other places where crowd surveillance is needed. The technology could eventually become incorporated into consumer video monitoring products, moving beyond the traditional "hot spot" and "zone watching" they currently do.

Pedestrian Safety Technology

A field study of 100 lighted crosswalks with 427 million vehicle crossings demonstrated that the accident rate was 80 percent less than predicted for uncontrolled, unlit crosswalks with a solar-powered, in-road light system that alerts motorists to the presence of a pedestrian crossing or preparing to cross the street. Amber lights are embedded in the pavement on both sides of the crosswalk and oriented to face oncoming traffic. In-road warning lights produce a daytime-visible light focused directly in the driver's line of sight clearly indicating the curve, hazard, crosswalk, variable lane, or lane edge. This requires no interpretation by the driver, resulting in increased visibility.

When the pedestrian activates the system, either by using a push-button or through detection from an automated device, the lights begin to flash in unison, warning the motorist that a pedestrian is in the vicinity of the crosswalk ahead. The flashing LEDs shut off after a set period of time, i.e., the time required for a pedestrian to safely cross the street.

Another "smart" device to protect the pedestrian is a reflector that can be wirelessly controlled via a mobile phone application created by VTT Technical Research Centre (Espoo, Finland) and safety reflector company Coreplast Laitila (Laitila, Finland). When a pedestrian is approaching a crossing the reflector—which features sensors, LED lights, wireless charging, and communications—can be made to blink and alert car drivers. In the future, the reflector could communicate directly with smart traffic lights or cars to warn, for example, a turning truck driver that a pedestrian is in the area of a crossing.

It is also possible to connect the reflector to other on-line activities such as mobile gaming, which could make it more attractive for teenagers to use. Reflectors could be set to shine in a common color or to react in real-time to gaming actions and to the track to which the user is listening.

Accessible Transportation Technologies

The Accessible Transportation Technologies Research Initiative (ATTRI) leads efforts to research, develop, and implement transformative solutions to help all people, particularly those with disabilities, effectively plan and execute their travel, addressing individual mobility needs. The initiative will enhance the capability of travelers to reliably, safely, and independently accomplish their unique travel plans. ATTRI leverages recent advances in vehicle, infrastructure, and pedestrian-based technologies, as well as accessible data, mobile computing, robotics, artificial intelligence, object detection, and navigation. These technologies are enabled by ever present wireless communications that connect travelers and their mobile devices, vehicles, and roadside infrastructure.

There are four priority areas for the development of ATTRI applications:

- Smart Wayfinding and Navigation Systems;
- Pre-trip Concierge and Virtualization;
- Shared Use, Automation, and Robotics; and,
- Safe Intersection Crossing.

Smart Wayfinding and Navigation Systems

Applications developed within the smart wayfinding and navigation realm will provide real-time, in-route assistance and situational awareness to ensure travelers can safely reach their destinations while traveling independently. These technologies could include, but are not limited to: wayfinding and navigation systems for indoor and outdoor use; beacons or electronic tags to interact with the built and pedestrian environments; transmittable data in multiple communication formats (visual/audible) including multiple languages; wearable technologies acting as discreet assistive navigation tools; connection with assistive mobile devices already in use; and, the use of community volunteers providing accessibility data on neighborhoods, buildings, and infrastructure elements, including crowd-sourced public/private maps for indoor and outdoor spaces for the real-time use of travelers with disabilities. Processes that affect wayfinding and navigation include: familiarization; localization and orientation; path planning; locomotion; guidance; and, of course, communication.

Pre-trip Concierge and Virtualization

Applications in this area could include new technology solutions that assist travelers with activities in everyday life, such as walking or getting to work seamlessly with unique traveler mobility needs and human transportation services. Applications could include improved personal mobility such as the ability to learn and remember routes across the transportation network by integrating data, personal needs, and profiles alongside available services. Applications could also relay traveler information for multiple transportation choices including cost, accessibility accommodations, distances, travel times, and integration with other modes for first mile, last mile options. Machine vision, Artificial Intelligence, assistive robots, and facial recognition software could help solve a variety of travel-related issues for people with

disabilities, through the use of devices creating "virtual caregivers" helping guide travelers and assisting with decision-making while connecting with their human caregivers and family members. For example, if applications in this area were applied to transit systems and stations, virtual exploration devices could help low-vision travelers familiarize themselves with the layout of a building or of the overall transportation network. In addition, for users of paratransit and taxicab-type services, applications could track vehicle location and how long it would be before it arrives at the pickup location.

Shared Use, Automation and Robotics

Automation and robotic technologies have the potential to bring about many changes to transportation barriers. Automated vehicles have the potential to provide greater safety, mobility, and energy efficiency. In addition, semi- or fully-autonomous vehicles, electric golf carts, and Segways have the potential to address first mile, last mile challenges.

Safe Intersection Crossing

Applications in this area will provide guidance, notifications, and alerts in various communication formats that assist pedestrians and all users of the transportation system, navigate safely through intersections. These applications should provide GIS information on curb cuts, bus stops, sidewalk grade and slope, and any disruption of the built environment (damaged infrastructure, dead ends, potholes) to aid travelers. Additional examples could include: futuristic and innovate approaches to solving this issue with automated intersection crossing assistance; technical design solutions; and, electronic tags to interact with the built environment.

Bikes

Innovations in the way of gadgetry are constant among avid bicyclists. Factors that affect mode shift to bicycles include climate, trip length, and facilities. Trip length is a function of housing location choice and land use patterns. Facilities include bicycle availability, a travel path, and storage at the destination.

In terms of availability, Citi is the title sponsor of the Miami Beach bike share program. It has expanded to downtown Miami and Coconut Grove with 1,750 bikes at 170 stations. Citi will be title sponsor of the program until 2019, and DECOBIKE will continue as the program operator. It is expected that in 2045 a bike-sharing program will exist on an expanded basis.

In terms of paths, separated facilities play an integral part in the overall bicycle transportation network. Cyclists traveling primarily on separated paths tend to make significantly longer trips. Separated paths minimize conflicts with vehicles and pedestrians, but are costly and require right-of-way. The current MDC LRTP includes a set-aside with planning to include bike/ped facilities, where feasible.

The 2004 TPO *Rail Convertibility Study* assessed the short- and long-term corridor potential for public transportation and bicycle/pedestrian activities of unused or underused rail corridors in the county. The *Miami-Dade County CSX Corridor Evaluation Study*, performed for the TPO in 2009, went into greater detail on the CSX rail lines. Planning studies continue with respect to best use of the rail corridors and where and how bicycle facilities can be included.

An opportunity is building pedestrian/bicycle links across canals, where there is no road, to increase mobility and connectivity. This would provide a modal advantage, not shared by vehicles, to encourage non-motorized trips at no expense to vehicular right-of-way.

An important factor in bicycle trip making is secure bicycle storage at destinations. Businesses can play an important role by providing such storage.

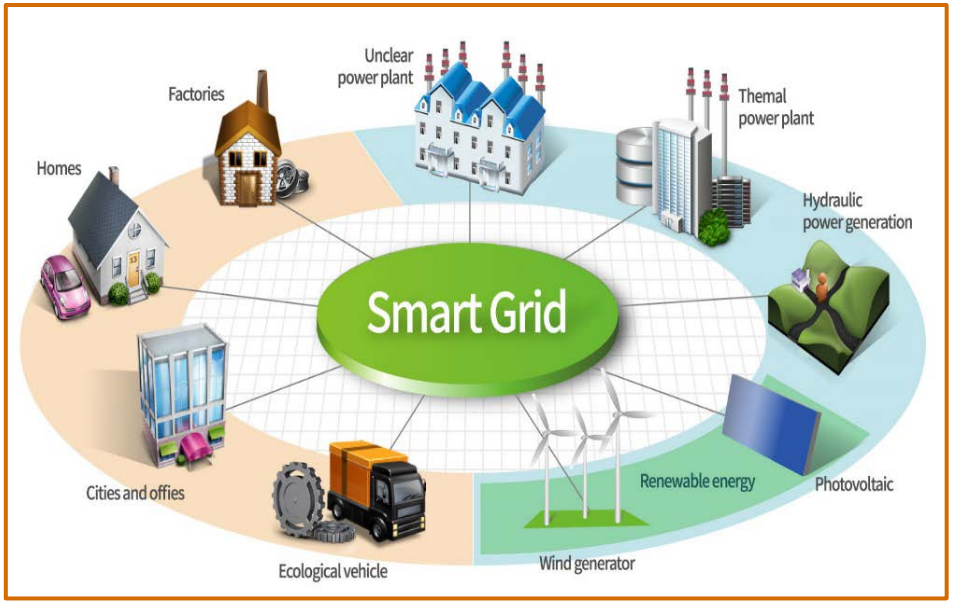
Parking

Parking issues are prevalent anywhere crowds of people gather. Autonomous vehicles can help address the issue. Once a person arrives at their destination in an autonomous vehicle it can self-park. Auto park and summons functions are required to reach Level 4 of vehicle automation (full self-driving). The amount of space required to park is greatly reduced compared to parking a traditional passenger vehicle. If the vehicle does not have any passengers inside when parking, then the doors do not need to open or close. Side mirrors are not needed for an autonomous vehicle to auto park. This results in the ability to park autonomous vehicles much closer together than traditional passenger cars. This saves on needed space. And, in the case of new parking structures, reduces the footprint to accommodate the same number of vehicles while at an existing facility, the space needed is reduced and the revenue, if it is paid-parking, is increased. Tesla Motors has already developed the technology to allow their vehicles to not only auto (self) park, but to also be summoned from its parking space to pick up passengers who are waiting at the door or curbside.

Energy

Residential electricity rates in Florida average 11.42¢/kWh, which ranks the state 22nd in the nation. The primary source of electricity is burning natural gas, and Florida is in the top five states in the nation in CO_2 emissions.

The ***smart grid*** is one of the most well-developed and widely recognized IoT systems. Smart grids rely on smart meters, which relay information about a system's energy usage to a central management system to efficiently allocate resources. Smart grids can be used to identify



and address outages and promote conservation through demand-based pricing. In addition to benefiting cities, new devices are also bringing the benefits of energy-related IoT to consumers. Citizens can reduce their energy bills with devices like ***Nest***, which can sense when someone is home and adjust temperatures automatically, and ***smart-me***, which allows users to monitor energy use, turn off unused devices, and manage the temperature in a home or office from a smartphone.

Solar energy has a huge potential for expansion. To sustain its use, local intelligent power grids need to be developed for solar energy generation, storage, distribution and utilization, at an affordable cost. These grids also need to provide enhanced securities of the energy supply. This can be achieved by establishing flexible transition between grid interconnected and non-interconnected operating modes.

With today's technology, solar energy can be captured in space as typified by solar powered satellites, and solar power on the international space station. The long-term goal is to capture solar energy in space, and then transmit that solar energy (or power) to earth wirelessly. The power-collecting platforms would most likely operate in geosynchronous orbit where they would be illuminated 24 hours a day. So, unlike systems for the terrestrial capture of solar, a space-based system would not be limited by the day-night cycle. Furthermore, if the transmission frequency is properly chosen, delivery of power can be carried out essentially independent of weather conditions. Space Solar Power could provide base load electricity.

Property Assessed Clean Energy Programs (PACE) are in place in unincorporated Miami-Dade County for solar panels, and other energy saving upgrades as a financing option to spread installation costs over a number of years. And, as a government, Miami-Dade has an "Electricity Master Plan" to govern use of electricity. The *2006 Florida Renewable Energy Technologies and Energy Efficiency Act* continues to provide consumers with rebates and tax credits for photovoltaic systems.

Solar Roadways

The Missouri Department of Transportation (MODOT) is building a pilot project along one of the most famous roadways in America, Route 66 (I-44). A solar roadway project is located at a Welcome Center (rest stop) near Conway, Mo., and is scheduled to be completed before the 2016 winter season. Phase 1 of the pilot project will install solar roadway

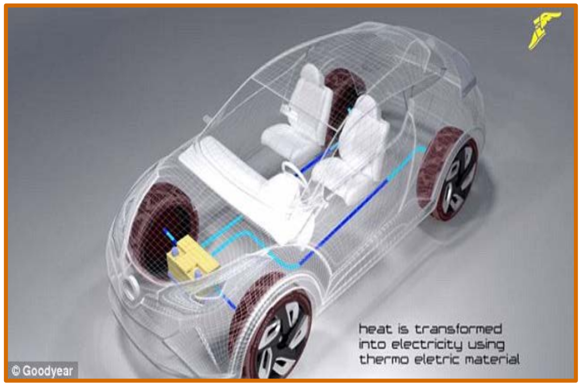
panels over the existing walkway surface. The MODOT hopes to expand upon the pilot project to add solar panels on top of the existing parking lot surface and eventually the roadway surfaces along Route 66 (I-44). The solar panels will generate electricity to power the rest stop, and will also generate heat to prevent snow and ice from accumulating on the panel surface during the winter. If this technology is successful, such that it can be placed onto roadways across the U.S., it could be the first roadway project that can pay for itself in the long run through generating and re-selling electricity.

Across the entire U.S., there are thousands of miles of roadway and walkway surfaces where solar roadway panels could potentially be installed. It has been estimated that, if all of America's roadway and walkway surfaces were covered with solar panels, they would collectively generate three times more energy than we consume. If the technology proves successful, by 2045 this could be happening in Miami-Dade County in rest areas, on private parking lots, and public roads.

Energy from Road Friction

A derivative of a solar roadway is to derive energy from road friction. Engineers at Goodyear recently showcased a concept tire called the BH-O3 that has an inner-coating that generates energy, which is fed back into the car's electrical system. The material can generate electricity in two ways, from heating or from the tire contact with the road. The heat can be generated from sitting in a hot parking lot or driving.

Engineers at the University of Wisconsin-Madison have developed a nano-generator which harvests energy produced by friction between an automotive vehicle's tire and the road surface. It works through what is called "triboelectric effect" or more-commonly known as static electricity. The tire uses an electrode to create an electrical current as the tire strikes the pavement which is stored in the nano-generator on board the vehicle. Nano-generator is the term researchers use to describe a small electronic chip that can use mechanical movements to generate electricity. While it is acknowledged that this technology won't replace gas or electric charging stations any time soon, the research team achieved a peak energy conversion efficiency of 10.4 percent—meaning they were able to recapture and use 10.4 percent of their test vehicle's spent energy. The implications for the electric and hybrid motor industry could be significant.



Smart Cities

IoT is allowing cities to transition towards real-time, data-driven management across urban systems, including water, energy, waste management, and transportation. But, while IoT offers opportunities to enhance efficiency, improve public safety, and support development, it also presents several challenges that cities will have to negotiate in order to realize these benefits. Four of the most important are:

- ***Design and Analysis Together:*** Cities often lack the skills or the technology to use the data they have. In order to make the Internet of Things valuable, cities must ensure that the data-gathering systems are designed together with analytics; the data collected should be easily understood and put to use by the governments that collect it.

- ***Recruiting Tech-savvy Leaders:*** The ability to remain "smart" can only be accomplished by engaging people who can envision and implement cutting-edge systems.

- ***Privacy and Security:*** Cities must ensure the privacy and security of citizen data. Defense from hacking/cyberattacks is a prevalent concern for a government's constituents, systems and infrastructure. In the latter cases, hacking smart meters can cost millions, but a more malicious intruder could compromise safety for residents. In order to be a "Smart City," privacy and security are top priorities.

With the IoT, the role of humans diminishes, to the point that, in many cases, they are removed from the equation: devices input, com-

municate, analyze, and act upon the information. A single vulnerable device can leave an entire ecosystem open to being attacked. That is why the IoT systems must be secure, vigilant and resilient.

- ***Secure:*** Effective risk management begins by preventing system breaches or compromises. Lack of interoperability and unwillingness of various organizations to adhere to common standards are more vulnerable to attack.

- ***Vigilant:*** Security must be complemented by vigilance to determine whether a system is still secure or has been compromised. As technology evolves, so too will threats. When safeguarding an IoT ecosystem, once security is established, remaining vigilant to new or unexpected challenges is crucial in order to maintain that security.

- ***Resilient:*** When a breach occurs, limiting the damage and re-establishing normal operations are much more easily and effectively done when there are processes in place to quickly neutralize threats, prevent further spread, and recover. But, there is no amount of security and vigilance that can guarantee a breach or compromise will never occur.

Cities are expected to spend $41 trillion on IoT technologies in the next 20 years in the following areas, in addition to energy, discussed above:

Environmental Conditions

Chicago's Array of Things, discussed earlier, is a model for the deployment of citywide sensor networks. Sensors on lamp posts monitor environmental conditions including temperature, noise, and air quality. The data are used to manage incidents, identify patterns in microclimates, and make predictions about vehicle and pedestrian congestion. These systems feed data into open portals, where the data are available to the public, allowing citizens to take part in tracking and responding to local environmental issues.

Water

Many cities face severe problems with water—too much or too little rain. In California, local governments are using IoT to develop innovative ways to plan and manage irrigation, facilitating extensive water conservation, and allocating scarce resources. Other areas, like Miami-Dade, struggle to address flooding and wastewater management during storms. In the latter cases, cities are often forced to dump raw sewage into waterways. Using tools developed by Opti, American cities can draw together systems that monitor the weather and those that control rainwater storage to determine when to hold onto water supplies and when to make room for new rainfall. With appropriate planning, cities can reduce overflow in combined sewers and minimize the pollution of waterways.

The citizen-led Oxford Flood Network has developed a system of sensors to gather data on water level from stream and groundwater sources and anticipate flood incidents. The system relies on sensors that use ultrasonic rangefinders, positioned above local waterways, to measure changes in the water level and indicate flood risks. The network makes use of TV

whitespace between channels—made available by the local telecom provider—to transmit data, making information publicly available in real time.

Waste

IoT companies are developing two-way communication tools to reduce labor and increase the efficiency of waste management systems. Companies like Big Belly have sensor-enabled trash receptacles measure waste levels in public bins and share the data with local authorities, allowing them to enhance efficiency by planning collection routes where and when pickup is needed. The same logic is being extended to the home.

In addition to these broad areas of the Smart City, other key elements of the LRTP in 2045 will include:

Transit

Be-In Be-Out (BIBO) refers to technology which allows passengers to enter and exit a transit system without checking in or out via fare cards or smart cards requiring contact or close proximity to readers, including those in gated (i.e., Metrorail) and non-gated (i.e., Tri-Rail) systems. The lack of an additional fare step allows better flow in and out of transit by removing queues found at kiosks, gates, or via fare collection boxes.

BIBO systems, through usage of reception devices, can detect the presence of smartcards, requiring no action from the rider except they must have their smartcard and they must have set it up before the transit trip. Cards are linked to a payment account, and fares are assessed at the end of the trip. Because BIBO systems can indicate where a person boards and where they exit, it can calculate the most appropriate fare for the user, allowing for applications in both fixed and variable fare systems. Due to the nature of the payment setup, it is imperative that a BIBO system acknowledge that the burden of information (fare knowledge) is on the consumer.

There are several challenges to implementing BIBO. Like with other fare systems, fare enforcement can be an issue; with BIBO, one means of preventing fare evasion is to have passengers flash their smartcard to the operator as they are boarding, or via random checks similar to how honor systems work. What remains to be seen is how much proximity is the setting for the devices to work, and if it is on a sleep mode until activated. Battery life will affect the device, and thus fare payment.

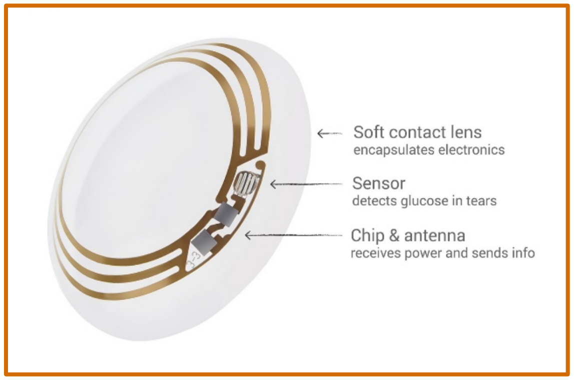
Security of the devices is important as well. Fraud is an issue that needs to be addressed. These devices are linked to accounts for fare payment, so bank and credit card security is a concern. Lastly, there is the issue of data privacy. With data storage, personal information regarding travel patterns could be tracked.

There is also the concern that signals can be intercepted and otherwise copied for re-use. As discounted fares are part of transit passes, the issue of identity applies.

Wellness/Healthcare

Using IoT to monitor health of patients extends beyond preventing industrial accidents to improving the wellness of the population in general. The consumer trend of using wearable technologies to enable the "quantified self" has increased dramatically in recent years, exemplified by devices from Apple, Fitbit, Jawbone, Pebble, and Sony. The number of personal health and fitness trackers (including smart watches) in use is expected to grow from over 40 million in 2015 to 100 million by 2020.

Healthcare organizations are moving beyond wearables, which generally track factors such as hours of sleep, steps taken, or calories burned. Some are leveraging IoT for an array of different and more complicated wellness monitoring applications. For example, Novartis and Google are developing smart contact lenses to



measure blood glucose levels for diabetes patients.

One of the biggest areas of value for IoT, in terms of both health and financial outcomes, is chronic disease management. Monitoring patients—their blood pressure, their compliance with medication instructions, the care they receive in a hospital or senior living facility—is perhaps the core application of IoT in healthcare. Products, such as so-called "smart pills," which feature tiny sensors embedded in the tablets swallowed by patients, illustrate how IoT-enabled biomedical device miniaturization can give doctors and scientists greater insights into disease. IoT can reduce the potential for medical error among caregivers, provide an opportunity to intervene in emergencies, help medical professionals and patients take a more longitudinal approach to care, and, in the aggregate, shape research.

It is important to note in the area of healthcare IoT, physicians may be affected by the liability of "knowing too much" as litigators may claim upon the death of a patient "… the doctor should have done more to protect my client's life with all the information at her/his disposal."

Retailing

IoT in the retail industry will drive efficiency through in-shelf availability, inventory and merchandise optimization, loss prevention, mobile payments, and more. These, in turn, will transform the customer experience. For consumers, improved efficiency will flow from several key IoT-reliant applications, including:

- Checkout optimization tools such as Qminder and Waitbot;

- In-store guidance for shoppers, such as the OSHbot, introduced by home improvement retailer Lowe's. This is a robot equipped with sensors, cameras, and speech and video analytics that assist with way-finding and the location of products; and,
- Mobile payments.

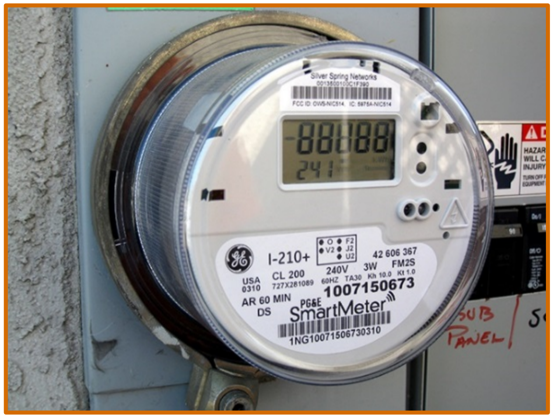
Here are a few ways retailers are using IoT devices to target offers, drive sales, and collect data about customers' in-store shopping habits:

- Beacons, paired with mobile apps, are being used in stores to monitor customer behavior and push advertisements to customers;
- Smart mirrors enable customers to try on clothes virtually, thereby enhancing the shopping experience;
- Digital signage pushes ads and price changes to stores in real time to create targeted sales; and,
- Smart shelving is used to determine when inventory is low and alerts the store manager to order more.

It is estimated that beacon-triggered messages influenced $4.1 billion in sales for the top-100 US retailers in 2015. In 2016, nearly $44.1 billion will be influenced by beacon-triggered messages for the same top-100 US retailers.

Utilities

Utility companies are increasingly turning to the IoT to make energy use more efficient by using smart meters installed in buildings and connected to smart energy grids, enabling utility companies to manage the flow of energy. Each smart meter is expected to save a utility company approximately $20 per year in reduced labor and energy savings. It is forecast that the global installed base of smart meters will increase at a 15 percent compound annual growth rate, from 450 million in 2015 to 930 million in 2020.



Based on a European Commission study, the forecast cost of installing smart meters for utility companies around the world will reach $107 billion by 2020, which will allow utility companies to save $157 billion by 2035, representing a net gain of $50 billion, without considering inflation.

Banking

Automation of banking is continuous; banking by phone, ATM, or on-line are the norms. The evolution of bank payment systems is rapid. In general, costs are leading many banks to close branches, especially considering on-line options.

Even small vendors can buy a credit card processor that can be attached to a phone to avoid use of cash or checks, and use a credit card payment system.

Getting paid with plastic used to mean a host of fees, expensive hardware, and complicated gateway services. Those days are long gone now, thanks to a growing plethora of card readers and other payment processors with simple, straightforward fees, access to inventory management tools, Point-of-Sale (POS) systems, and so much more. Now the smartphone or tablet can handle the bulk of selling needs, making things much easier for a small business. A number of systems link to inventory control, and accounting systems to track sales and tax reporting. Meanwhile, third party payment systems such as PayPal are well established. Major retailers continue to promote proprietary credit cards that discount prices when used at that store.

Buildings

Building managers throughout the world are looking to implement IoT solutions that save money and improve their buildings' attractiveness. A few ways buildings are being connected include:

- HVAC systems are being connected to monitor and control the temperature throughout the building. This reduces energy consumption, which saves money.
- Connected light bulbs also reduce energy usage.
- Buildings are being equipped with advanced IoT security solutions.

A survey from Daintree Networks found that the majority of lighting fixtures in buildings are not LED. This means they could opt for connected LED bulbs when replacing the current bulbs.

An increasing number of elevators are being connected to the internet, making them smarter and more efficient. The need for increased efficiency in the elevator market is staggering. In 2010, New Yorkers' total time spent waiting for elevators equated to 22.5 years, according to IBM. The smart elevator market is expected to grow from $12 billion in 2015 to $23 billion in 2020.

Manufacturing

The IoT opens new possibilities for analyzing and automating manufacturing processes. Manufacturers are expected to increase their investment in IoT devices and analytic systems significantly by 2020 because:

- The price of sensors required for IoT devices has dropped seven percent over the past five years and will continue to drop.
- Over the past two years, tech companies have been marketing the IoT to manufacturers to show how the manufacturers can increase profits.
- Thirty-five percent of manufacturers already use smart sensors, ten percent plan to implement them within a year, eight percent plan to implement them within three years, and 24 percent plan to implement them but don't have a timeframe.

IoT enables managers to understand what is occurring at a given moment in a manufacturing/factory environment—the performance of machines, ambient conditions, energy consumption, status of inventory, or the flow of materials. Preventative maintenance is a key use of IoT. Sensors can alert managers (or machines) that a physical asset in the factory is exceeding acceptable levels of vibration or temperature, is malfunctioning, or is otherwise prone to fail. This has major implications in terms of overall equipment effectiveness (OEE), a key metric of manufacturing productivity, and has positive ripple effects throughout the supply chain.

Manufacturers invested $29 billion in 2015; in 2020 they will invest $70 billion, representing a 19 percent compound annual growth rate. Manufacturing IoT devices will grow from 237 million in 2015 to 923 million in 2020. This will primarily be comprised of sensors retrofitted to pre-existing manufacturing equipment. New manufacturing equipment commonly will come outfitted with IoT technology in the near future.

Digital Dashboards

Monitoring and controlling all of the technologies presented above requires use of digital dashboards to gauge how well systems are performing. Benefits of using digital dashboards include:

- Visual presentation of performance measures;
- Ability to identify and correct negative trends;
- Measurement of efficiencies/inefficiencies;
- Ability to generate detailed reports showing new trends;

- Ability to make more informed decisions; and,
- Quick identification of data outliers and correlations.

Digital dashboards track the flows inherent in the processes that they monitor. Graphically, users can see the high-level processes and then drill down into low-level data for analytical purposes. Three main types of digital dashboard dominate the market today: standalone software applications, web-browser based applications, and desktop applications.

The AT&T/Miami-Dade County SMART Cities Operation Center includes a visualization dashboard housed in the Mayor's office.

ELEMENTS OF THE 2026–2035 PERIOD OF THE LRTP

Based on the proposed elements of the LRTP in the period of 2036–2045, and the evaluations included on **Table 2**, it is possible to propose the elements of the 2026-2035 period.

Autonomous Vehicles/Cars

Referring to **Table 4**, it is expected that the penetration of privately-owned AV cars will be about 25 percent during the period 2026–2035. This will cause some job losses in the transportation sector. Nonetheless, while AVs will have limited personal ownership, their impact cannot be ignored. Therefore, updating the Travel Demand Model suite, discussed earlier, should begin as soon as possible.

AV Ridesharing vs. Car-sharing

It is expected that ridesharing will widely expand in 2026–2035, much of which will be in autonomous vehicles. Uber expects its entire fleet will be fully autonomous by 2030. That, too, will have a job impact, albeit relatively small, both for Uber drivers and those in the taxi business.

Car-sharing will be more limited than ridesharing. Still, it will place a number of AV cars on the road.

Autonomous Vehicles/Buses

It is possible that AV buses will have a significant place in MDC transit. The job impact here will be complicated by union relations/negotiations. In this area, there will be a need for increased skills, with higher pay, and, likely, increased numbers of maintenance personnel to service the new AV technology.

Autonomous Vehicles/Trucks

The number of self-driving, heavy-duty trucks will be very limited but growing during the period 2026–2035. As noted earlier, acceptance of AV trucks by the unions is an issue. So is the willingness of fleet owners to accept completely driverless vehicles—ones that are hands off the wheel as well as foot off the accelerator and brake. Rather, there is more of a focus on "semi-autonomous" truck capability, perhaps for short durations on the highway but more applicable in low speed environments such as at truck stops or at warehouse docks.

Autonomous Vehicles/Ambulances

AV ambulances will still be considered experimental in 2026–2035 because fully autonomous ambulances will need to achieve the highest level of automation (Level 4) before allowing the EMT ambulance driver to assist the other EMT with patient care while the ambulance is in motion. On the other hand, there will be increased use of ambulance drones (or Air-Mules) by hospitals and, to a lesser degree, by government.

AV Infrastructure

V2I technologies are not likely to be extensively deployed in the United States in the period

2026–2035. According to USDOT, V2I technologies will likely be slowly deployed in the U.S. over a 20-year period as existing infrastructure systems are replaced or upgraded.

Roadway Traveler Information Systems

These systems, already widely in use, will continue to expand.

Electric Vehicles (EVs)

There are many limitations that prevent suddenly swapping out large numbers of current vehicles for electric ones. Not everybody has access to a charging station. Drivers would still need to address alternatives on days when an EV vehicle won't do—long business trips or vacations, for example. Nonetheless, with the sale by General Motors of the Chevy Bolt at a reasonable price, and the Obama Administration’s commitment of $4.5 billion to support development and use of EVs, their presence will grow in the period 2026–2035.

Bus Rapid Transit

The first of three new BRT lines is expected to be in operation during the 2026–2035 period.

Gondola

An MDC TPO study examined a number of options for a gondola and concluded a 1.2 mile, two-station Marlins Park (Little Havana)-to-Downtown alignment was preferred. Nonetheless, it is not expected this will be part of the LRTP in the 2026–2035 timeframe.

Rail Freight

By becoming more digitally focused by way of machine-to-machine communications and mobile devices, rail operations will accelerate the transformation to a more interconnected, transparent, and agile form between 2026 and 2035.

Marine Freight

Proponents of automated cargo handling at U.S. ports have a rule: where megaships call, robots soon follow. That is why ports from Miami to New York are likely to automate. Automating a container terminal is expensive, so ports are holding off on buying into the technology until absolutely necessary. Port infrastructure and operations experts say new equipment and technology typically costs hundreds of millions of dollars. Even so, it is expected that the Port of Miami will, in the 2026–2035 period, begin to make the substantial investment needed in automated cranes and other robotics in order to continue its position as a leading world port.

Logistics

Creating the optimum logistics system requires strong collaboration and investment by all segments of the supply chain. The MDC TPO should facilitate that participation/cooperation, beginning as soon as possible and continuing through the 25-year LRTP planning period. That will allow the logistics scenario, described earlier, to be fully realized by 2045.

3D Printing

3D printing will begin to affect manufacturing and shipping in the 2026–2035 timeframe. Remote production overseas in lower-cost locations could be replaced by manufacturing facilities located at home closer to the consumer, allowing for a more responsive manufacturing process and greater quality control. As these efforts gain momentum, the need to ship many parts, products, or raw materials to market will be reduced. Footwear, toys, ceramic products, electronics, and plastics industries have the highest potential for disruption.

Drones

Between 2026 and 2035 drone use will extend beyond aerial photography, real estate, various inspections, agriculture, and filmmaking, to department stores and food stores plus firefighting, search-and-rescue, and conservation.

Traffic Management Technology

By 2026, Miami-Dade County will be increasing the installation of pole-mounted wireless technologies (cameras, sensors of environmental conditions) to manage everything from traffic/pedestrian activities to flooding to ozone/pollution problems. The investment will need to be steady and significant.

Pedestrian Safety Technology

MDC will advance in installing solar-powered in-road light systems which detect the presence of a pedestrian crossing or preparing to cross the street, plus safety reflectors which feature sensors, LED lights, wireless charging, and communications made to blink and alert vehicle drivers to pedestrian movements.

Bikes

MDC has done extensive study and implementation of bicycle facilities and programs. It is expected to continue that work over the next generation to provide a truly multimodal transportation system.

Parking

Tesla Motors has already developed the technology to allow their vehicles to not only auto (self) park, but to also be summoned from its parking space to pick up passengers who are waiting at the door or curbside. Yet, the company admits more tests are needed to perfect the technology. So, in the period 2026–2035, vehicle self-parking will be more prevalent. But, its effects on parking facilities will have to wait until the number of AVs in the vehicle population reaches more than a majority.

Energy

The smart grid is one of the most well-developed and widely recognized IoT systems. Smart grids rely on smart meters, which relay information about a system's energy usage to a central management system to efficiently allocate resources. Smart grids can be used to identify and address outages and promote conservation through demand-based pricing. In addition to benefiting cities, new devices are also bringing the benefits of energy-related IoT to consumers. Citizens can reduce their energy bills with devices which monitor energy use, turn off unused devices, and manage the temperature in a home or office from a smartphone.

In the period 2026–2035, MDC will push forward in this area of energy efficiency.

Solar Roadways

While possible, it is unlikely that solar roadways will play a significant role in MDC by 2036. The technology is years away from being proven.

Energy from Road Friction

This technology is not likely to be widely applicable for some time because it needs to be proven.

Smart Cities

The Smart Cities technologies that are expected to be part of the LRTP by 2045, and defined above, are: Energy, Water, Waste, Transit (BIBO), Retailing, Utilities, Wellness/Healthcare, Banking, Buildings, and Manufacturing. A number of these will be the responsibility of the private sector, which is expected to continue its ongoing activities for "self-preservation." The public sector will play a role in broader community-based initiatives, such as energy, water, waste, utilities and transit. It may well have a regulatory role in others like buildings, and manufacturing.

It is expected that all of these elements will be aggressively moving forward in the 2026–2035 period of the LRTP.

ELEMENTS OF THE 2020–2025 PERIOD OF THE LRTP

The sense people have is that “new technology is exploding”—and they are correct. That is, the concepts and test products are manifold. However, many new items are not ready for wide-scale implementation because of constraints such as government regulations (like those just published by USDOT on AV vehicle approvals) and consumer acceptance. Furthermore, until the government funding situation at the federal level is re-energized, there will be limitations on what “bold initiatives” can be undertaken. So, in the period of 2020-2025, wide use of new technologies will likely be limited to the following.

Infrastructure

The key to planning for the *Internet of Things* revolution is to establish a network of technology infrastructure that is capable of supporting future technology needs. This network must also provide the ability for the technology infrastructure to be upgraded quickly and efficiently. With the technology infrastructure in place, you can then build out the Internet of Things in any city, town, rural area, or along any roadway, any bridge, or any corridor. The impacts, the potential benefits, and the disruptive changes to everyday life as we know it, are just beginning.

As noted earlier, advanced wireless transmissions need access to fiber optic cables at frequent geographic intervals built on street light and traffic signal poles—NOT telephone poles—because government most-often owns the former, not the latter.

Building that network must begin in the period 2020–2025. Also during those years, in terms of infrastructure, MDC will advance on installing solar-powered in-road light systems which detect the presence of a pedestrian crossing or preparing to cross the street, plus safety reflectors which feature sensors, LED lights, wireless charging, and communications which can be made to blink and alert car drivers to pedestrian movements.

It will also expand the roadway traveler information system. Likewise, it will take advantage of the recently announced federal program ($4.5 billion) to support use of electric vehicles by installing EV charging infrastructure in an electric vehicle “charging corridor.” Achieving the latter definition for I-95, or I-75 across the U.S. will require strong Congressional leadership in Washington, D.C.

Transit

Planning for BRT, if it is to be implemented in later stages of the LRTP, must be stepped-up in 2020–2025. Likewise, Advanced Driver Assistance should include all appropriate transit vehicles. Modes of mass transportation, including planes, trains, and buses, are now using internet connectivity to help improve customer satisfaction and reduce maintenance costs to reduce service cost and downtime, and extend equipment life.

Freight

The Port of Miami will move on the next generation IoT to track and monitor freight faster, more accurately and securely. Through the IoT, the Port will gain clear and continuous visibility on the movement of goods as well as item-level condition to ensure that goods arrive in time, at the right place, and intact. Telematics sensors in trucks and multi-sensor tags on items transmit data on location, condition (whether any thresholds have been crossed), and if a package has been opened (to detect possible theft). Location and condition monitoring through IoT will provide a new level of transport visibility and security.

Logistics

IoT devices will save logistics businesses billions by helping move goods and assets through their supply chains and warehouses faster and more cheaply because fleets will cut travel time and costs by taking the most efficient route possible thanks to real-time traffic updates. Warehouses will be fast adopters of industrial robots.

Smart Cities

The Smart Cities technologies that are expected to be part of the LRTP by 2045, and defined above, are: Energy, Water, Waste, Transit (BIBO), Retailing, Utilities, Wellness/Healthcare, Banking, Buildings, and Manufacturing. It is expected that all of these elements will be aggressively moving forward in the 2020–2025 period of the LRTP.

PILOT PROJECT PROPOSAL

A pilot/demonstration project is proposed on a "Smart City" basis. The pilot is conceived as being conducted: 1) in a compact area, i.e., a smaller incorporated area of Miami-Dade County; 2) starting by 2020 and continuing for three to five years; and, 3) in cooperation with a local university already engaged in technology research.

Based on the results of the analysis of hundreds of technologies, the following are **not** considered available for inclusion in the near-term pilot project.

- Maglev, Pod (gondola), and dual-mode systems;
- Rain channels converted to roadways;
- Vehicles propelled by hydrogen or nanocells; and,
- Solar roadways.

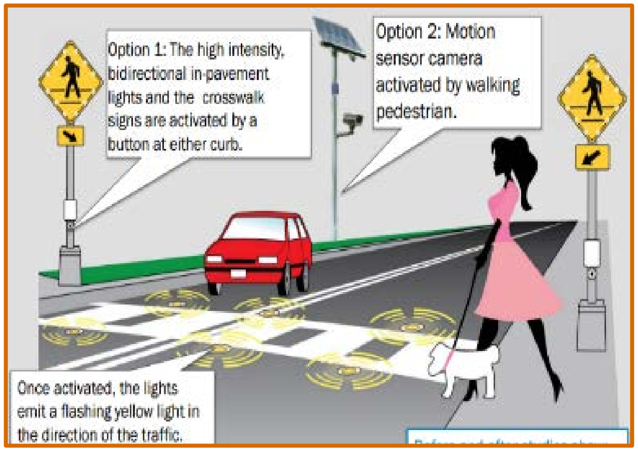
Also, significant private ownership of autonomous vehicles (AVs), and use of AV emergency equipment (e.g., ambulances) are not expected to be part of the pilot project; the year 2020 is too soon for these technologies to be reliably available. On the other hand, car sharing, and AV taxis (e.g., Uber and Lyft (ridesharing) are considered elements of the demonstration project.

These and other vehicles will be powered by electricity at an increasing rate as the range of travel on a single charge of the vehicle's battery improves, and as re-charging stations along public roads become more numerous. Likewise, small AV transit vehicles can be part of the demonstration project. Freight carried by trucks, trains and marine vessels will be "tagged" for continuous point-to-point tracking. 3-D printing, while evolving, will not be counted on to produce enough products, particularly large ones, to have a role in the pilot.

Bus Rapid Transit (BRT), while considered "doable in the near-term future" will likely not be in place as part of the pilot program. And, because of the public's skepticism about securing personal information and fraud protection, the BI/BO (Be-In, Be-Out) system will be limited. Nonetheless, Transit Mobility apps will be in use. They currently allow for traveler information for smart phone users, providing information on trip options, transfer points, and real-time information for transit services. Miami-Dade allows online loading of the EASY card. Other cities have integrated these Transit Access Pass (TAP) cards into their online presence or on apps, both are accessible by smart phone. Logging onto MDC transit websites will allow for prepaid amounts to be added to the smartcard. On what is known as the Octopus Card app, a mobile device can allow the transit pass to double as a debit card, incorporating a function to pay online vendors. But, security to one's personal finances is a major concern that has not yet been resolved.

Buses will be equipped with Advanced Driver Assistance technology in a basic form (GPS, "in-cab" notifications to maintain schedule) as part of the pilot project. And, while the pilot area may be relatively small, a highway traveler information system will serve the project area.

A number of intersections will be equipped with solar-powered, in-road light systems that alert motorists to the presence of a pedestrian crossing or preparing to cross the street.



If the pilot project were to include the Port of Miami, the supersized ships docking there will likely not be met by an army of robots, because the cost and labor union challenges will take time to address. On the other hand, the Internet of Things (IoT) devices and systems can improve port efficiency in the very near term through real-time cargo identification/tracking; management of mooring space; predicting capacity demand; and, evaluating port traffic throughput.

Within the pilot project area, Smart City technologies will affect everyday life in the following ways:

- Selected Smart homes will be powered by solar energy through roof tiles;
- Smart buildings will optimize HVAC performance, lighting, and security;
- Healthcare advances will monitor a patients' diagnostic information and recovery progress through mobile devices/apps;
- Many shopping deliveries will be done by drones;
- Utilities will install "smart meters" to manage energy use;
- Banking will continue to streamline; and,
- Travel will not only be by AV shared vehicles and transit, but also by bikes through expanded bike sharing.

These technologies will be monitored through a "digital dashboard" which will track data at a central location to measure systems performance; identify and correct negative trends; and, generate reports to make informed decisions. The security of these systems will be paramount and costly, but borne by the private sector. Nonetheless, the IoT will return more benefits than not.

To enhance communications, apps—such as "Nextdoor"—will be employed by people in the pilot project area. This technology functions as a "neighborhood watch" program. It also allows partnering with local authorities so emergency alerts are readily communicated. Importantly, the app is free, and its use is easily taught to seniors. So, the only cost is that of a mobile device, which virtually everyone has.

During the time to prepare for and then undertaking the demonstration project, investments by the private sector in everything from retailing to Smart buildings to IoT/Healthcare advances will rise exponentially. And government funding of the transportation system will become more robust and reliable. Some change/improvement is need if facilities and programs are to be sustained and enhanced. Keeping up with these developments, and taking advantage of them, will be an ongoing effort of those who manage the pilot project.

From a planning perspective, an upgraded suite of travel demand models is expected to be developed by 2020. This is essential to assess the effects of advanced driving technologies on travel demand. The current models' speed and capacity calculations and volume/delay functions must be updated to account for increased capacities, number and length of trips, and changes in land use patterns that will be associated with new technology.

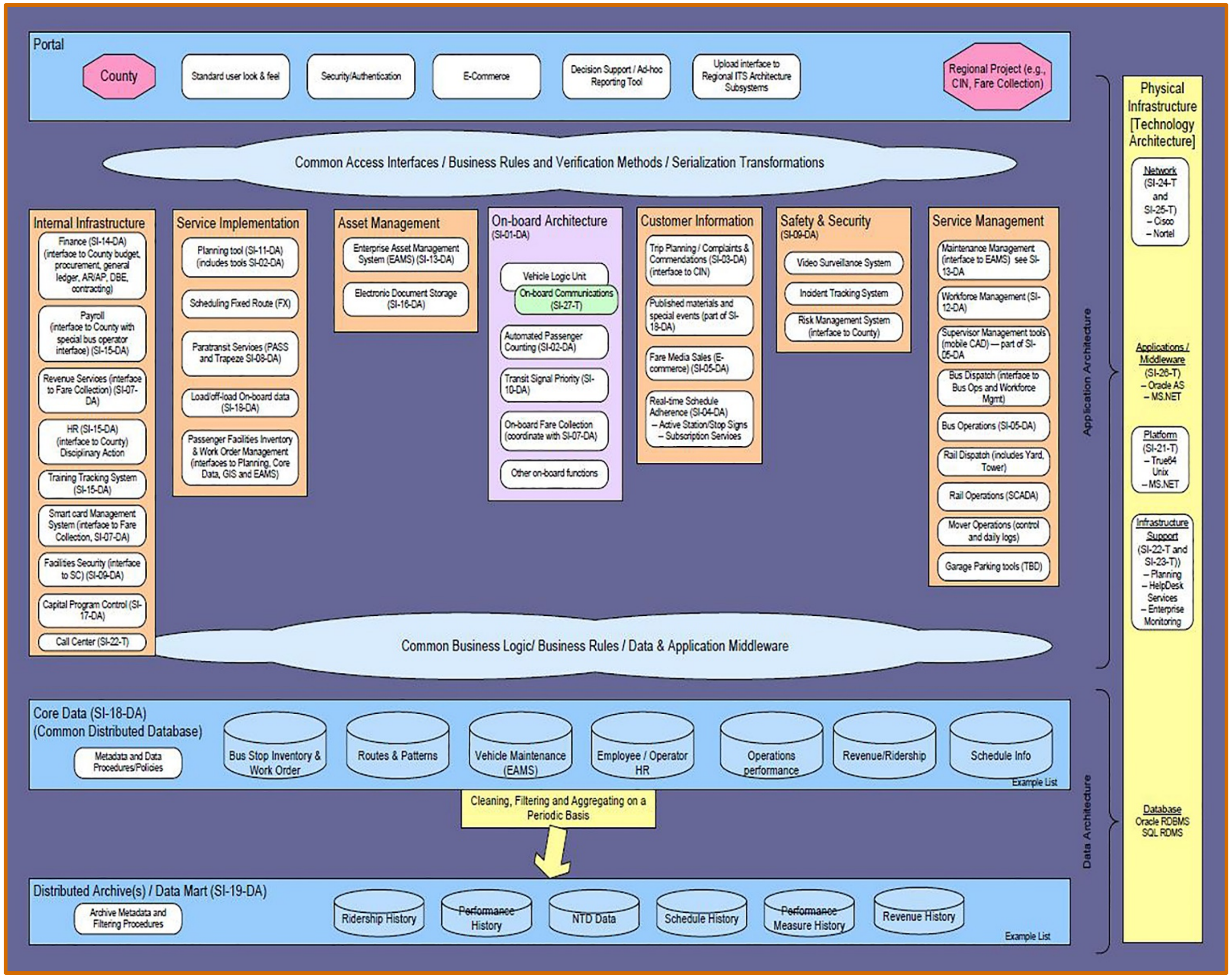
IMPLEMENTATION

A comprehensive plan for the pilot project needs to be developed by all stakeholders—MDC and TPO, governments of the pilot project area, a local university, FDOT, private partners, and others. Once the plan is developed, private and public funding needs to be gathered. This includes the local government of the pilot project area, the MDC Commission, and FDOT. Eventually, once the pilot project demonstrates success, it should be presented as an attractive addition to the USDOT Smart City program.

SYSTEMS ARCHITECTURE

The chart to the right illustrates the Miami-Dade County systems architecture for just one segment of the county's transportation operation—transit. There are equally intricate designs to manage roadway traffic, data/devices of all kinds, water and sewer information/facilities, and on and on. Therefore, to address the IoT architecture of the future takes a crystal ball, which is not available, at least not to this consultant. As a result, the approach to this task is to "borrow" examples of basic concepts developed by researchers/scientists at IBM, Symantec, The Reason Foundation, Universities like Carnegie Mellon, Florida, Michigan, and others to illustrate current thinking, which will surely and quickly evolve as more technological developments become available. Miami-Dade County is already advancing toward being a robust IoT SMART

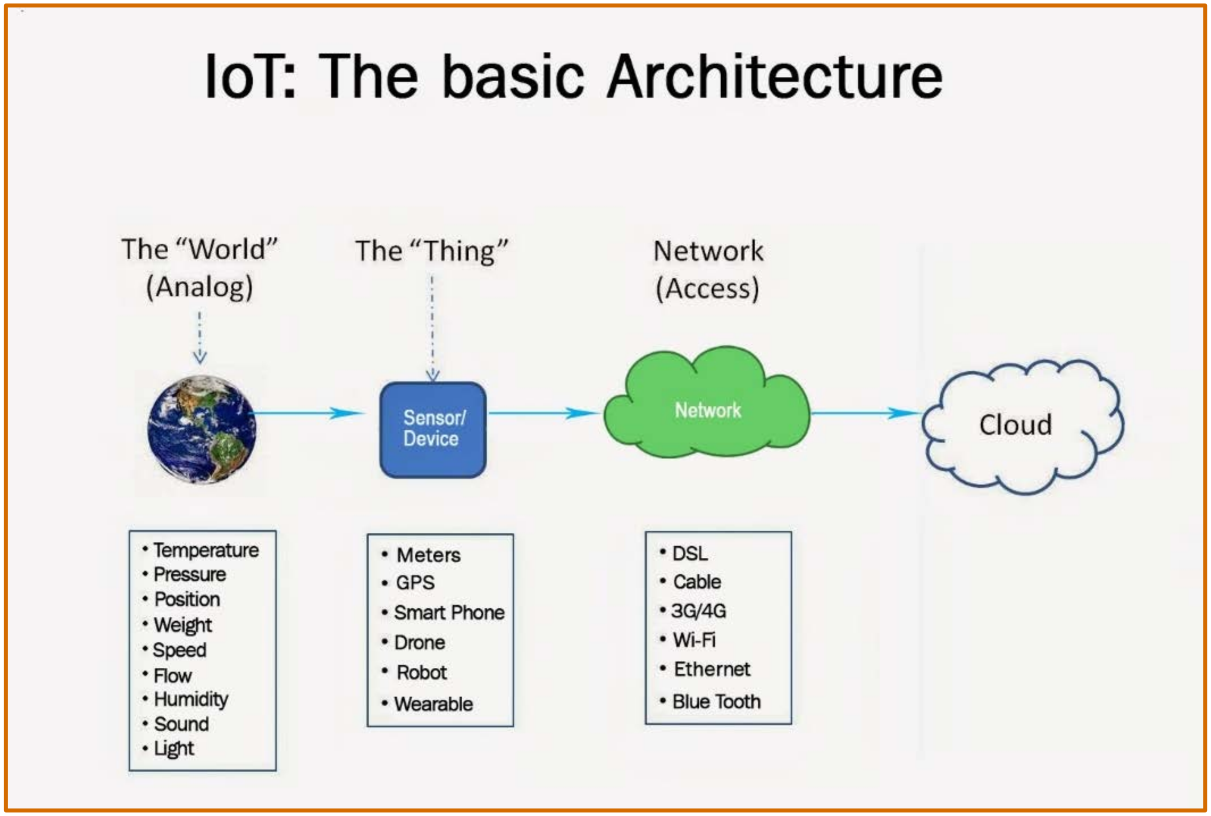
Miami-Dade County Transit System IoT Architecture



Source: Miami-Dade County

Community by becoming the first municipality to launch an AT&T Smart Cities Operation Center.

A basic IoT structure is offered by Greywale Management[10] in the graphic to the right, which essentially digitizes a real-world parameter (e.g. temperature or power) through a device (e.g. drone, smart phone) to send it through a network to the "cloud" for analysis and possible action. To illustrate the challenges of developing and maintaining the array of systems structures that will be needed for the County to function, the basic architecture for ***freight movement/logistics, airports/airlines, autonomous vehicles, health care,*** and ***the home*** are discussed below.

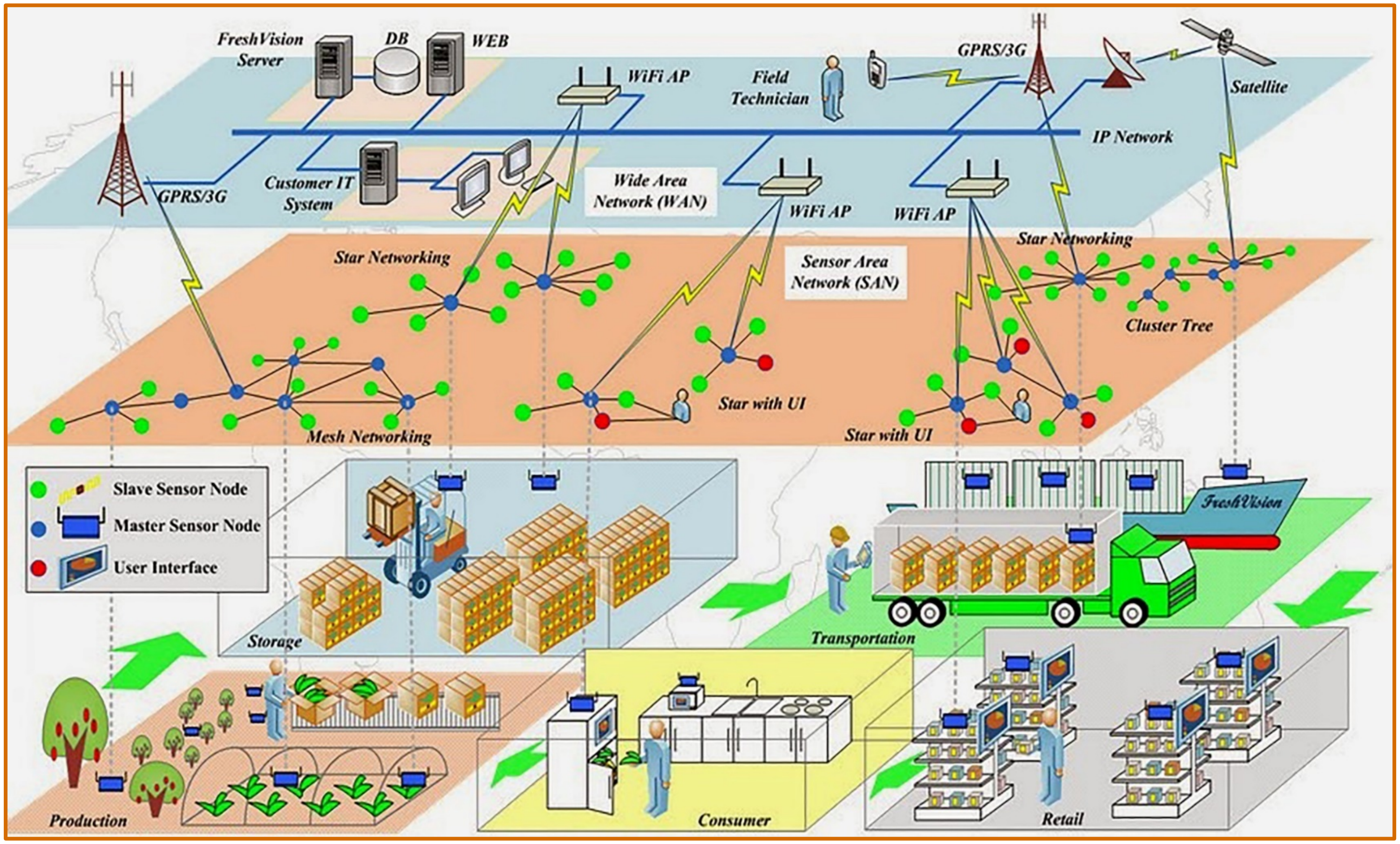


Source: http://greywale.blogspot.com/2014/06/iot-success-batteries-backhaul.html

[10] http://greywale.blogspot.com/2014/06/iot-success-batteries-backhaul.html

A possible structure to handle IoT of ***freight movement/logistics*** is illustrated to the right. IoT is expected to bring profound changes to the global supply chain via intelligent cargo movement. This will be achieved by means of continuous process synchronization of supply-chain information, and seamless real-time tracking and tracing of objects. It will make the supply chain transparent, visible and controllable, enabling intelligent communication between people and cargo, plus global positioning and auto identification of freight, decreased energy consumption and increased overall efficiency.

Conceptual Freight Movement/Logistics IoT Architecture



Source: http://smartscience.files.wordpress.com/2015/09/logistics.jpg

The construct of this IoT architecture in Miami-Dade County that includes the Port of Miami will require the Port to install a host of equipment and devices, including costly robots. It is expected the Port will begin the substantial investment in this equipment in the period 2026–2035. Without knowing what will be involved and when, developing an architecture now is not possible.

The ***airport/airlines*** IoT architecture must encompass a vast array of activities and the people doing them that include, as shown to the right:

Airport Operations:

- Airport Security Services;
- Airport Safety Services;
- Flight Operations;
- Flight Information;
- Airport Gate Management;
- Baggage Management;
- Services Vehicle Management; and,
- Energy Management.

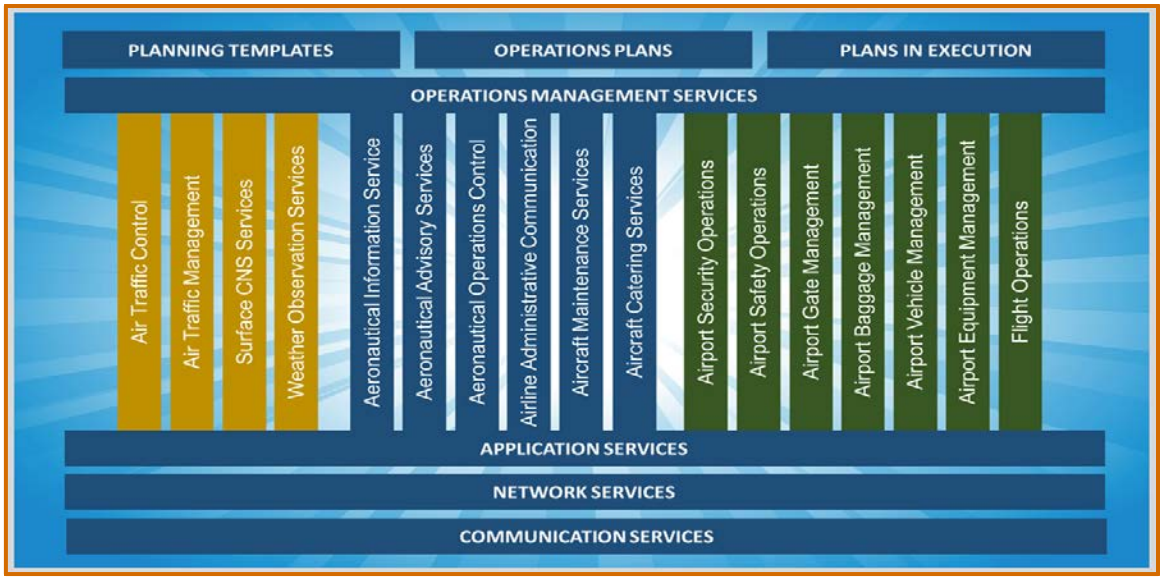
Airline Operations:

- Aeronautical Information Service;
- Aeronautical Advisory Services;
- Aeronautical Operation Control;
- Airline Administrative Communication;
- Aircraft Maintenance Services; and,
- Airline Catering Services;

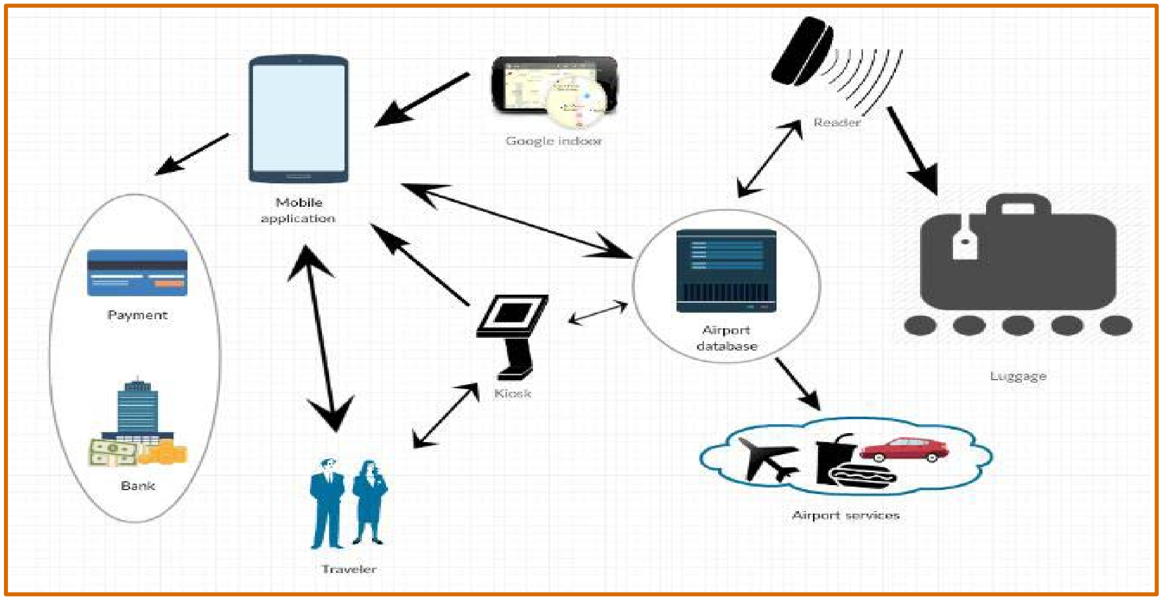
Air Traffic Control and Management:

- Air Traffic Control;
- Air Traffic Management;
- Surface Services;
- Weather Observation; and,
- Meteorological Data Services.

An example SMART airport terminal IoT architecture is also shown to the right. It consists of: mobile application; kiosks; the traveler; the



Source: Celestain AeroMACS



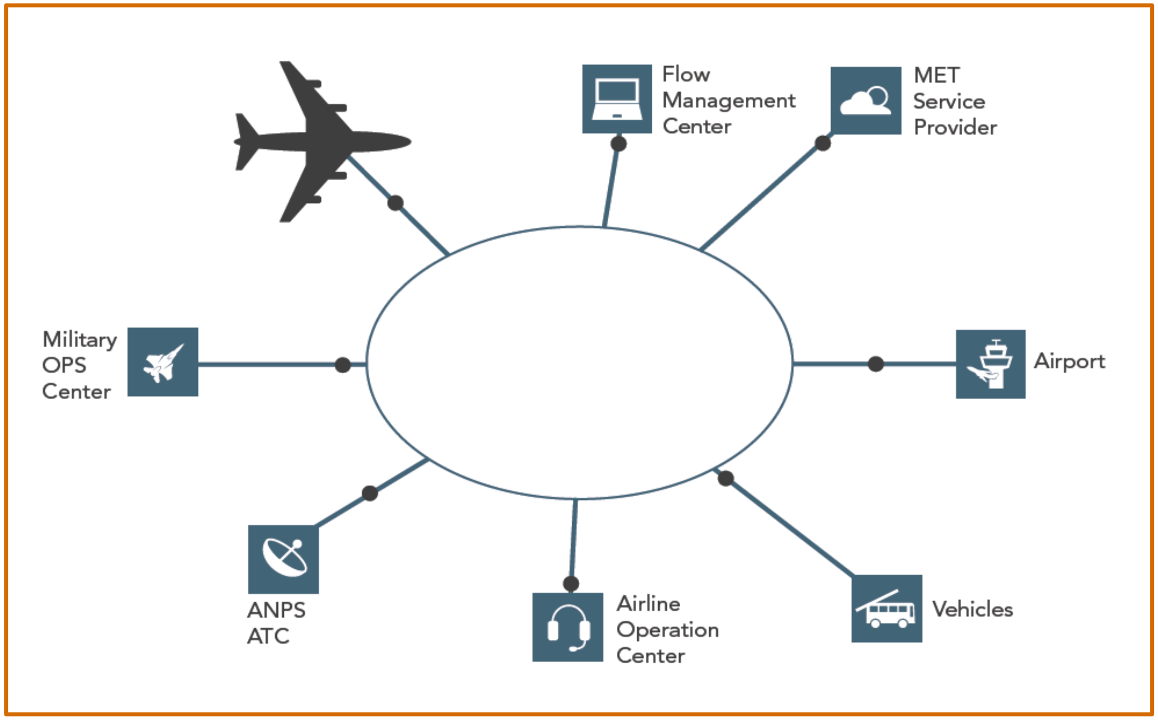
Source: Smart Airport Architecture Using the Internet of Things, Abdullah Alghadeir, Hasan Al-Sakran

RFID (radio frequency identification) to read luggage tags to distribute baggage to specific conveyor belts; the credit card; and, Google maps connected to the mobile application to verify payment details and to show the current traveler location. Kiosks help the traveler to change their preferences and to print the boarding pass and/or luggage tag. All these features are connected in one database to provide all airport services.

The MIA terminal area has a network of some 500 beacons providing detailed information and personalized services to customers at its terminals and various concessionaries. It's new localized app, "MIA Airport Official 2.0", communicates with these beacons, giving gate information, as well as shopping and dinner details.

Users are able to scan boarding passes and receive turn-by-turn, blue-dot navigation guides to their gates which will include estimated walk times, real-time flight updates, even suggestions for nearby shopping and dining, based on a customizable personal profile.

For the airlines, the IoT architecture can be implemented through an open, internationally agreed-upon cloud service known as System Wide Information Management (SWIM) which



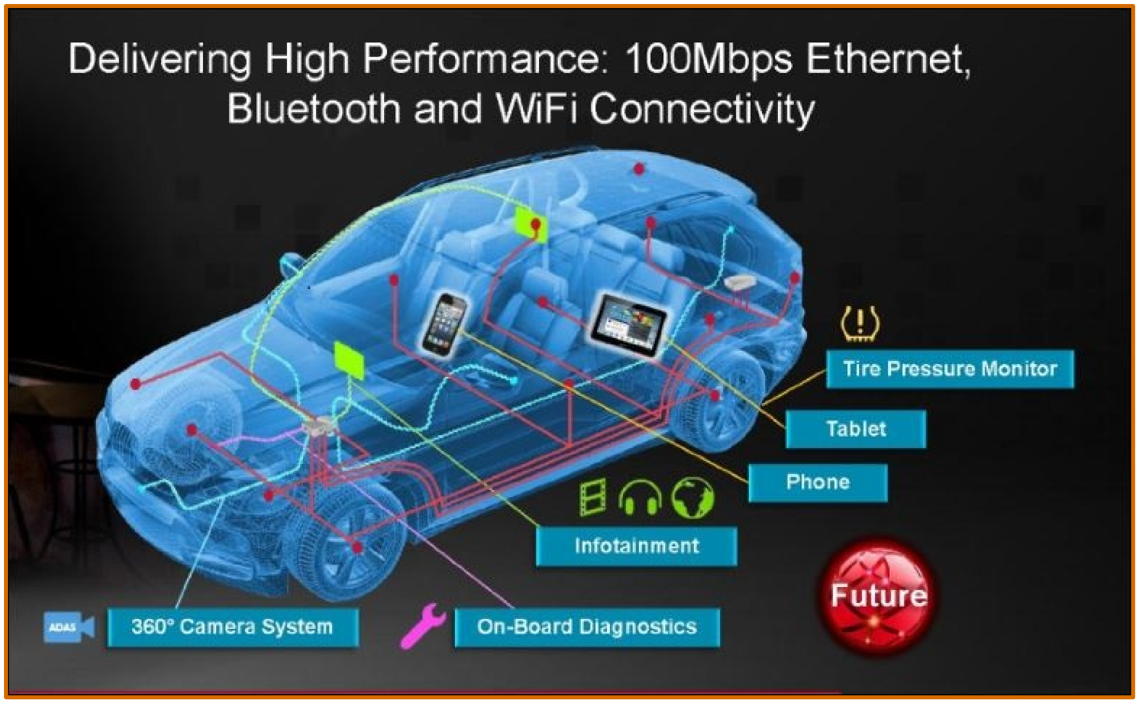
Source: The Internet of Things in Commercial Aviation, WIND, An Intel Company

aggregates data about all aspects of aircraft operations, including flight paths, coordination of takeoff and landing, weather information, and operational data about airspace and airports. By combining data from various sources, additional benefits can be provided. For example, aircraft encountering turbulence can report that information through SWIM to allow other airspace users to avoid that area.

Delta Air Lines, that serves the MIA airport, deployed an IoT analytics systems on part of its fleet, with the goal of improving airplane maintenance. The platform is designed to unify billions of traditionally siloed data points across aviation and air traffic management to increase awareness, discover new business insights, improve operations and asset performance by reducing downtime and lowering fuel costs.

The future of the automotive industry is the ***connected/autonomous vehicle*** to turn it into a valuable partner in the IoT, where every device is connected to the Internet. The practical way in generating data was usually through humans, but in the future data will be generated by devices. This trend will increase the amount of modules and software in the vehicle. Sensors will eventually be placed throughout the body of the vehicle.

The automotive industry is heading to self-driving autonomous cars. A recent technology and product line driven by this is Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) technology, which is generally referred to as Vehicle-to-Everything (V2X). The process of exchanging data is relatively straightforward for many manufacturers and automotive suppliers, but the competitive piece of the architecture is consolidation, security, and consumer privacy. With these connected features, the modules open many entry points to potential hackers. Hackers can potentially cause accidents and remotely control vehicles.

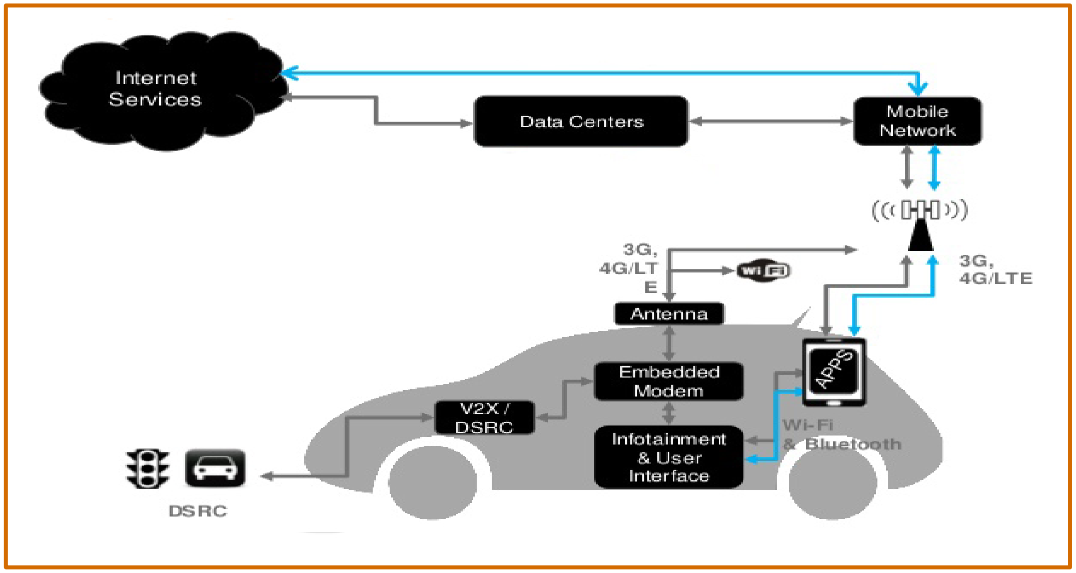


Source: http://www.edn.com/electronics-blogs/automotive-innovation/4403736/The-connected-car-as-a-platform

There can be multiple vulnerabilities for the vehicle, but some of the physically achievable threats are access to a driver's mobile device that is connected to the vehicle and the cloud infrastructure. It is technically known as an electronic control unit (ECU). To achieve greater security, protocol, authentication, authorization, encryption, and data protection have to be bulletproof.

Over-the-Air updates (OTA) can alter code in vehicle modules that then update software to do new things. Moreover, the vehicular network can easily be reverse-engineered; that's why it's essential to protect diagnostic data, firmware update, or critical commands. For connected devices, the ability to get into the software of the systems can lead to the exchange of deception techniques with malware.

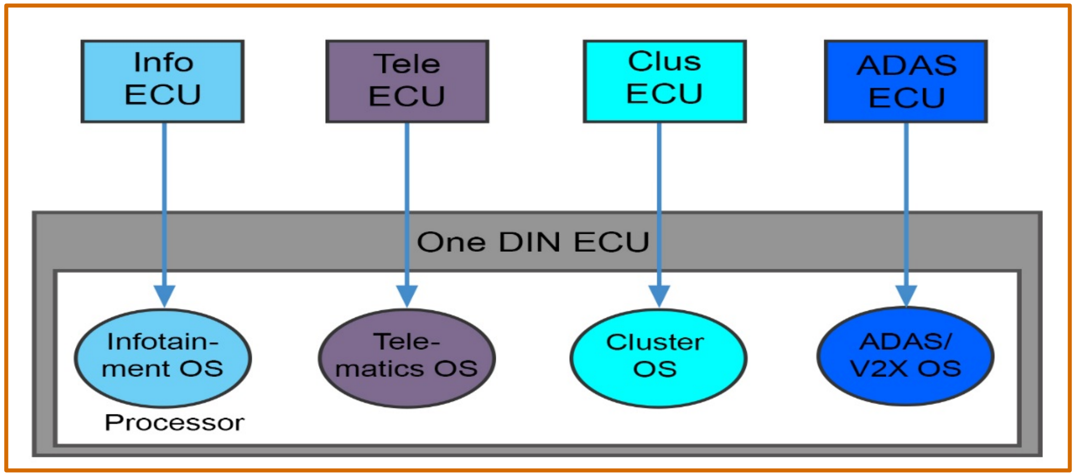
The top right graphic displays a basic architecture for a connected car, with many hardware modules that can interact with the outside world. The connected car is equipped with Internet access to allow the vehicle to be made available for shared data. That connection is typically done by a built-in embedded modem on-board the car called a Telematics Control Module (TCU) and a Wi-Fi connection available within a module inside the car.



Source: Visteon

The bottom right graphic shows a suggested architecture to achieve ECU consolidation and help increase efficiency and security, reduce cost, and intuitively allow effective communication among domains. Domain refers to the different functions:

- Infotainment-related features, including AM/FM, navigation and audio amplifiers.
- Telematics features and downloadable applications defined by automakers.
- A driver information solution for the cluster and head-up-display (HUD).
- Advanced Driver Assistance Systems (ADAS), including rear-view camera, 360°-camera, parking assist, and V2X communication.



Source: Hardware Virtualization

These advances will allow a connected/autonomous vehicle to also detect pedestrians. They will be aided by crosswalks with a solar-powered, in-road light system that alerts motorists to the presence of a pedestrian crossing or preparing to cross the street. Amber lights are embedded in the pavement on both sides of the crosswalk and oriented to face oncoming traffic. In-road warning lights produce a daytime-visible light focused directly in the driver's line of sight clearly indicating the curve, hazard, crosswalk, variable lane, or lane edge. This requires no interpretation by the driver, resulting in increased visibility.

When the pedestrian activates the system , either by using a push-button or through detection from an automated device, the lights begin to flash in unison, warning the motorist that a pedestrian is in the vicinity of the crosswalk ahead. The flashing LEDs shut off after a set period of time, i.e., the time required for a pedestrian to safely cross the street.

Another “smart” device to protect the pedestrian is a reflector that can be wirelessly controlled via a mobile phone application created by VTT Technical Research Centre (Espoo, Finland) and safety reflector company Coreplast Laitila (Laitila, Finland). When a pedestrian is

approaching a crossing, the reflector—which features sensors, LED lights, wireless charging, and communications—can be made to blink and alert car drivers. In the future, the reflector could communicate directly with smart traffic lights or cars to warn, for example, a turning truck driver that a pedestrian is in the area of a crossing.

It is also possible to connect the reflector to other on-line activities such as mobile gaming, which could make it more attractive for teenagers to use. Reflectors could be set to shine in a common color or to react in real-time to gaming actions and to the track to which the user is listening.

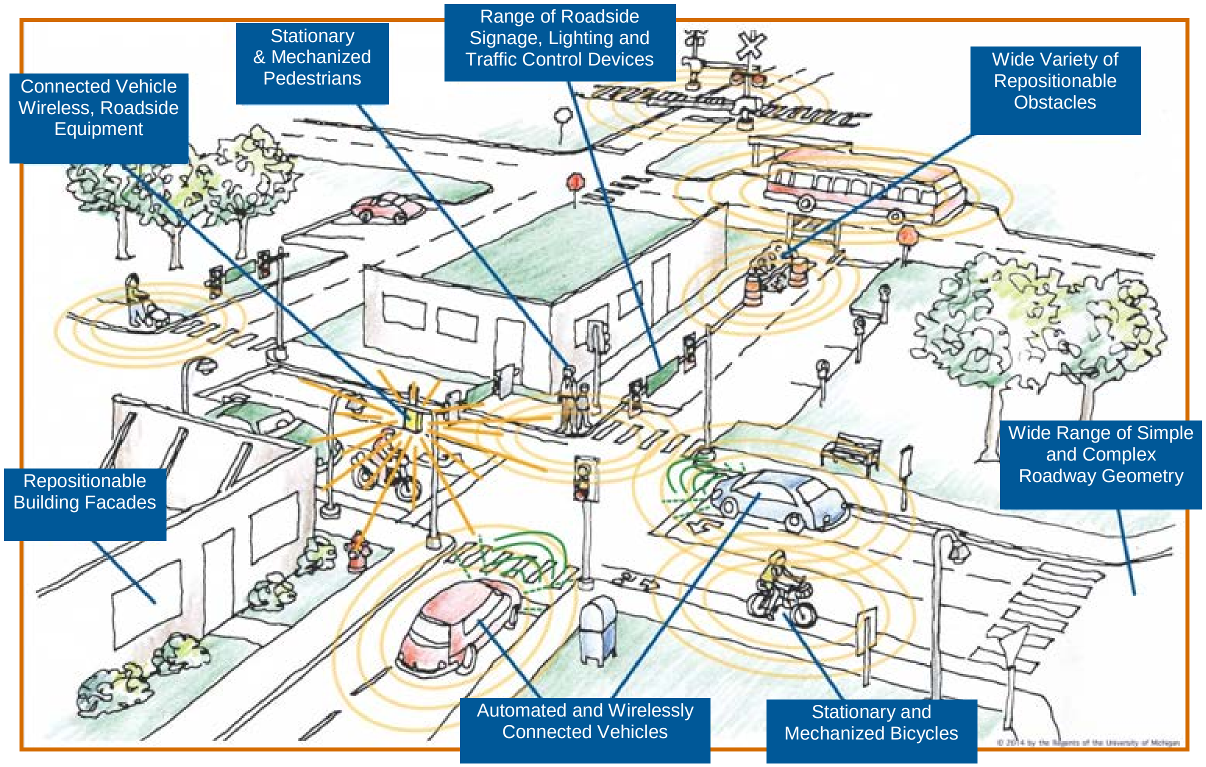
But a driverless car is not able to distinguish the age of a pedestrian or the number of occupants in a car. There isn’t an “ethical engine” to do so today. Algorithms are making decisions that have very important consequences on human life. While the car may have made the best decision based on the data available, to humans it’ll always be a machine that’s capable of error without human input. And that’s a problem technology hasn’t yet solved.

Perhaps, the work at USDOT-selected AV Test Centers will advance the technology to address the moral dilemma of “who lives and who dies.” These centers are:

- City of Pittsburgh and the Thomas D. Larson Pennsylvania Transportation Institute;
- Texas AV Proving Grounds Partnership;
- U.S. Army Aberdeen Test Center;
- Contra Costa Transportation Authority;
- (CCTA) & GoMentum Station;
- San Diego Association of Governments;
- Iowa City Area Development Group;
- University of Wisconsin-Madison;
- Central Florida Automated Vehicle Partners;

- North Carolina Turnpike Authority; and,
- American Center for Mobility (ACM) at Willow Run, Michigan.

The last center is a collaboration of the University of Michigan, the private sector, and Michigan state government. The university's North Campus has been a unique testing site since July, 2015. ***MCity***, as it is known, simulates the broad range of complexities vehicles encounter in urban and suburban environments. It includes approximately five lane-miles of roads with intersections, traffic signs and signals, sidewalks, benches, simulated buildings, street lights, and obstacles such as construction barriers.

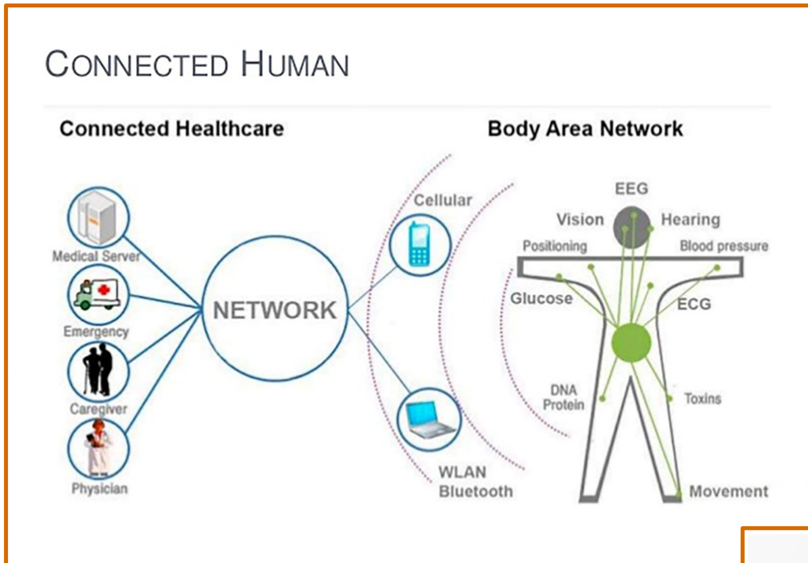


Source: Mobility Transportation Center, University of Michigan

Mechatronic pedestrians, who occasionally pop out into traffic, provide a critical measure of whether sensors and automatic brakes can react in time to avoid running down a real person. As in a Hollywood backlot, building facades can be rearranged to add to the chaos confronting the chip-controlled vehicles.

Controlling and preventing illnesses/diseases are main goals of ***healthcare***. Today, people can be tracked and monitored by specialists when both are not at the same place. Tracing peoples' health history is another aspect that makes IoT-assisted e-health very versatile. Providing information about the real-time condition of a patient makes the healthcare process more efficient, and makes doctors and patients much more satisfied.

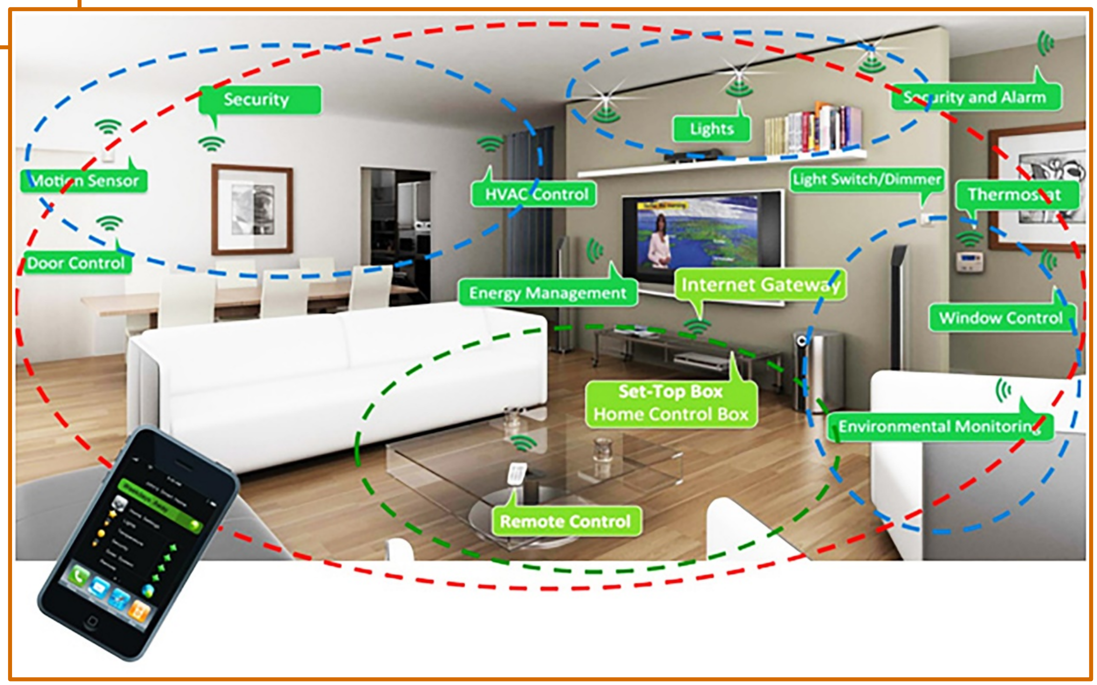
Important stakeholders in this scenario will be public and private hospitals and institutes. Telecommunications operators, drug manufacturers, equipment manufacturers, and makers of hearing aids, contact lenses, and prostheses



are already active in e-health field. Tying together these elements will be a continuing challenge as technology advances and more devices/systems are developed and refined.

Future ***smart homes*** will be conscious about what happens inside the building, impacting a number of aspects, particularly: resource usage (water conservation and energy consumption), security, and comfort. Two goals are achieving better levels of comfort while cutting overall expenditures. Smart homes also address security issues by means of complex security systems to detect theft, fire or unauthorized entries. There are different stakeholders that will cooperate in the user's home, such as Internet companies, device manufacturers, telecommunications operators, media-service providers, security companies, utility companies, and so on. One set of stakeholder is home owners and their insurance company.

Smart homes with connected devices and sensors let insurance companies improve service for their policy holders while providing insight into risks in the home. For example, leak-detection sensors and valves could monitor for water leaks and protect the home from resulting damage. The insurance company benefits from access to the device data so it can provide an improved experience to its policy holders. This happens in the following steps as depicted on the following page.



1. Sensors and actuators are deployed in the home and attached to the device maker's cloud service. The sensors can include water leak detection, water flow and temperature, and the actuators can include automatic water shutoff valves.

2. The Homeowner logs in to the insurance mobile app and authorizes the insurance service to access the device maker's cloud and the device's data. The mobile app sends the authorization and insurance company identifier to the cloud service.

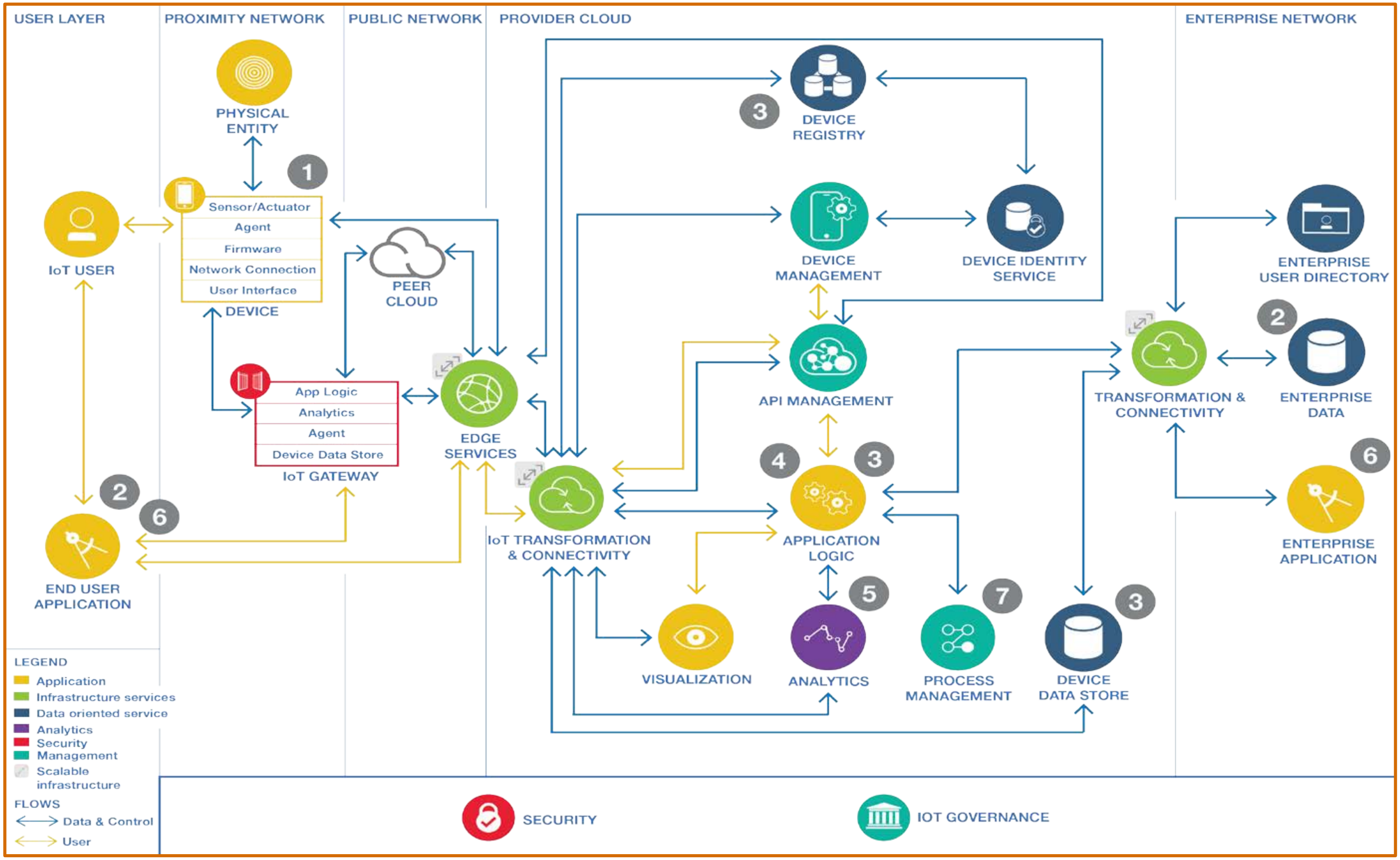
3. The insurance service receives information such as authorization, device details, and insurance identification from the insurance mobile app and processes this in several nodes (application logic, device registry, and device data store).

4. The insurance service app connects to the device maker's cloud and requests the data.

5. The data are analyzed to determine if there is a potential for damage to the home (including water damage, freeze potential, and more). Once it is determined that there is a problem, notifications are sent to the homeowner and to the insurance company. The homeowner can then take an action to respond to the notification and determine if damage has occurred and the insurance company can initiate a claim process.

6./7. If damage has occurred, the process of claims management is initiated. This can be accomplished in the cloud service, the enterprise app, or the mobile apps.

IBM's Example Smart Home IoT Architecture



Source: IBM Cloud Architecture Center

Miami-Dade County has begun to advance in areas listed on the graphic to the right, and will do even more through the AT&T Smart Cities Operation Center. The architecture of each will be developed and connected to produce a truly SMART Community.

A Few Building Blocks of Complete IoT Architecture

Service Domain	Services
Smart Home	Entertainment, Internet Access
Smart Office	Secure File Exchange, Internet Access, VPN, B2B
Smart Retail	Customer Privacy, Business Transactions, Business Security, B2B, Sales & Logistics Management
Smart City	City Management, Resource Management, Police Network, Fire Department Network Transportation Management, Disaster Management
Smart Agriculture	Area Monitoring, Condition Sensing, Fire Alarm, Trespassing
Smart Energy & Fuel	Pipeline Monitoring, Tank Monitoring, Power Line Monitoring, Trespassing & Damage Management
Smart Transportation	Road Condition Monitoring, Traffic Status Monitoring, Traffic Light Control, Navigation Support, Smart Car Support, Traffic Information Support, ITS (Intelligent Transportation System)
Smart Military	Command & Control, Communications, Sensor Network, Situational Awareness, Security Information, Military Networking

Source: Internet of Things (IoT) – Part 2 (Building Blocks & Architecture), by Sukanya Mandal

DTPW'S EFFORTS RELATED TO SMART CITIES AND CAV TECHNOLOGIES

Following is a summary of the ongoing efforts at the Miami-Dade County Department of Transportation and Public Works (DTPW).

DTPW'S ONGOING EFFORTS

ADAPTIVE SIGNAL CONTROL TECHNOLOGY (ASCT) DEPLOYMENT

As part of the programmed technology upgrade to County's traffic signal system, DTPW, in partnership with FDOT, has begun upgrading the entire traffic signal system from the model170 controller to the new model2070LX controller to enable the traffic signal infrastructure to be integrated with connected vehicles. The new system will be connected to the recently upgraded Traffic Management Center (TMC). The upgrade of County's signal controllers to V2I capable controllers and advanced traffic flow detection systems (consisting of a combination of sensors, Bluetooth and Wi-Fi readers technology, DRSC, cameras, and fiber optic, to improve data collection and communication capabilities) started in late 2016.

As part of the initial deployment phase, DTPW selected 12 arterial corridors as pilot projects where advanced traffic management strategies will be deployed and evaluated. The new equipment with adaptive control capabilities will be installed on these corridors (300 traffic signals) that will allow the deployment of CV technologies including Multi-Modal Intelligent Traffic Safety System (MMITS), Signal Phase and Timing (SPaT) messages, and queue warning technologies.

ADVANCED TRANSIT MANAGEMENT SYSTEM AND AV TECHNOLOGY

DTPW has implemented one of the most advanced transit management systems in the region. DTPW, in partnership with FDOT is currently installing Mobileye crash avoidance devices on ten Metrobuses in a pilot program to test the safety performance and effectiveness of these AV technologies. The pilot is programmed to start in Spring 2017.

SMART STREETLIGHTING

The street lighting and LED retrofit project is underway. It will improve safety, reduce operating costs, enable traffic data collection, and digital displays among others items.

MOBILE APPS

DTPW has launched the MDT tracker and MDT Transit Watch.

- **MDT Tracker** — Allows riders to track Metrobus, Metrorail and Metromover and to access ETAs in real time. It is an easy, convenient and quick way for riders to plan a trip, pay for passes, reload EASYcard, provide feedback in real time and rate transit service via the "Rate Your Ride" option. It provides information of Municipal Circulators.

- **MDT Transit Watch** — This mobile app facilitates reporting of security incidents in real time and anonymously.

- **Upgrade of DTPW's Fare Collection System and Infrastructure** — In 2016, DTPW began upgrading its fare collection system. This Open Back-End Integration project, will provide an account-based system that works across different fare structures and transportation providers to allow purchase of transit tickets/passes, book and pay for services, reload account(s) cards instantly, and eliminate the need to carry EASYcard for Pay-as-You-Go. The new system will allow the use of Near Field

Communication (NFC)-enabled smartphones, wearables and contactless bank cards. This infrastructure project will allow the creation of an all-inclusive trip planner and payment app.

- **All-inclusive Trip Planner & Payment App** — DTPW's goal, once the modernization of the fare collection system and infrastructure is completed, is to create a universal and all-inclusive mobile app, a convenient smartphone-based solution for routing of, booking and paying for trips involving several modes of transportation, including both public and private transportation service providers: Metrobus, Metrorail, Metromover, STS, as well as shared transportation services (bikeshare, rideshare, carpooling, taxis, water transport, slow-speed electric vehicles, and private transit and parking facilities (e.g., park-and-ride facilities, remote parking, etc.)) The app will facilitate access to "chain-linked" trips for all users including most vulnerable citizens: elderly, the digitally or economically challenged, the disabled and children. In the future, this mobility platform will facilitate booking, on-demand planning and payment for autonomous shared vehicle transportation services.

- **On-Demand, Flexible Transit Program** — As part of first/last mile solution, DTPW is developing on-demand flexible transit to increase access to and from transit stations.

- **CIVIQ Mobility Experience (CME)** — This marketing partnership program will provide advanced Wi-Fi and interactive kiosks at public places and transit centers, on all Metrobus, Metrorail and Metromover vehicles to increase the wide access to Wi-Fi across the County.

- Other ongoing projects/efforts include implementing:
  - ✓ PayByPhone, mobile parking payment applications for Metrorail parking garages and parking-and-ride facilities;
  - ✓ WAZE partnership for data exchange;
  - ✓ Bikesharing program for Metrorail stations and other transit facilities, dynamic carpooling application (RideFlag);
  - ✓ Sidewalk Labs' Smart Parking App to help drivers find available parking in real time through Google maps;
  - ✓ RideFlag/SFCS Partnership for dynamic carpooling app;
  - ✓ Reversible traffic flow lanes;
  - ✓ Transit Signal Priority for buses; and,
  - ✓ EV Infrastructure network plan to increase availability of charging stations across the county, particularly at transit facilities to increase access to transit.

FDOT AND MDX CAV RELATED EFFORTS

- **FDOT's Freight Signal Priority (FSP) pilot CV technologies** — FDOT is evaluating how FSP using CV technologies can support freight mobility in the area surrounding MIA.

- **MDX's SMART 836** — The portion of SR-836 between LeJuene Road (SW 42nd Avenue) and W 137th Avenue (approximately 10.3 miles) has been designated as "SMART 836" to implement CAV technologies. The following CV technology initiatives on SMART

836 are scheduled to occur in Fiscal Year 2017.

- ✓ SMART 836 CV Technology Deployment - Installation of DSRC-based roadside equipment (RSE) and on-board equipment (OBE) units on SMART 836 to ex-change safety and travel-related information in a safe environment.

- ✓ V2I Mobility Applications Deployment - Implementation of V2I-based mobility applications to enhance the FDOT's SunGuide Traffic Management Center(TMS) software. Several years ago FDOT implemented a Connected Vehicle module as part of a demonstration project during the Annual ITS America Event. MDX plans to review this module and update it as needed with new features and technological capabilities.

- ✓ DSRC-Based Application for Pavement Surface Analysis - Development of a pavement surface analysis application using DSRC as the communication infrastructure. This initiative will consist of an application to evaluate the conditions of the roadway and reporting in real time using DSRC communication back to MDX's Fiber Optic backbone.

- ✓ Bluetooth and Wi-Fi Readers Technology Deployment-Deployment of Bluetooth and Wi-Fi readers technology to improve data collection capabilities. With the deployment of Bluetooth and Wi-Fi readers it is expected to improve data collection capabilities, travel time, as well as, origin and destination information accuracy and reliability for distribution and dissemination to the public.

WHAT CAN BE SEEN/EXPECTED IN 2020 AND BEYOND

The future as seen by DTPW includes:

- **Autonomous shared vehicle transportation services**, including autonomous shuttles, ridesharing, car-sharing, carpooling, etc.

- **Implementation of Mobility as a Service (MaaS):** The integration of public transit and private transportation service providers along with the modernization of the DTPW's fare collection system and infrastructure will facilitate the implementation of MaaS concept. This will combine transportation services from public and private transportation providers (including shared-use transportation services, parking, tolls, etc.) through a unified gateway that creates and manages the trip, which users can pay for with a single account. Users can pay per trip or a monthly fee for a limited distance. This in turn will facilitate "chain-linked" trips and more affordable transportation options by reducing the costs related to car ownership. In the future, this could include autonomous shared vehicles, leading to a significant increase in shared-used mobility and access to more affordable housing, reduction in the use of private car and repurpose of facilities and land use.

- **Mobility Platform**: Creation of a modular data platform that will collect, aggregate and analyze real-time traffic, transit and shared-used mobility information from different sources and providers. This will provide the analytics and shareable information needed to planning and manage the entire transportation network.

IMPLEMENTATION

Beginning immediately, the TPO should update its Travel Demand Model, consistent with the proposal presented in this report. Likewise, research on funding mechanisms is key to developing a cost-affordable plan. New funding concepts should be explored, such as: Vehicle Mile Charge in place of fuel tax; Rental Car Passenger Facility Charge; Value Capture/Tax Increment Financing with tax districts around stations or along segments of the route. The TPO should engage a Study Advisory Committee with members from the public and private sectors to test/brainstorm the schedule/viability of items in the time periods for implementation. Then—with the LRTP consultant engaged—the full analysis will begin, as well as public involvement. Coordination with SMART Plan developments will be essential. New technology, and high-type transit, in combination with possible and significant land use changes will affect the future of the TPO region more than at any time in the past.

To respond most effectively to the ever-changing advancements in technology, a team within the TPO may need to be formed to monitor and report on ongoing research. This includes, but is not limited to, innovative smartphone and mobile technology, wearable technology, accessible transportation technologies, and other assistive and enabling technologies, operations, and/or techniques whether currently being pursued in research, or readily available in the market. The same is the case for Intelligent Transportation Systems (ITS), software platform development, on-demand technologies, and data standards and interoperability (i.e., effective connectivity among devices and systems). The latter is particularly important in developing applications aimed at enhancing personal mobility. Data must begin to work across service providers, utilize available real-time data sources and communicate in an efficient, and adaptable manner to meet individual user needs with various abilities. Technology applications to be considered for development will provide almost ubiquitous access to a wealth of real-time, situational data sources, including data specific to transportation systems allowing smoother access and transferring between accessible transportation services.

CONCLUSION

The “IoT Revolution” is changing the world faster than ever with impacts greater than past “economic” revolutions.

Over the next few decades, technology will continue to revolutionize our way of life. The transformations are, in many ways, unfathomable. Residential neighborhoods, public utilities, education, healthcare, manufacturing, and public safety will transform in ways that will change the entire world. Over the next 50 years, vehicles will no longer have a driver’s seat, steering wheel, or pedals. The shipping industry will become further automated and autonomous, where the need for drivers of semi-trucks, cargo ships, and trains could disappear.

The key to participating in the *Internet of Things* revolution is to establish a network of technology infrastructure that is capable of supporting human needs. This network must provide for the technology infrastructure to be upgraded quickly and efficiently. With the infrastructure in place, any city, town, rural place, or area along any roadway/corridor can build out the Internet of Things. The impacts, the potential benefits, and the disruptive changes to everyday life as we know it, are just beginning.

Miami-Dade County will be at the forefront of this technology revolution as will other world-class cities.

REMINDER

Please review the video at the following link to see how the technologies presented in this report fit together:

https://vimeo.com/209590464

https://vimeo.com/209590865


TPO
Miami-Dade Transportation
Planning Organization