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16. Abstract

The state of transportation is experiencing disruptive technological, institutional, and cultural changes, prompting transportation agencies to respond to and anticipate the needs of future customers. The Texas Technology Task Force (TTTF) is a strategic initiative that supports the Texas Department of Transportation in navigating change and developing a common vision for the state's transportation system. Composed of thought leaders from public agencies, industry, and research, the TTTF provides insight into portfolio development, impact analysis, and strategic planning. The Emerging Technology Portfolio includes the following six major categories that may be combined to serve a multimodal purpose: 1) Next Generation Vehicles & Energy, 2) Information & Communications, 3) Infrastructure & Construction, 4) Service-Based Platforms, 5) Materials & Additive Manufacturing, and 6) Other Technologies.. Each technology is then analyzed along four dimensions: 1) Goals, 2) Barriers, 3) User-Groups, and 4) Modes. A primary focus of this phase of work was on developing technical papers on two core strategies, managing customer relationships with data and developing a communication plan, White papers were also developed for freight and logistics technologies, drones, and big data. These papers serve as background pieces for a Strategic Technology Business Plan.

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CENTER FOR TRANSPORTATION RESEARCH

Phase III Texas Technology Task Force Activities Report

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Disclaimers

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Research and Technology Implementation
Dana Glover, Research and Technology Implementation Director
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Products

This report contains the following products as appendices:

- Appendix A: *Updated List of Task Force Members* (0-6803-01-P1)
- Appendix B: *Emerging Transportation Technology Portfolio* (0-6803-01-P2)
- Appendix C: *Critical Emerging Technologies (Preliminary Analysis)* (0-6803-01-P3)
- Appendix D: *White Papers* (0-6803-01-P4)
- Appendix E: *Update to the Work Plan for the Completion of Strategic Business Plan* (0-6803-01-P5)
- Appendix F: *Transition Plan* (0-6803-01-P6)

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1. Introduction

The Texas Technology Task Force (TTTF) was formed in 2013, encompassing a group of professionals with expertise in areas such as information and communications technologies, telematics, computing, economic and legal issues, public relations, and various emerging transportation technologies. The first three meetings of the TTTF took place during Phase I of work in Austin, Texas, from February 2013 through August 2013. These meetings focused on identifying new, transformational technologies that have potential to drastically change transport in Texas in the mid to long term. Work completed by the Task Force during this period resulted in the development and implementation of an evaluation framework for categorizing and selecting groups of emerging technologies for development and promotion. Three white papers on critical technologies were developed with the themes of autonomous vehicles, connected vehicles, and cloud computing and crowdsourcing. At the close of Phase I, the Task Force developed recommendations for an initial program of work for a public-private consortium and next steps. This included recommendations for an initial program of work for a public-private consortium that would be supportive of emerging technologies based on findings from the first two tasks. It also included recommendations for next steps, continuing research, and further potential legislative and/or policy recommendations.

The second phase of TTTF of work took place from September 2013 through December 2013 and resulted in initial background work for the establishment of the Strategic Technology Business Plan. Phase II's sole task was to start initial work to support the creation of a business plan that would ultimately serve to facilitate partnerships between public and private participants in technology. Such partnerships will be integral to enabling TxDOT's vision of providing a safe and reliable transportation system for Texas, while addressing congestion, connecting Texas communities, and becoming a best-in-class state agency. Phase II of the TTTF project focused on the initial work toward a strategic technology business plan for the state. Phase II saw the completion of initial background work for the establishment of the strategic business plan, following recommendations from Phase I. The intention is that in later phases of the technology study, the strategic business plan will be completed to fully demonstrate how public and private partners can collaborate in the creation of an economic roadmap to diversify and strengthen the state economy and transportation system though transformative emerging technology adoption. Final contents of the plan will provide an analysis on the state's transportation, information, and communication technology industries; establish state goals and objectives; develop an action plan for implementation; and articulate investment priorities and funding sources.

The third phase of the TTTF project focused on transformative technology discovery and expanding the portfolio of emerging technologies beyond those identified in earlier phases. It was the intent of the Task Force and research team to expand the portfolio to encompass newly developed technologies not on the Task Force radar in 2013 and to also expand focus by selecting technologies that apply across multiple modes.

This phase was conducted over the period of September 2014 to August 2015 with the following primary tasks.

1. Reconvene the Task Force.
2. Expand emerging technology portfolio.

3. Identify critical technologies.
4. Develop white papers on critical topics.
5. Develop a transition plan for next phases of work.

Primary research methods used were 1) Task Force member interviews, 2) literature and media syntheses, 3) development and application of technology evaluation framework, and 4) subject matter expert interviews.

This document provides an overview of research activities during this phase of work and provides all previous work products produced during this phase in the appendices for reference.

2. Research Tasks and Methods

The following section describes in more detail the objective of each primary research task and the research method used for completion.

2.1 Reconvene the Task Force

The task force was reconvened to review and revise Phase I and II work and expand the list of other highly transformational technologies or integrated systems. The research team, in consultation with TxDOT partners, conducted interviews with returning Task Force members to obtain their feedback and recommendations for additional participants.

Appendix A includes a list of returning Task Force members (who were interviewed), and a list of proposed additional participants for consideration. This was submitted as a project deliverable titled *Updated List of Task Force Members* (0-6803-01-P1).

2.2 Expand Emerging Technology Portfolio

To identify emerging transportation technology portfolio, the research team, in parallel with internal literature reviews and media synthesis, the research team conducted phone and in-person interviews with TTTF members from the last two phases and other technology thought leaders. The interviewees were technology experts representing consulting firms, public agencies, and research institutes (see Table 1). A questionnaire was developed to streamline the interview conversations. The questionnaire included a table summarizing the key technology areas (with newly added areas for smartphone applications, social networking, materials, energy, and manufacturing) and their emerging and potential applications identified through the literature review. Using that table as a starting point, the interviewees provided their recommendations on three topics: 1) New technology areas worth looking into, e.g., unmanned aerial vehicles (UAV); 2) Specific technologies and/or technology applications, e.g., low-speed autonomous vehicles; 3) Evaluation of technologies in a broader context, in terms of intermodal transportation (especially transit and freight), human behavior, land use, financing, insurance, and smart city management.

Table 1: Interviewee List

Name	Affiliate	Expertise Areas
Steve Dellenback	Southwest Research Institute	CAV, UAV, smartphone applications
Mike Heiligenstein	Central Texas Regional Mobility Authority	V2I, roadway energy & materials, freight, parking, human behavior
Shelley Row	Shelley Row Associates LLC	CAV, TaaS, 3D printing
Harry Voccola	Nokia Location & Commerce	Freight, alternative fuels, CAV, big data
Michael Morris	North Central Texas Council of Governments	Freight, energy, CAV
John Betak	CAIT, Rutgers University	Freight, UAV, 3D printing
Darran Anderson	TxDOT	Transportation systems, technology
JD Stanley	Cisco	Communications
Srimat T. Chakradhar	NEC Labs	Big Data, Advanced Analytics

CAV= Connected and/or autonomous vehicles
UAV=Unmanned aerial vehicles
*: Interview TBD
V2I = Vehicle-to-Infrastructure capability
TaaS=Transportation as a service

Synthesizing the subgroup interview inputs, the team updated the initial identified technology areas and developed the emerging transportation technology portfolio, by expanding the known technology areas, specific technology applications, and re-organizing the previous categorization. The team grouped individual technologies (described below) into six primary technology areas shown in Figure 1.

2.2.1 Emerging Technologies

Autonomous Vehicles, which may include specific applications in the following areas: autonomous freight technology, platoons, and pilots; personal autonomous vehicles including neighborhood/low speed and non-neighborhood vehicles; commercial uses (taxis); and autonomous parking in urban cores. For the evaluation process, these are broken into two categories: levels one and two automation and levels three and four automation.

Connected Vehicles, including current and prospective applications, trials and, pilots; V2I implementation/wrong way driver detection; and studies of human behavior and driver interface with CV applications. For the ranking process, these are broken into two categories: V2I and vehicle-to-vehicle technologies.

Electric Vehicles and Systems, including smart highways, solar highways, or roadway energy storage and transmission; battery technology; distributed nuclear energy; alternative fuels, inductive charging or wireless energy transfer; DC fast charging systems, and smart grids.

Unmanned Aerial Vehicles (UAV) including surveillance applications and logistics.

Information and communication technologies including ***cloud computing*** with big data, distribution and analysis (automotive cloud), and super-fast computing for V2I, and

crowdsourcing, which includes smartphone applications and surveillance or emergency management examples and applications.

Infrastructure and construction technologies, including infrastructure enhancements such as fiber optics and ITS technologies, and construction techniques and equipment, including truss sliding and vacuum consolidation.

Materials, including self-healing pavements and nanotechnologies.

Additive manufacturing for vehicles and infrastructure (***3D printing***).

DETAILED EMERGING TECHNOLOGY PORTFOLIO		
Next Generation Vehicles & Energy	**Information & Communications**	**Materials & Additive Manufacturing**
Autonomous Vehicles	Cloud Computing	Self-Healing Pavements
Connected Vehicles	Crowdsourcing	Nanotechnologies
Electric Vehicles		3D Printing
Unmanned Aerial Vehicles		
Infrastructure & Construction	**Service-Based Platforms**	**Other Technologies**
Infrastructure Enhancements	Location-Based Services	Google Glass
Construction Techniques	Transportation Subscription Services	Virtual Reality
Equipment		

Figure 1: Updated Emerging Technology Portfolio

A full description of the process followed and outcome of the portfolio identification process can be found in a deliverable titled *Emerging Transportation Technology Portfolio* (0-6803-01-P2), included as Appendix B.

2.3 Identify Critical Technologies

Two primary methods were used to identify the most critical technologies for additional focus. Those were Task Force and expert interviews and evaluation framework. The full evaluation framework along with implementation and results were documented in a deliverable titled *Critical Emerging Technologies (Preliminary Analysis)* (0-6803-01-P3), which is provided as Appendix C.

The evaluation framework was designed to assess individual technologies, providing a basis for comprehensive evaluation when selecting preliminary critical technologies for further inspection. The assessment focused on four primary dimensions:

- **Strategic Goal Alignment:** Ability to meet or further national and state transportation goals, which mainly pertain to safety, congestion, and the environment.
- **Deployment Barriers:** Presence of barriers to adoption and implementation, which include the regulatory, cost-efficiency, and safety aspects.
- **Mode-Specific System Enhancement**: Ability of technology to improve transportation in different modes, encompassing highway traffic, bicycle/pedestrian, freight, transit, aviation, port, etc.
- **User Group Enhancement:** Ability of a technology to enhance or improve transportation user group experience. User groups will closely align with trip purpose and mode combinations. For example, passenger vehicle travel for home-based work trips may use technologies differently than passenger vehicle trips for leisure travel, or interregional freight travel may receive different benefits from a particular technology than intraregional freight travel will.

For each evaluation, each research team member was asked to rank technologies in a matrix of technologies across columns against each evaluation dimension (rows) on a scale from zero to five. Each integer on the ordinal scale corresponded to each individual's belief about how each dimension represents each technology, with lower values indicating less relevance in a dimension and higher values indicating more relevance. For example, when considering the benefits that lower levels of vehicle automation could have on travel, a rank of zero would indicate no benefit and a rank of five would indicate a monumental impact on travel. A full summary of the assessments along these four dimensions and corresponding factors considered are listed in Tables 1a–d in Appendix C. After individual rankings, results from each team member are to be combined to form one final set of evaluation matrices to reflect the consensus of the team.

The final combined rankings were be used to inform a trade-offs analysis to compare technologies along common dimensions. The final evaluation in this step allows for the assessment and comparison of technologies along various dimensions so that a final set of critical technologies may be chosen for further analysis in subsequent steps.

Observations from the results show that overall, the most critical technologies in terms of alignment with goals, minimized barriers to adoption and diffusion and enhancements across modes and users were those that fall into autonomous vehicles, connected vehicles, information and communication, and service-based technologies.

Discussion at meeting of the Task Force on May 11, 2015, and August 11, 2015, also provided guidance on critical topics. Task Force members and TxDOT leadership indicated that critical topics for further exploration were the following:

1. The Customer of the Future
2. Global Freight and Logistics
3. Small UAVs
4. Big Data
5. Strategic Communication Planning

White papers on these topics were developed and are described in the next section.

2.4 Develop White Papers on Critical Topics

The following describes the five white papers developed by the research team and lists strategies for transportation agencies to follow. A description of each white paper's core message and identified strategies are provided below. Full white papers can be found in Appendix D.

2.4.1 Understanding the Customer of the Future

By viewing transportation as an interconnected experience, Texas can develop customer service strategies that ensure every touchpoint in the customer journey results in a seamless transition to the next stage. Using data to study the customer profile, transportation agencies can better understand their customers' needs and develop personal communication strategies that will resonate with each individual. Through customized incentives, transportation agencies can encourage customers to modify their route, time of day, and mode choices to benefit the transportation system as a whole. By developing a customer-centric mentality and prioritizing the customer relationship, transportation agencies can gain a deeper understanding of their stakeholders' interests.

Key Strategies

Study the Customer Profile
Changing demographics and cultural trends are impacting the customer base. Using the latest technology, transportation agencies can leverage relevant data to provide customers with a personal and valuable experience.

Discover the Customer Experience
When transportation agencies understand the five factors that are shaping the customer experience, they can utilize technology to strengthen customer engagement and build their brand.

Respond to Consumer Behavior
E-commerce, the shared economy, and evolving travel patterns have major implications for the transportation system. Transportation agencies will need to be prepared to respond to and incorporate new strategies into their planning efforts.

Exceed Customer Expectations
The transportation agency that goes above and beyond empowers the customer to become a brand advocate. By providing quality traveler information, roadway maintenance, and roadside assistance services, transportation agencies increase customer satisfaction.

Deliver Quality Customer Service
Proactively communicating important information to customers improves relationships and reduces potential dissatisfaction. By monitoring all communication channels, transportation agencies can respond swiftly and effectively, creating a consistent level of quality customer service.

2.4.2 Revolutionizing the Global Logistics Industry

With strong state growth, the connectivity of the interstate highway network, and proximity to the Mexico border, Texas could leverage state resources and conditions to appeal to logistics providers. By developing a synergistic environment that supports emerging technologies, such as 3D printing, the Internet of Things, drones, and RFID, Texas has the potential to become a leading candidate for logistics providers to perform new technology trials. Initial planning activities should focus on providing improved intermodal connections, expanding shipping choices, conducting intermodal studies to aid local and regional economic development efforts, and facilitating the cooperative operations between mode-specific agencies. States and regions that plan for and support increase in freight movement will enhance their own competitiveness in international and domestic markets.

Key Strategies

Understand the Full Suite of Technologies
The future of freight and urban logistics hinges upon technology development and adoption. Understanding the suite of emerging technologies is critical for integrating them into logistics services and supply chain management.

Develop an Interface between Modes
Planning for the interface between modes will provide for the optimum use of all of the state's transportation modes for freight movement. When modes interface well, paths for goods movement increase as congestion and delay decrease.

Identify Future Markets and Influences
Growth in freight shipment has a strong connection with population growth and overall economic health and is also influenced by many other factors. Understanding trends in these areas will provide indications to transportation agencies as to the amount and types of freight movement that needs to be accommodated.

2.4.3 Understanding Opportunities and Challenges of UAVs

The possibility of commercial and civilian uses of small UAVs, also known as drones, offer many beneficial applications in the areas of emergency response, structure inspections and safety, traffic monitoring and investigating, delivery and logistics, and more. Transportation agencies at all levels can get creative with proposed drones applications, which will offer safety, cost savings, and operational efficiency gains. In order for these benefits to be realized, transportation agencies should be proactive in planning by staying informed of FAA rules and regulations, understanding technological and operational barriers, and planning to mitigate citizen concerns through strategic initiatives. Transportation agencies can also support UAV integration by taking steps to provide the necessary support infrastructure, personnel, and programs.

Key Strategies

Monitor FAA Rulemaking and Regulations
The FAA is expected to issue updates to rules governing commercial and civil uses of drones in late 2016 or early 2017. Transportation agencies should watch for these updates and take advantage of other key initiatives for UAV integration supported by the FAA.

Identify Commercial and Civil Applications
Already a number of commercial uses of UAVs have been proposed by companies across the U.S. Transportation agencies can monitor these proposals in order to plan for their operations, learn from those trials, or partner with the partner sector for their own trials.

Discover and Mitigate Operational Obstacles and Barriers
Many barriers and obstacles exist, which will slow the introduction of UAVs for commercial and civil uses. Transportation agencies should anticipate these barriers and have a mitigation plan in place to increase the safe integration of UAVs.

2.4.4 Managing Customer Relationships Using Big Data

Texas has the potential to develop a truly interconnected transportation system by utilizing data as a platform for engaging with its customers. Empowering the customer with a voice and listening to his or her concerns are small steps that can have large impacts on the transportation network. Big Data can also be transformed into an effective decision-support tool. The key is to match the right tool to the right problem in order to effectively communicate to the decision-maker in a timely manner the best course of action. By making a commitment to data-driven decision-making, transportation agencies can take advantage of improved efficiencies, effective resource management, and cost savings across the state.

Key Strategies

Capture Data
By viewing data as a core asset, transportation agencies move beyond reactive and silo-based approaches to proactive and integrated management strategies. Collecting real-time data and relaying information to the customer can inform travel decisions that generate immediate value.

Integrate Silos of Information
Shifting from a single source to multi-source, multi-modal approach creates a comprehensive, data-rich environment from which state, regional, and local agencies can draw valuable information about their customers.

Analyze for Insight
Matching the right tool to the right problem enables the transportation agency to effectively communicate to the decision-maker the best course of action for the customer. Improvements may be achieved in efficiency, resource management, and cost savings.

Measure Performance
Developing a system of key performance indicators monitors the health of the enterprise and evaluates whether a transportation agency is achieving the goals it defined. Benchmarks and milestones are useful tools for establishing a concrete direction for the agency.

Leverage Data to Create Value
Knowing the customer helps the agency to better serve the customer and the public as a whole. Equipped with information, transportation agencies have the potential to offer incentives encouraging customers to shift to an alternative route, time of day, or mode.

2.4.5 Formulating a Communications Strategy

A successful strategic plan requires stakeholder engagement in order to facilitate adoption and implementation. Developing customized communications strategies tailored to specific interests ensures that each stakeholder's contribution is valued. By defining its main objectives, Texas can prioritize its stakeholders and craft a relevant message for each of its audiences. Transportation agencies can relate to customers on a personal level by identifying everyday transportation challenges that can be improved with technology. By providing valuable and quality customer service in each of these micro-moments, transportation agencies empower their stakeholders to become brand advocates. Developing a clear communications strategy is a first step in signaling that Texas is on the move again, leading the transportation of people, goods, and information.

Key Strategies

Know the Stakeholders
A successful strategic plan requires stakeholder engagement in order to facilitate adoption and implementation. Developing customized communications strategies tailored to specific interests ensures that each stakeholder's contribution is valued.

Build the Agency Brand
Transportation agencies portray themselves through the style represented in their brand, logo, and organization identity. Policies and guidelines on applying brand identity ensure that materials used in all stakeholder communication channels convey a coherent message.

Engage through Multiple Channels
By viewing the transportation experience through the eyes of the customer, transportation agencies can orchestrate the customer experience across all layers so that it is seamless, integrated, and consistent.

Embrace Digital Marketing
Transportation agencies can use digital marketing to strengthen brand awareness, improve engagement, and empower customer advocates. Content marketing in particular can be designed to encourage customers to adjust their travel patterns and behaviors.

Empower Champions of Change
Highlighting current successes and recognizing leaders who are improving the mobility of people, freight, and traveler information for the benefit of all develops a culture of which people feel proud to be a part.

3. Transition Plan

Finally, additional work toward the establishment of the Strategic Technology Business Plan was completed and a transition plan for continuing phases was developed and submitted as 0-6803-01-P5; this plan is included here as Appendix E.

With the conclusion of Phase III in August 2015, the TTTF is preparing to transition to its next phase. The Performing Organization has submitted a three-year work plan proposal (0-6803-01-P6) to the Sponsoring Organization that is currently under review. This proposal is provided as Appendix F. This three-year work program shall enhance previously completed work by the TTTF and provide necessary supporting research on emerging technologies and their trial programs to form the basis of recommendations to TxDOT regarding the development of programs and initiatives for technology adoption and integration in Texas.

4. Texas Technology Task Force Meetings

The Task Force held two meetings at TxDOT offices—one on May 11, 2015, and August 11, 2015. At each of the meetings TxDOT leadership and key staff were asked to attend along with the research team and special subject matter experts (SMEs) on identified technology topics. At the first meeting in May, three technology-centered panel discussions were held with SMEs on the topics of global logistics, unmanned aerial vehicles, and big data. At the August meeting, again three technology-centered panel discussions were held with SMEs on the topics of ports and logistics, data privacy and security, and logistics and smart cities. Each meeting provided dedicated time for discussion between the SMEs, Task Force, and TxDOT leadership attendees.

Full meeting materials with agendas, panel discussion descriptions, notes, and other materials can be found in Appendix G.

Appendix A: *Updated List of Task Force Members* (0-6803-01-P1)

CENTER FOR TRANSPORTATION RESEARCH

0-6803-01-P1

UPDATED LIST OF TASK FORCE MEMBERS

TxDOT Project 0-6803-01: Texas Technology Task Force (TTTF)

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Texas Technology Task Force

(current list of members as of 12/31/14)

The following is a list of prospective returning or new subject matter experts to serve as members of the Texas Technology Task Force in the current phase of work. Prospective new members have been added by recommendation of previous members and other transportation and technology experts close to the project. The list is neither exhaustive nor final as Task Force membership is intended to evolve as the need for new expertise is identified. Experts listed below will be asked to either participate in the Task Force activities or to help identify additional experts needed on the Task Force.

Returning Members

Steve Dellenback
Director, Intelligent Systems Department
Southwest Research Institute

David Ferdman
Chief Strategy Officer
CyrusOne, Inc.

Mike Heiligenstein
Executive Director
Central Texas Regional Mobility Authority

Shelley Row
President and CEO
Shelley Row Associates LLC

Harry Voccola
Executive Advisor
Nokia Location & Commerce

Michael Morris
Director of Transportation
North Central Texas Council of Governments

JD Stanley
Public Sector CTO
Internet Business Solutions Group Cisco

Michael Walton
Ernest H. Cockrell Centennial
Chair in Engineering
Department of Civil, Architectural and Environmental Engineering
The University of Texas at Austin

Proposed New Members (or guest speakers)

Kristi Lafleur
Executive Director
Illinois Tollway

Michael Manser
Program Manager, Senior Research Scientist
Texas Transportation Institute

Johana Zmud
Senior Research Scientist
Texas Transportation Institute

Joseph Kopser
CEO
RideScout

Thomas Bamonte
General Counsel
North Texas Tollway Authority

Richard Bishop
Bishop Consulting

Wesley Smith
Chief Development Officer & Founder
Wireless Advanced Vehicle Technology

Appendix B: *Emerging Transportation Technology Portfolio* (0-6803-01-P2)

0-6803-01-P2

EMERGING TRANSPORTATION TECHNOLOGY PORTFOLIO

Jia Li
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Kristie Chin
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TxDOT Project 0-6803-01: Texas Technology Task Force (TTTF)

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Summary

In this document, we present the emerging transportation technology portfolio identified through internal literature survey and interviews with a subgroup of Texas Technology Task Force (TTTF) members and other technology thought leaders, conducted from September to December 2014. The team first identified and examined emerging technologies in areas of smart vehicle, sensing, computing, robotics, social networking, location-based service, manufacturing, energy, and materials, which are envisioned to reshape the transportation landscape in the short, middle, and long term. Seven key technology areas are included in the proposed technology portfolio, based on the inputs from subgroup interviews. For each technology area, we describe its scope, recent technology advances, market, and policy issues. We also synthesize qualitative and quantitative approaches to assess and manage the emerging technology portfolios and discuss how these approaches are applied in current context.

1. Background

Texas's 83rd Legislature passed the General Appropriations Bill, S.B. No. 1, Item 44, VII-31 and charged the Texas Department of Transportation (TxDOT) with examining and evaluating innovative transportation technologies to achieve cost savings, reduce traffic congestion, enhance safety, and increase economic productivity. As a result of this charge, the TTTF was formally created in 2013 to develop a vision for the future Texas transportation system that furthers the mission of TxDOT via technology-based solutions. TxDOT's mission is to provide a safe and reliable transportation system for Texas, while addressing congestion, connecting Texas communities, and becoming a best-in-class state agency.

In Phase I (February to August, 2013), the TTTF began with an internal core group that sought experts in various transportation technologies to provide directions for the Task Force. Three full-day workshops were held in Austin, on April 29, June 12, and July 13 of 2013. In each meeting, participants discussed emerging transportation technologies, their development stages, evaluation methods, and short- and long-term visions. The Phase I work resulted in the development and implementation of an evaluation framework for categorizing and selecting groups of emerging technologies and work plans for establishing a public-private consortium to further develop key emerging technologies and a work plan for developing test platforms for new transportation systems.

In Phase II (September to December 2013), the Task Force mainly focused on the background research pertaining to the strategic technology business plan, including a strengths/weaknesses/ opportunities/threats (SWOT) analysis, environmental scan, and vision and strategy development. The Phase II work resulted in a work plan and background research for completion and implementation of the strategic technology business plan in the next phases.

Phase III, i.e., the current phase, started in September 2014. The purpose is twofold: (1) review and revise past work; (2) expand the list of other highly potential technologies and/or integrated systems, and establish a transition plan for implementing and completing the strategic technology business plan. Between September and December of 2014, the research team conducted in-person and phone interviews with a subgroup of Task Force members, and determined an expanded list of emerging transportation technologies (i.e., technology portfolio) and a list of task force members. Section 2 summarizes this effort.

Built on subgroup interviews and literature survey findings, the purpose of this document is to provide an overview of emerging transportation technology portfolios and assessment and analysis framework. Sections 3 and 4 of this document address two areas: (1) synthesis of scope, trends, and qualitative benefit-cost appraisal of emerging technologies in the areas of automation/robotics, informatics, energy, and material, which are transformative to transportation systems (including surface, freight, and transit) in the broad sense; (2) a vision for the transportation technology portfolio analysis and management methods and their applications in current context.

2. Subgroup Interview

To identify emerging transportation technology portfolio, from September to December of 2014, in parallel to internal literature survey, the research team conducted six phone and in-person interviews with a subgroup of TTTF members from the last two phases and other technology thought leaders. The interviewees are technology thought leaders representing consulting firms, public agencies, and research institutes (see Table 1). A questionnaire was developed to streamline the interview conversations (see Appendix A). The questionnaire includes a table summarizing the key technology areas (newly added areas include smartphone applications, social networking, materials, energy, and manufacturing) and their emerging and potential applications identified through literature review. Using that table as a starting point, the interviewees provided their recommendations on three topics: 1) New technology areas worth looking into, e.g., unmanned aerial vehicles (UAV); 2) Specific technologies and/or technology applications, e.g., low-speed autonomous vehicles (AV); 3) Evaluation of technologies in a broader context, in terms of intermodal transportation (especially transit and freight), human behavior, land use, financing, insurance, and smart city management.

Table 1: Subgroup Interviewee List

Name	**Affiliate**	**Expertise Areas**
Steve Dellenback	Southwest Research Institute	CAV, UAV, smartphone applications
Mike Heiligenstein	Central Texas Regional Mobility Authority	V2I, roadway energy & materials, freight, parking, human behavior
Shelley Row	Shelley Row Associates LLC	CAV, TaaS, 3D printing
Harry Voccola	Nokia Location & Commerce	Freight, alternative fuels, CAV, big data
Michael Morris	North Central Texas Council of Governments	Freight, energy, CAV
John Betak	CAIT, Rutgers University	Freight, UAV, 3D printing
Darran Anderson	TxDOT	Transportation systems, technology
JD Stanley*	Cisco	Communications
CAV= Connected and/or autonomous vehicles UAV=Unmanned aerial vehicles *: Interview TBD		V2I = Vehicle-to-infrastructure capability TaaS=Transportation as a service

Synthesizing the subgroup interview inputs, the team updated the initial identified technology areas and developed the emerging transportation technology portfolio, by expanding the known technology areas, specific technology applications, and re-organizing the previous categorization. The team identified xix primary technology areas and included in the portfolio four other technologies (Table 2):

Table 2: Emerging Transportation Technology Portfolio

	Technology Area	**Highlighted Applications**
Primary	AVs	Personal, freight, transit, rideshare
	Connected vehicles	Safety (e.g., wrong-way travel), TaaS
	Electric vehicle and systems	Smart grid, energy storage and transmission
	Cloud computing	Vehicular cloud computing
	Crowdsourcing	Surveillance and emergency management
	UAVs	Surveillance, logistics
Other	Location-based service	Rideshare, social network
	Google Glass	Virtual reality, Internet of Things
	3D printing	Distributed manufacturing
	Self-healing materials	Self-healing pavement

3. Emerging Transportation Technology Portfolio

In this section, we provide a synthesis of the scope, trends, applications, and barriers of each item in the technology portfolio provided in Table 2.

3.1 Autonomous Vehicles

AVs are vehicles capable of sensing the environment and navigating with limited-to-no human inputs [1][2]. There were two surges of AV developments. The first surge was driven by traditional car manufacturers, dating back to the 1980s (Mercedes-Benz robotic van). The second surge is driven by technology companies (for example, Google) starting from 2009–2010, and features high-resolution maps and artificial intelligence. Current AVs employ recent advances in areas including but not limited to sensing, computer vision, automated control, and artificial intelligence. AVs feature comprehensive use of various sensors, which include short- and long-range radar, Lidar (light detection and ranging), GPS, infrared sensors, and cameras. Table 3 provides a comparison of the applicability and limitations of these sensors. These sensors are used to collect environmental (including roadway, neighboring vehicles, and pedestrian), vehicle, and driver information in real time, which is processed by onboard computers to generate corresponding actions, such as automatic cruising, automatic braking, lane-keeping, warning of potential collision, automatic parking, etc.

Table 3: Environment-Sensing Technologies Used in AVs

Sensor	Range	Limitation
Laser (i.e., Lidar) detector	Generates constantly updated 3D map of car's vicinity	Low performance in adverse weather and with dirty (non-reflective) vehicles; low spatial resolution and slow scanning speed
Long-range radar	Detection range 150–250 meters, sees through fog	Price
Short-range (millimeter-wave) radar	Detection range 0.5–10 meters	Low spatial resolution, slow scanning speed, more expensive than laser-based sensor (but more robust in rain and fog)
Camera, i.e., video sensor	Can be used where visual information (e.g., lane marking, traffic sign, obstacle) plays a role	Less robust than short-range radar in foggy, night, or direct sunshine conditions. Requires more computing resources.
GPS	Navigation and routing	Public encoding—low resolution navigation
Infrared sensor	Senses proximity or motion based on infrared radiations	Inaccuracy, due to temperature-based working mechanism

The National Highway Traffic Safety Administration (NHTSA) (2013) categorized AVs into four levels of automation: L1—function-specific automation involving one or more specific control functions, or multiple functions operating independently; L2—combined function automation, involving at least two primary control functions to work together; L3—limited-self driving; L4—full self-driving.

The autonomous functionalities fall into categories of *safety-oriented* and *driver-assistance*. Safety-oriented features include collision avoidance, collision warning, automatic braking, blind spot warning, and driver monitoring. Driver-assistance features include adaptive cruise control (also known as "autopilot"), intelligent parking, and automatic reporting (e.g., OnStar) based on telematics.

AVs can impact various modes of transportation, including freight, transit, shared service, farming, and military; the primary mode influenced will be passenger cars. The Google driverless car was developed for and tested in urban and rural settings. In 2014, Google released a new driverless car prototype with a top speed of 25 mph, intended for urban and suburban settings rather than highways. As of 2015, many major car manufacturers (including GM, Mercedes-Benz, Volkswagen, Audi, Nissan, Toyota, Volvo, Tesla, and Google) have demonstrated AVs at various occasions, and announced plans to launch cars with partial autonomous features (L1 & L2), e.g., adaptive cruise control in stop-and-go traffic, to consumer market around 2015–2020, aunching fully autonomous cars (L3 & L4) around 2020–2025. In freight transportation, automated convoying of trucks can contribute to fuel saving. AV-based shared mobility service (ridesharing or TaaS—Transportation as a Service) is another area

attracting increasing attention, as it can complement the traditional public transit. In addition to these areas, AVs are also used in military and farming applications.

AVs can have immediate impacts on traffic safety (fewer vehicle and pedestrian collisions), driver experience (decreased stress related to driving and parking), mobility (smoother traffic flow and less congestion), and accessibility (for mobility-constrained groups), as well as long-term impacts on driver behaviors (e.g., vehicle miles traveled), land use, and related industries such as technology, manufacturing, insurance, and healthcare. Most existing studies are based on simulations involving hypothetical assumptions or stated preference studies based on traveler surveys. But since there are currently no large-scale deployment and field tests of AVs, the comprehensive impact of AVs is still an unexplored issue and characterizing it involves substantial uncertainties.

Several barriers prevent or delay the consumer market's adoption of AV technologies. The cost of full-fledged sensor system on an AV is still high (for example, Lidar system on Google's driverless car costs $70,000), although decreasing trends in the prices of technology products are often observed (Moore's law). Also, due to the dependence on sensors, satisfactory AV performance requires relatively good weather, light, and infrastructure conditions. Potential liability is another issue, considering the possibility of crashes involving driverless cars. This issue requires state-level and federal efforts on legislation and policymaking.

3.2 Connected Vehicles

Connected vehicles refer to vehicles equipped with communication devices that allow them to communicate with each other (V2V—vehicle to vehicle), to road side devices (V2I—vehicle to infrastructure), to personal mobile devices, or to the internet (vehicular cloud).

According to the underlying technology, connected vehicles can be categorized as cellular based or DSRC (dedicated short range communication) based [3][4]. The former uses the 3G or 4G cellular network, the same as smartphones. DSRC is a one-way or two-way short-range to medium-range wireless communication channel and corresponding set of protocols and standards dedicated for automotive applications (other short-range wireless communication protocols include IEEE 802.11, Bluetooth, and CALM). DSRC uses a 75-MHz spectrum in the 5.9-GHz range. Compared to cellular-based connectivity, DSRC features very low latency and high reliability. Its recommended use is to broadcast Basic Safety Messages at 10 times per second. Besides DSRC, other communication standards are permitted for non-safety-critical applications [5].

Connected vehicles underpin numerous transportation applications in the areas of safety, mobility (operations and management), and environment. Safety is a primary application, in particular for DSRC-based V2V and V2I systems. Safety applications envisioned include intersection collision warning, wrong-way travel warning, curve speed warning, red light violation warning, transit pedestrian detection, automatic incident reporting, forward collision warning, approaching emergency vehicle warning, vehicle safety inspection, rollover warning, highway-rail intersection warning, etc. The most significant mobility-oriented applications include Cooperative Adaptive Cruise Control, signalized intersection control, intelligent merge control, probe data collection, and emergency vehicle signal priority. Through connected vehicles, the information can be more effectively collected and disseminated, which enables TaaS and eco-driving. In addition, connected vehicles will allow more effective electric toll

collection and road use measurement. Based on cellular connectivity, the applications cover real-time data, infotainment, safety diagnostics, and driver statistics.

The adoption of connected vehicles mainly faces a choice between DSRC and cellular technology, as both technologies are mature and inexpensive today. Policymaking is necessary to mandate the adoption of DSRC, as sufficient market incentives are lacking. Rulemaking concerning DSRC in the United States has been active since late 1990s. In 1997, ITS America petitioned the Federal Communication Commission (FCC) for allocation of the 5.85–5.925 GHz (i.e., 5.9 GHz spectrum) for DSRC. In 1999, the FCC allocated 75 MHz of spectrum in the 5.9 GHz band to be used by intelligent transportation systems (ITS). In 2003, the FCC adopted a report and order establishing licensing and service rules for DSRC in ITS radio service. In 2003, the USDOT announced the Vehicle Infrastructure Integration initiative. Nonetheless, in the last several years, due to the sparse actual deployment of DSRC device, the ITS community faces a "use it or lost it" situation in possessing the 5.9 GHz spectrum resource. In 2012, the FCC opened a Notice of Proposed Rulemaking (NPRM), on the revision of the commission's rules to permit unlicensed national information infrastructure devices in the 5 GHz band. In 2013, the National Telecommunications and Information Administration expressed concerns about the potential risks, and agreed with ITS America that further analysis is needed to determine whether and how the multiple risk factors can be mitigated. In 2014, the NHTSA issued an Advance NPRM to begin implementation of V2V communication technology (mandating DSRC on light-duty vehicles), and an NPRM is expected to be delivered by 2016. An overview of the DSRC rulemaking process is shown in Figure 1.

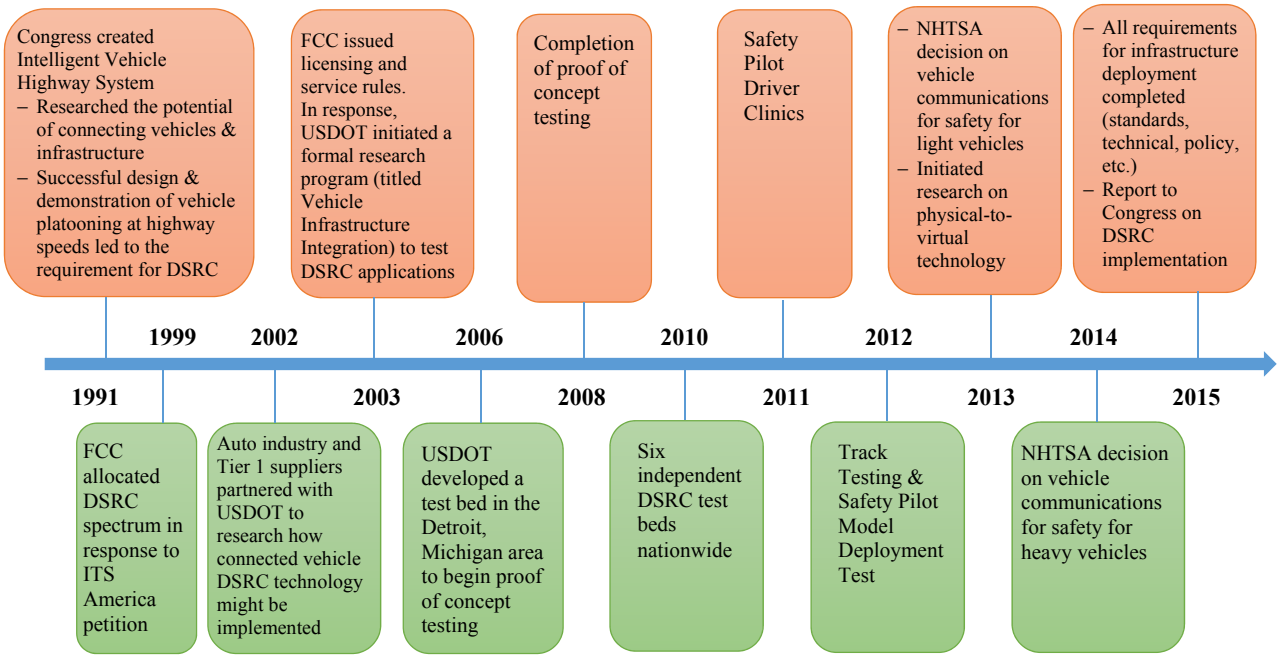

Figure 1: Rulemaking on DSRC (Adapted from tollroadsnews.com)

In contrast to the DSRC situation, in the last five years 3G and 4G communication architectures and devices have become mature, and cellular technology has drawn increasing attention, now

applied in infotainment and subscription-based communications (e.g., OnStar) [13]. Car manufacturers, technology companies, and wireless carriers are all engaged in this area. Many car manufacturers are implementing or modifying the apps of Google and Apple in their cars. In 2013, Tesla connected all of its cars to the internet over 3G and 4G through AT&T's M2M (machine-to-machine) suite of applications, which is AT&T's Internet of Things platform. In 2013, GM switched its provider OnStar (OnStar provides emergency services and vehicle diagnostics and directions based on voice and data communication) from Verizon to AT&T for 2015 models, after partnering with Verizon for almost 20 years, partially due to the compatibility of AT&T's communication standards with other countries. As of September 2014, AT&T announced partnership with eight car makers, Verizon announced four, Sprint announced two, and T-Mobile announced one. In 2014, Google and Apple introduced their infotainment systems, respectively called Android Auto and CarPlay. Android Auto features audio and messaging, while CarPlay features Siri, Maps, and iTunes Radio.

Connected terminals will increase to 50 billion by 2015, among which 0.75 to 1 billion will be automobiles. Fusion of DSRC with cellular technology is possible and anticipated. In 2011, the GSM Association predicted that DSRC/WAVE (Wireless Access for Vehicular Environments) may be integrated into 4G to provide diagnostics and maintenance functions, through heterogeneous or "vertical" roaming and software-defined network (SDN). Many peer-to-peer wireless systems will likely interact closely with the 4G. DSRC/WAVE units are expected to utilize wireless backhaul to the cloud through cellular or dedicated wide area networks.

3.3 Electric Vehicles and Systems

Electric vehicles (EVs) are powered through a collector system by electricity from off-vehicle sources, or may be self-contained with a battery or generator to convert fuel to electricity. Broadly speaking, EVs include road and rail vehicles, surface and underwater vessels, electric aircraft, etc. [6][7]. EVs can be wirelessly charged, through a technology using electrodynamic induction. Electric systems include power storage, transfer, and distribution systems that support EVs. They include DC fast wireless charging stations along highways, wireless charging embedded in roadways, nano-batteries, solar highways, smart grids, and vehicle-to-grid (V2G) technology (vehicles are capable of directing electricity both from and to the grid).

Significant applications in this area include wireless charging and solar roadways. Electric wireless charging is most suited to transit, which has fixed route, range of travel, and stops. In the United States (e.g., Utah), Korea, and several European countries (the U.K., Italy, Germany, the Netherlands, etc.), some public transit systems have adopted wireless charging. Besides transit, market penetration of EVs in the personal car market is non-negligible. As of 2014, more than 600,000 highway-capable plug-in electric passenger cars and light utility vehicles have been sold worldwide, among which 356,000 are all-electric cars and 248,000 are plug-in hybrids. The United States is the market leader of EVs. Since 2008, 260,000 units of EVs have been delivered. A new Navigant Research report estimated that by 2023, EVs (including plug-in hybrid vehicles) account for 2.4% of U.S. auto sales. Solar roadways use photovoltaic pavement that can generate electricity by collecting solar power. Candidate locations of this technology include parking lots, foot paths, driveways, streets, and highways. Solar driveways and parking lots will allow charging of EVs with clean energy, and solar highways can allow charging while driving. These features will solve the notorious "range anxiety" issue associated with EVs. In addition, solar roadways can provide needed power and light after infrastructure-disturbing events such as

earthquakes, etc. Besides wireless charging and solar roadways, V2G is another noteworthy technology that has military applications and was used for emergency generators in the aftermath of the 2011 tsunami and earthquake in Japan.

Many benefits are envisioned with EVs and electric systems (wireless charging, solar roadway, V2G, etc.): EVs can mitigate the dependence on fossil fuels and reduce the environmental footprint of transportation. Barriers to widespread adoption include the cost of electric or hybrid cars, which is still higher than that of regular cars. In addition, zero or lower gas consumption means lower gas taxes. Therefore, to compensate for the lost tax revenues, seven states are charging or planning to charge a special fee to electrical vehicle drivers: Washington, Colorado, Nebraska, Virginia, North Carolina, and Wisconsin.

3.4 Cloud Computing

Cloud computing is the delivery of on-demand computing resources (everything from applications to data centers) over the Internet on a pay-for-use or subscription basis [8]. While the concept of cloud computing dates back to 1950s, it has rapidly developed in the last decade, when computing and communication architectures become mature. The primary aim of cloud computing is to cut costs and help the users focus on their core business instead of being impeded by IT obstacles. The National Institute of Standards and Technology identifies five essential characteristics of cloud computing: on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service. Cloud computing services can be categorized as Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). See Figure 2 for the hierarchy in a mobile cloud computing architecture. In transportation, the most relevant concept is mobile cloud computing, which involves three layers in the architecture: application layer, platform layer, and infrastructure layer. Vehicular cloud computing is a particular type of cloud computing, which refers to "A group of largely autonomous vehicles whose corporate computing, sensing, communication and physical resources can be coordinated and dynamically allocated to authorized users." The architecture of vehicular cloud computing is illustrated in Figure 3.

Aligned with the three-layer architecture of mobile cloud computing, applications of cloud computing in transportation fall into three categories: IaaS at the infrastructure level (e.g., data streaming and archiving on public or private cloud), PaaS at the platform level, and SaaS at the software level (e.g., smartphone apps). In last five years, research and development (R&D) activity on vehicular cloud computing has been very active. In 2011, IBM announced the IBM SmartCloud framework to support their Smarter Planet initiative. Among the various components of the Smarter Computing foundation, cloud computing is a critical piece. In 2011, Microsoft committed 90% of its $9.6 billion R&D budget to cloud computing. The Ford Motor Company combines social networks, GPS location, and real-time vehicular data to assist drivers using the cloud. Toyota and Microsoft also announced a $12 million partnership to bring cloud computing to Toyota. It is predicted that cloud applications will account for 90% of total mobile data traffic by 2018, compared to 82% at the end of 2013.

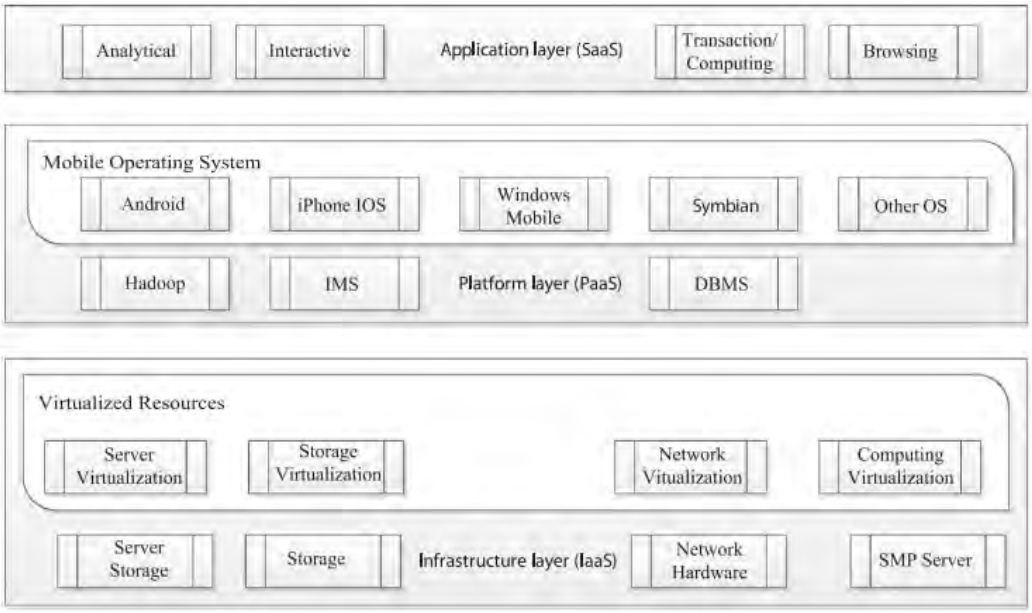

Figure 2: Mobile cloud computing architecture (Source: Dinh et al., 2011 [10])

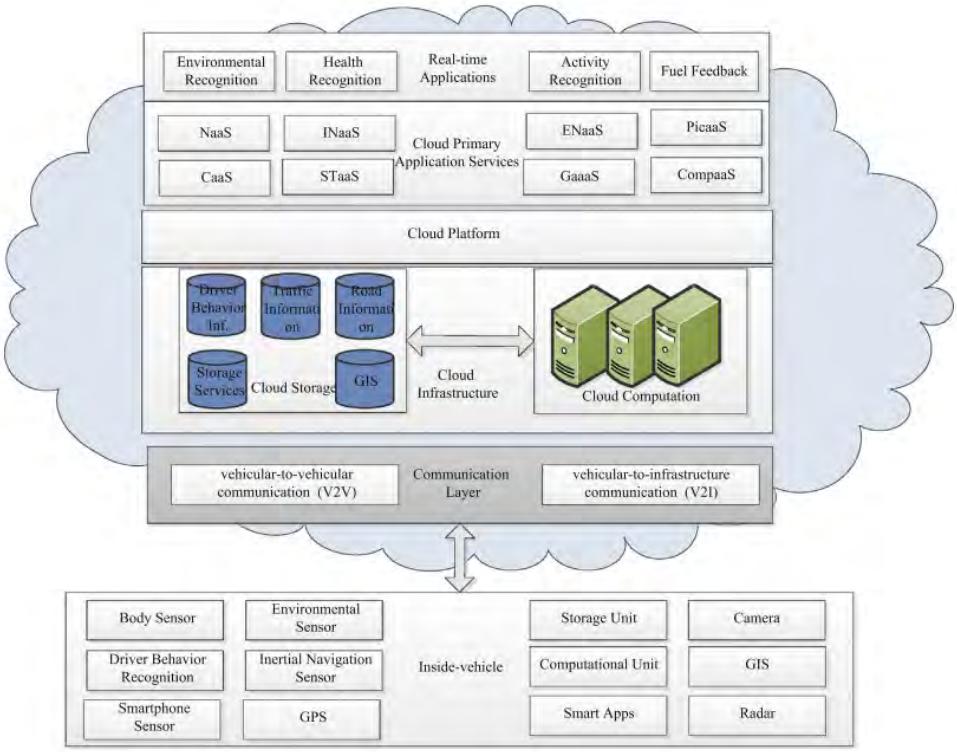

Figure 3: Vehicular cloud computing architecture (source: Md Whaiduzzaman et al., 2014 [9])

3.5 Crowdsourcing

Crowdsourcing is the process of getting information or funding, usually online, from interested individuals. In transportation, the smartphone is the primary platform, which enables mobile/location-based crowdsourcing. Outside the area of transportation, the crowdsourcing concept has been applied to analyzing the data of social networks and search engines. Examples include the Google flu prediction, geo-statistical analysis of Twitter data during Hurricane Sandy, and geo-spatial visualizations that identify residence and activity patterns.

Crowdsourcing technology has found broad applications in traffic data, transit, parking, road condition monitoring, and hazard monitoring [11]. Crowdsourcing has gained popularity as smartphones have become increasingly prevalent and now several successful commercial applications are based on the technology. In 2008, Waze Ltd. was founded. Waze is a crowdsourcing-driven GPS-based smartphone app. In 2013, Google bought Waze for $966 million, and added a social data aspect to its mapping business [12]. Google, Inrix, and Cellint are developing models for 'trading' information with traffic data consumers: consumers will launch an application on their smartphones that displays crowdsourced data about traffic flow in the area, and in return, their location information would be transmitted to the company for analysis. With the crowdsourcing technology, Cellint developed a different idea from Waze and Inrix. Their TrafficSense service looks into movement of signals from all smartphones within range of a cellular network. Cellular signal data is analyzed to generate speed, incident, and travel time information. TrafficSense can detect 99% of traffic slowdowns within a few minutes.

Several of the above mentioned companies are also working out similar agreements with public- and private-sector operators of vehicle fleets. Inrix has made agreements with auto companies, including Audi, BMW, Ford, and Toyota, to offer built-in computer connectivity in some car models. Inrix's data consists of 60% fleet data and 40% consumer data. The estimated traffic speeds are within 5 miles an hour of the actual speed 98% of time. The Inrix app offers routing, estimated arrival time, and warning of events and hazards. Inrix's data is used in Virginia and Massachusetts for travel time on dynamic message signs.

In addition to collecting traffic data, the crowdsourcing concept is being applied to public transit and road condition monitoring. Examples include Moovit (transit), Ototo (transit), Koozoo (parking and traffic), and StreetBump (road condition) [14]. In 2014, the Utah DOT released a crowdsourced road hazard (e.g., adverse weather) smartphone app.

3.6 Unmanned Aerial Vehicles

A **UAV**, also known as a drone, an unpiloted aerial vehicle, or a remotely piloted aircraft, is an aircraft without a human pilot aboard. There are two types of UAV: autonomous aircraft, and remotely piloted aircraft. UAVs are often preferred for missions that are too 'dull, dirty or dangerous' for manned aircraft. Related to UAV, an Unmanned Aircraft System emphasizes the other elements beyond an aircraft itself, including the UAV, control system, control link, and related support equipment.

UAVs are attracting increasing attention and related R&D activities have increased in the last several years. In 2007, DARPA (Defense Advanced Research Projects Agency) revealed a program to develop technology for a UAV with an endurance capability of over five years. In 2013, Amazon founder Jeff Bezos announced that Amazon was planning rapid delivery of lightweight commercial products using UAVs. In 2014, Google revealed it had been testing

UAVs in Australia for two years. The Google X program, known as "Project Wing," aims to produce drones that can deliver not only products sold via e-commerce, but larger delivery items. Of about 500 drone manufacturers worldwide, approximately one-third are based in Europe, which will create up to 150,000 jobs by 2050. U.S. manufacturers have about 60% market share. The global UAV market was valued at $6.762 million in 2014, and is expected to show robust growth, reaching $10,573 million in 2020. The compound annual rate growth is 7.73%.

Policymaking is underway concerning the civil applications of UAV, in both the United States and Europe. In 2013, the Federal Aviation Administration (FAA) selected six states to host test sites, emphasizing respective research goals. The six states are Alaska, Nevada, New York, North Dakota, Texas, and Virginia. In 2014, the National Transportation Safety Board issued a decision affirming the jurisdiction of the FAA to regulate UAVs. The FAA is expected to demand drone operators hold licenses and agree to flight limitation if the UAVs are used commercially. As of 2014, UAVs may only be flown by hobbyists for purely recreational reasons or by businesses that have obtained special FAA exemptions allowing commercial operations. To date, the FAA has issued only seven exemptions for commercial operations—all to movie production companies. The European Commission is keen to adopt a friendly-skies policy for the introduction of civil drones, which it sees as a great commercial opportunity. In the next 10 years, civil drones could make up an estimated 10% of aviation market, around 15 billion euros per year.

3.7 Other Technologies

Table 4 enumerates other technologies that may have significant impacts on future transportation.

Table 4: List of Other Emerging Technologies

Technology	Applications	Barriers
Location-based services: Program-level services that use location data to control features.	- Ridesharing: Uber and Lyft - Navigation: Waze - Incentive-based traffic management: Metropia - Tolling payment (as a substitute of traditional electronic toll collection): Xerox, 3M, and Q-Free	Regulation is needed for ridesharing apps. In some cities in the United States, Europe, and China, protests were reported on Uber and apps alike.
Google Glass: Google Glass is a wearable technology that can display information in a hands-free format. Wearers communicate with the internet via natural language voice command.	- Released in March 2013 - Consumer release of the Glass remains unknown - Google Maps can be used - Has potential applications in healthcare and journalism	Security and privacy concerns; safety concerns while driving. UK and West Virginia have banned Google Glass in certain situations.
3D Printing: 3D printing (also called "additive manufacturing") refers to various processes for printing a 3D object. 3D printing allows mass customization, rapid manufacturing, and rapid prototyping. When combined with cloud computing, it allows decentralized distributed production.	- In 2005, home-use market was established with inauguration of RepRap project - Applications cover industrial design, automotive, GIS, and many others - In early 2014, Koenigsegg announced a supercar that utilizes many 3D printed components - Local Motors, Oak Ridge National Laboratory, and Cincinnati Incorporated are developing 3D printing for entire car body	Mass production capability is limited due to efficiency and cost-effectiveness.
Self-healing materials: Self-healing materials are a class of smart materials that have the structurally incorporated ability to repair damage caused by mechanical usage over time. [15]	- In 2013, TU Delft researcher demonstrated the potential of self-heading asphalt for repairing micro-cracks and extending service life of roadways in Netherlands	Large-scale field tests haven't been carried out, and cost-effectiveness is unknown.

4. Technology Portfolio Analysis and Management

Resource limitations require the organization to strategically allocate the available funding and labor to individual projects. Portfolio management is a tool to select the optimal set of technology projects.

4.1 Technology life cycle and synergy

Table 5 summarizes the stages that each primary technology has reached. While technologies like crowdsourcing are mature and have underpinned commercial successes, other technologies are still in the stage of demonstration and deployment (initial). Surmounting the barriers in cost-

effectiveness, liability, and other dimensions (e.g., privacy, and cyber security) calls for the collaborative efforts of engineers, policymakers, and manufacturers.

Evidently, these technology areas are not mutually exclusive, and a synergic trend is evident. For example, cars with both autonomous and connected features are anticipated, and the combined technology will bring further benefits. Detailed discussion of this effect will be presented in the strategic technology business plan.

Table 5: Development Stages of Emerging Transportation Technology Portfolios (2015)

	R&D	Demo	Deployment	Diffusion	Commercial Maturity
AVs	X	X	O	P	P
Connected Vehicles	X	X	O	P	P
Electric Systems	X	X	X	P	P
Cloud Computing	X	X	X	O	P
Crowdsourcing	X	X	X	X	O
UAVs	X	X	O	P	P
X: Completed; O: Underway; P: Pending.					

4.2 Technology Portfolio Management

A comprehensive technology-dimensional evaluation framework will be used to manage the full list of technologies by narrowing down the full technology portfolio into a shorter, critical list for further study. The use of such a framework is to be useful not only for comprehensive evaluation and understanding of the particular technologies but also for selecting and prioritizing which technologies to further focus on. The following provides a proposal for a tentative evaluation framework to apply to the technologies in the portfolio and is intended to be illustrative, as it will become refined based on Task Force guidance.

Four evaluations will be applied to assess technologies on the following four dimensions.

- Goal attainment: Ability to meet or further national and state transportation goals
- Barrier presence: Presence of barriers to adoption and implementation
- User group enhancement: Ability of technology to enhance or improve transportation user group experience
- Mode specific enhancements: Ability of technology to improve transportation by mode

For each evaluation, the research team and each Task Force member will be asked to rank technologies (columns) on each evaluation dimension (rows) on a scale from zero to five. Each integer on the ordinal scale will correspond to each individual's belief about how each dimension represents each technology, with lower values indicating less relevance in a dimension and higher values indicating more relevance. A key with dimensional ranking considerations will be provided (see Tables 6a–d for an example). In a Delphi-like process, each Task Force member

will fill in a ranking for each technology-dimension intersection on each of the four matrices, and results from all members will be combined to form one final evaluation. An example set of matrices is provided in Tables 7a–d.

The final combined rankings will be used to inform a trade-offs analysis to compare technologies along common dimensions. Figure 4 illustrates an overview of the evaluation process. The final evaluation (radar chart within the spider chart) allows for the assessment and comparison of technologies along various dimensions.

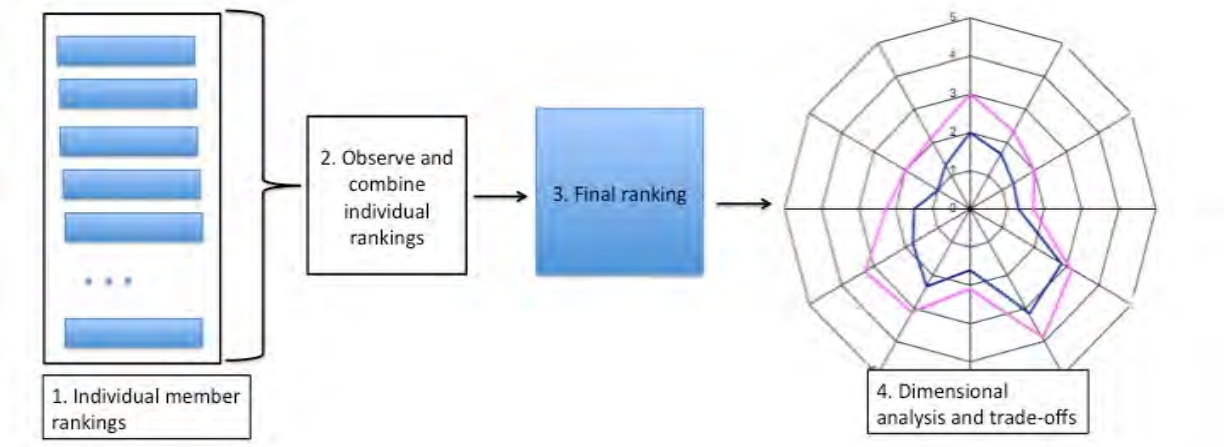

Figure 4: Overview of tentative technology evaluation framework

Technology-Dimensional Rankings Considerations

Table 6a: Example Factors Considered in Goal Rankings

Goal	Ranking Consideration
Safety	• Crash frequency reduction • Crash severity reduction
Congestion	• Decreased hours of congested travel • Improved traffic flows during congestion • Improved travel time reliability
Environmental sustainability	• Reduced fuel and energy consumption • Reduced air pollutant emissions, to meet EPA standards

Table 6b: Example Factors Considered in Barrier Rankings

Barriers	Ranking Consideration
Regulatory	• Legislative regulatory changes (may be helpful or necessary) • Administrative regulatory changes (may be helpful or necessary)
Cost	• Direct public agency costs
Safety	• New crashes or incidents otherwise avoidable • Increased crash or incident severity • Electronic security vulnerabilities

Table 6c: Example Factors Considered in User Group Enhancement Rankings

Enhancements	Ranking Consideration
User Cost	• Reduced operational cost • Reduced fuel cost
Safety	• New crashes or incidents otherwise avoidable • Increased crash or incident severity • Electronic security vulnerabilities

Table 6d: Example Factors Considered in Transportation Mode Enhancement Rankings

Enhancements	Ranking Consideration
Operational Cost	• Reduced fuel costs • Reduced labor cost
Safety	• New crashes or incidents otherwise avoidable • Increased crash or incident severity • Electronic security vulnerabilities

Technology-Dimensional Evaluation Matrices

Table 7a: Assessment of Ability of Technologies to Further National and State Goals

	AVs	**Connected Vehicles**	**Electric Systems**	**Materials**	**…**
Congestion					
Safety					
Environment					
…					

Table 7b: Assessment of Barriers to Technology Adoption

	AVs	Connected Vehicles	Electric Systems	Materials	…
Regulatory					
Safety					
Cost					
…					

Table 7c: Assessment of Impact from Technologies on System Users

	AVs	Connected Vehicles	Electric Systems	Materials	…
Freight (interregional)					
Freight (intraregional)					
Personal (commute)					
School/Student					
…					

Table 7d: Assessment of Impact from Technologies on Transportation Mode

	AVs	Connected Vehicles	Electric Systems	Materials	…
Highway					
Transit					
Bike/Pedestrian					
Aviation					
…					

5. Concluding Remarks

Now that the full list of prospective transformative transportation technologies in the portfolio has been developed based on subgroup interviews and literature survey findings, the next steps towards evaluation, prioritization, and promotion of critical technologies are described below.

The next task (Task 2) will see the reconvening of the full Task Force and the presentation of the technology portfolio to members. The research team will seek guidance regarding the specific technologies to pursue and the implementation of an evaluation framework for narrowing the technologies to the final critical technology list. The metrics and tables presented in the last section will be used as a starting point for the evaluation.

Task 3 will see the completion of Technology White Papers, which will contain complete in-depth research on identified critical technologies and core topics.

Task 4 will build on the previous three tasks and inform content for the completion of the Strategic Technology Business Plan, where comprehensive assessment of the critical technologies and their synergies will be performed, and the transition plan will be developed. Finally, for Task 5, the Task Force and the research team will develop an implementation plan that outlines the goals, priorities, recommendations, and strategies regarding transportation technology innovation and adoption in Texas for next steps.

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Appendix A. Subgroup Interview Questionnaire

I. Introduction to the purpose of the survey and objectives of the call/interview

This informal questionnaire/interview guide should be use to gain insight and facilitate ideas and discussion regarding technology research topics of top importance to the Texas Technology Task Force, the TxDOT Transportation Commission, TxDOT staff and policy makers, and Legislative Officials. Four objectives have been identified (listed below):

A. Obtain information and opinions on specific technologies from the interviewee that he/she believes will be important or transformative in each of the technology categories and for each of the transportation areas (listed in section II).

B. Inquire about which (if any) additional technology categories should be added or modified.

C. Identify gaps in expertise (based on the composition of last TTTF).

D. Identify who (if anyone) the interviewee would recommend as a Subject Matter Expert (SME) for missing expertise areas. If specific person is not known, identify where he/she would recommend looking (e.g., what company or organization would have staff that is an expert in that area).

II. List of specific questions that invite the interviewee to comment and discuss

A. Technology Specific: which technologies do you believe should have explicit focus in the next phase of TTTF work? Use the following categories and a guide to the discussion and for illustration of technologies.

   a. For each technology suggested, what is a supporting reason for including/focusing on it?

Technology Area	Examples for commentary
1. Autonomous Vehicle	Various levels of automation, automobile industry updates and advances, low speed autonomous vehicles, Policy and regulatory updates (federal, state, municipal)
2. Connected Vehicle	DSRC vs. Cellular based, Field tests and trials, Policy updates
3. Electric System	Smart grid, Electric vehicles, and also include other alternative fuels (CNG, solar, …)
4. Crowdsourcing and Mobile Cloud Computing	Waze, Moovit, HopStop, Ototo, Urban dynamics applications
5. Smartphone Applications	Rideshare, EnLighten, Insinc, Traveler Information, Demand induction, Tolling payment
6. Social Networking	Sentiment analysis, Geosocial networking, public relations, emergency preparedness, response and communications
7. Others (Materials, Energy, Manufacturing)	Nano carbon composite, Self-healing materials, Nano battery, 3D printing, dynamic traffic signals

b. Is the interviewee aware of new, disruptive trends and technologies in the following transportation areas:
    - Surface transportation
    - Transit
    - Freight
    - Ports, marine, waterway, and harbors
    - Air/aviation
    - Traveler information systems

c. Is the interviewee aware of new, disruptive trends and technologies in the following transportation-related areas:
    - Alternative financing (e.g., public-private partnerships)
    - City performance management (e.g., citizen engagement, open data portals, dashboards)
    - Land use (e.g., transit-oriented development)
    - Other

B. What additional, broad technology categories would the interviewee add?
    a. Include any justification for changes and additions.

C. Where are the gaps in expertise (based in composition of last TTTF)?

a. In addition, based on any added technologies or groupings that were not used in the past phases, is an added TTTF member needed to serve as SME for that technology?

D. Who would the interviewee recommend as a SME for that area? Or, if specific person is not known, where he/she would recommend looking (e.g., what company or organization would have staff that is an expert in that area).

III. Closing: next steps and follow-up with interviewee

Note: this section is an open discussion and left blank intentionally.

Appendix C: *Critical Emerging Technologies (Preliminary Analysis)* (0-6803-01-P3)

0-6803-01-P3

CRITICAL EMERGING TECHNOLOGIES (PRELIMINARY ANALYSIS)

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TxDOT Project 0-6803-01: Texas Technology Task Force (TTTF)

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Performing Organization:	**Sponsoring Organization:**
Center for Transportation Research The University of Texas at Austin 1616 Guadalupe, Suite 4.202 Austin, Texas 78701	Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080
Performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.	

1. Introduction

This report builds on a preceding report titled *Emerging Transportation Technology Portfolio* (0-6803-01-P2), and like the preceding report is completed for the Texas Technology Task Force (TTTF). The prior report outlines a full portfolio, describing emerging technologies with transportation applications that industry experts have deemed transformative in nature.

The portfolio is the product of Step 1 in a three-step process for researching and identifying some of the most critical technologies for Texas to pursue. This report builds on Step 1 and focuses on the application of a proposed framework by the Task Force research team. Observations from the applied framework (provided in Section 3) are intended to serve as preliminary results, highlighting the most critical of technologies from the full portfolio.

Since transportation systems are complex and embody varying goals and barriers across various modes and user groups, a multidimensional evaluation framework is needed to understand how technologies could impact the system across multiple dimensions. At a minimum, assessing the performance of transportation systems requires consideration of the safety, mobility, and environmental dimensions, among others. Further, measurable and quantifiable indicators are needed along each dimension. The remainder of this report focuses on outlining a framework that allows for the analysis of a technology across multiple dimensions and present results from step 2.

2. Portfolio Development and Management

The three-step technology portfolio development and management process is described in Sections 2.1 through 2.3.

2.1. Step 1—Technology Identification: In this step, subgroup interviews with the Task Force members and literature surveys were conducted in parallel. The interview questions and direction of the literature survey were periodically updated based on each other's inputs. The output of this step was the full, initial technology portfolio. A summary of technologies in the portfolio is provided below (see 0-6803-01-P2, *Emerging Transportation Technology Portfolio*, for full descriptions of technologies).

> ***Autonomous Vehicles,*** which may include specific applications in the following areas: autonomous freight technology, platoons, and pilots; personal autonomous vehicles including neighborhood/low speed and non-neighborhood vehicles; commercial uses (taxis); and autonomous parking in urban cores. For the evaluation process, these are broken into two categories: levels one and two automation and levels three and four automation.
>
> ***Connected Vehicles (CV).*** For the ranking process, these technologies are broken into two categories: vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V). This includes current and prospective applications, trials and, pilots; V2I implementation/ wrong-way driver detection; and studies of human behavior and driver interfaces with CV applications.

Electric Vehicles and Systems, including smart highways, solar highways, or roadway energy storage and transmission; battery technology; distributed nuclear energy; alternative fuels, inductive charging, or wireless energy transfer; DC fast charging systems, and smart grids.

Unmanned Aerial Vehicles (UAV), including surveillance applications and logistics.

Information and communication technologies, including ***cloud computing*** with big data, distribution, and analysis (automotive cloud), and super-fast computing for V2I, and ***crowdsourcing,*** including smartphone applications and surveillance or emergency management examples and applications.

Infrastructure and construction technologies, including infrastructure enhancements, such as fiber optics and ITS technologies, and construction techniques and equipment, including truss sliding and vacuum consolidation.

Materials, including self-healing pavements and nanotechnologies.

Additive manufacturing for vehicles and infrastructure (***3D printing***).

Service-based technologies, which are divided into ***location-based services*** (including ridesharing and social networking applications for transportation) and ***transportation subscription services*** (including shared vehicle fleets).

These technologies are carried forward into Step 2, described in the next section.

2.2. Step 2—Technology Assessment: Upon the completion of expert interviews described in Step 1, an initial technology list was generated, which became the initial technology portfolio. Step 2 was designed to assess individual technologies, providing a basis for comprehensive evaluation when selecting preliminary critical technologies for further inspection. The assessment focuses on four primary dimensions:

- **Strategic Goal Alignment:** Ability to meet or further national and state transportation goals, which mainly pertain to safety, congestion, and the environment.
- **Deployment Barriers:** Presence of barriers to adoption and implementation, which include the regulatory, cost-efficiency, and safety aspects.
- **Mode-Specific System Enhancement**: Ability of technology to improve transportation in different modes, encompassing highway traffic, bicycle/pedestrian, freight, transit, aviation, port, etc.
- **User Group Enhancement:** Ability of a technology to enhance or improve transportation user group experience. User groups will closely align with trip purpose and mode combinations. For example, passenger vehicle travel for home-based work trips may use technologies differently than passenger vehicle trips for leisure travel, or interregional freight travel may receive different benefits from a particular technology than intraregional freight travel will.

For each evaluation, each research team member was asked to rank technologies in a matrix of technologies across columns against each evaluation dimension (rows) on a scale from zero to five. Each integer on the ordinal scale corresponded to each individual's belief about how each dimension represents each technology, with lower values indicating less relevance in a dimension and higher values indicating more relevance. For example, when considering the benefits that lower levels of vehicle automation could have on travel, a rank of zero would indicate no benefit and a rank of five would indicate a monumental impact on travel. A full summary of the assessments along these four dimensions and corresponding factors considered are listed in Tables 1a–d. After individual rankings, results from each team member are to be combined to form one final set of evaluation matrices to reflect the consensus of the team.

The final combined rankings will be used to inform a trade-offs analysis to compare technologies along common dimensions. The final evaluation in this step (radar chart) allows for the assessment and comparison of technologies along various dimensions so that a final set of critical technologies may be chosen for further analysis in subsequent steps. The area that each technology covers (area score) on the radar chart is calculated help identify critical technologies. A diagram of this full ranking and combining process is shown in Figure 1.

Table 1a: Factors in ranking considerations for goals evaluation

Proposal Goal	Factor Consideration
Economic development	• Quantity and quality of jobs directly created in Texas
Safety	• Crash frequency reduction • Crash severity reduction
Congestion	• Decreased hours of congested travel • Improved traffic flows during congestion • Improved travel time reliability
Connect Texas communities	• Enhanced access to goods and services • Increased Texas gross state product • Public relations and dissemination of information to Texas communities
Best-in-class agency	• Agency able to deploy resources more efficiently
Infrastructure condition	• Direct improvement to infrastructure condition • Indirect improvement to infrastructure condition
System reliability	• Improved system efficiency
Environmental sustainability	• Reduced fuel and energy consumption • Reduced air pollutant emissions, to meet EPA standards
Reduce project delivery	• Reduced project delivery delays due to shortened time during construction

Table 1b: Factors in ranking considerations for barriers evaluation

Proposal Issues & Concern	Factor Consideration
Institutional	• Internal public transportation agencies changes • Potential new agency positions and duties • Technology standardization and coordination • Cross-agency and private institution collaboration
Infrastructure	• Extent of new infrastructure required • Existing infrastructure repurposed
Regulatory	• Legislative regulatory changes (may be helpful or necessary) Administrative regulatory changes (may be helpful or necessary)
Policy	• Public agency direction and support
Cost, public	• Direct public agency costs
Safety	• New crashes or incidents otherwise avoidable • Increased crash or incident severity • Electronic security vulnerabilities
Energy	• Energy consumption of new technology greater than potential savings
Public concerns	• Disparate impacts across income groups • Privacy concerns Neighborhood concerns • Other non-safety or energy concerns
Cost, private	• Consumer technology purchase costs • Corporate technology development costs
Time (develop & deploy)	• Timeframe required to complete phase after entering
Technology	• Technical barriers technology development

Table 1c: Factors in ranking considerations for modal enhancement evaluation

Mode	Factor Consideration
Surface transportation **Transit** **Freight** **Ports, waterways** **Air/aviation**	• Increased safety • Increased mobility • Decreased cost on system • Operations and maintenance benefits

Table 1d: Factors in ranking considerations for user group enhancement evaluation

Mode	Factor Consideration
Freight (interregional) **Freight (intraregional)** **Personal (commute)** **Personal (recreational)** **Emergency** **School/students**	• Increased safety • Increased mobility • Decreased cost on system • Operations and maintenance benefits

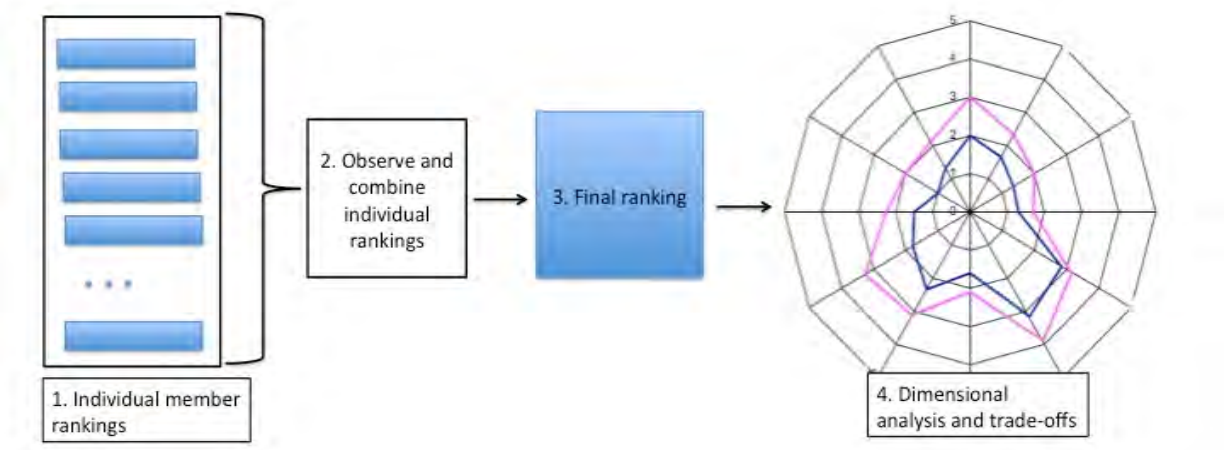


Figure 1: Overview of technology assessment

Step 2.3. Step 3—Portfolio Assessment: This third and final step, which will be carried out during the next stage with the help of the TTTF, will more rigorously assess the technologies and build on Step 2. Due to resource limitations, agencies need to strategically allocate the available resources to technologies under consideration. As a final step, a comprehensive portfolio assessment framework will be used to gain a deeper, more technical understanding of the technologies. The key difference between this step and the previous ones lies in a more comprehensive perspective—based on the current and forecast attributes of individual technologies, we consider the technology life cycle; short- and long-term institutional, technological, and economic uncertainties; and the synergy of technologies. To be specific, we will examine these facets:

- **Technology Life Cycle:** This analysis will provide a better understanding of the development phases and trajectory of technologies, and highlight opportunities for synergy. Life cycle curves will be used to visualize the evolution phases of technologies.
- **Scenario Generation:** The team will forecast possible technology adoption scenarios for the analysis of portfolio benefits in terms of safety, congestion, and environmental issues.
- **Technology Synergy:** This analysis will formally investigate the synergy effect that can be realized by pairing technologies. The possibility of synergy and potential benefits will be analyzed together.
- **Performance Metrics:** Different portfolios will be compared to select and prioritize individual technologies within the portfolio. Three sub-steps will be taken:
    - Convene the Task Force and use a Delphi-like process to further rank the technology portfolio and obtain feedback from TTTF members.
    - Combine input from individual Task Force members to support development of the critical list.
    - Select technologies based on highest rankings among technology-dimension intersections weighed against Task Force member input.

The above steps constitute a tentative evaluation framework to apply to the technologies in the portfolio and is intended to be illustrative, as it will be refined continuously based on Task Force guidance.

3. Observations from Application of Step Two: Technology Evaluation

Figure 2 presents the ranking matrices, while Figure 3 displays the results of the combined rankings.

Observations on strategic goal alignment

For each of the technologies on the radar chart, the total area was calculated such that technologies that align more closely with goals would have larger coverage areas. The total area (area score) is shown in the final row of each matrix. The technologies with the highest area score were ***V2I technologies*** (47.7), ***cloud computing*** (48.4), ***crowd sourcing*** (40.3), ***location-based services*** (32.9), and ***transportation subscription services*** (40.0), **(**perhaps ***automation levels three and four*** (32.2) could be included). Electric systems technologies show the lowest alignment with goals overall, although they ranked the highest in the environmental sustainability dimension.

Observations on deployment barriers

To minimize barriers for transformative technologies, those with low area scores are highlighted in Figure 2's result depictions. The lowest scores were for ***automation levels one and two*** (10.3), ***crowd sourcing*** (14.5), ***materials*** (18.7), ***transportation subscription services*** (19.8), and ***V2V technologies*** (19.1). Note that crowd sourcing, transportation subscription services, and location-based services showed high goal alignment and simultaneously low barrier to implementation. In addition, technologies that are less transformational and unlike any existing technology have higher barriers to overcome, whereas technologies with marginal enhancements over existing ones face lowers barriers to adoption and diffusion.

Observations on mode-specific system enhancements

Results from the modal enhancement analysis show that ***automation of all levels***, CVs (***V2V and V2I***), and ***cloud computing*** provide the most benefit across modes with area scores as follows: automation levels one and two (31.5), automation levels three and four (37.5), V2I (31.5), V2V (37.5), cloud computing (34.3). For surface transportation, location-based services and transportation subscription services would also greatly enhance travel. For transit, the same is true. For freight, automation and CVs showed the most enhancements along with the diffusion of 3D printing, which could have great impact on freight travel. For ports and waterways, the greatest enhancements could come from automation levels three and four, V2I technologies, cloud computing, and infrastructure and construction enhancements. Finally, the single largest impact on air and aviation likely arises from the use of UAVs/drones.

Observations on user group enhancements

Results of the user group enhancement rankings show that all levels of ***automation, CVs, cloud computing, crowd sourcing, and location-based services*** have the greatest ability to enhance travel across user groups with area scores as follows: automation levels one and two (36.8), automation levels three and four (49.5), V2I (33.6), V2V (46.0), cloud computing (31.1), crowd sourcing (34.6), and location-based services (31.8).

Overall, the most critical technologies in terms of alignment with goals, minimized barriers to adoption and diffusion and enhancements across modes and users were those that fall into

autonomous vehicles, ***connected vehicles, information and communication***, and ***service-based technologies***.

Ratings 0-5: 0 = Does not address goal, 5 = Disruptively beneficial solution

		Autonomous Vehicles		Connected Vehicles				Information and Communication						
Goals		A1/A2	A3/A4	V2I	V2V	Elec. Sys	UAVs	Cloud Comp.	Croud Sourcing	Infrastra. & Const. Enhance	Materials	3D Printing	Location Based Services	Transp. Subscription services
Texas Goals	Safety	5	5	5	5	1	2	4	4	3	4	3	3	3
	Congestion	2	4	4	4	1	3	4	5	3	2	3	4	5
	Connect TX communities	2	4	3	4	1	3	5	4	2	1	3	5	5
	Best in class agency	3	4	5	3	2	3	5	4	3	4	3	4	4
Other National Goals	Infrastructure condition	3	2	5	2	2	5	4	4	5	5	3	2	2
	System reliability	3	3	4	4	1	4	4	4	4	4	3	3	4
	Environmental sustain.	3	3	4	3	5	3	4	3	3	4	3	3	4
	Reduce proj. delivery	2	2	3	2	2	3	3	2	3	2	4	3	3
Area Score		22.3	32.2	47.7	31.8	9.5	30.4	48.4	40.3	30.4	30.4	27.6	32.9	40.0

Ratings 0-5: 0 = No Barrier, 5 = Barrier likely insurmountable in

	Autonomous Vehicles		Connected Vehicles				Information and Communication						
Barriers	A1/A2	A3/A4	V2I	V2V	Elec. Sys	UAVs	Cloud Comp.	Croud Sourcing	Infrastra. & Const. Enhance	Materials	3D Printing	Location Based Services	Transp. Subscription services
Institutional	1	4	3	2	2	4	2	2	3	2	3	3	3
Infrastructure	1	4	3	2	3	2	3	1	3	3	2	2	2
Regulatory	2	4	2	3	2	5	3	3	1	1	4	4	3
Policy	2	4	3	2	2	4	3	3	3	2	3	4	4
Cost, public	4	2	3	2	4	1	3	2	4	4	4	2	2
Safety	2	4	3	4	2	4	2	2	1	2	2	2	2
Energy	1	1	2	1	3	1	1	1	3	1	1	1	1
Public concern	1	4	3	4	2	5	3	3	2	2	2	2	2
Time (develop and deploy)	1	4	2	3	3	3	2	2	3	4	3	2	2
Technology	1	4	1	2	4	2	2	2	2	3	3	2	2
Area Score	10.3	42.4	24.4	19.1	23.0	31.5	21.2	14.5	21.6	18.7	25.1	21.9	19.8

Ratings 0-5: 0 = No benefit to mode, 5 = Greatly benefits travel/operations on mode

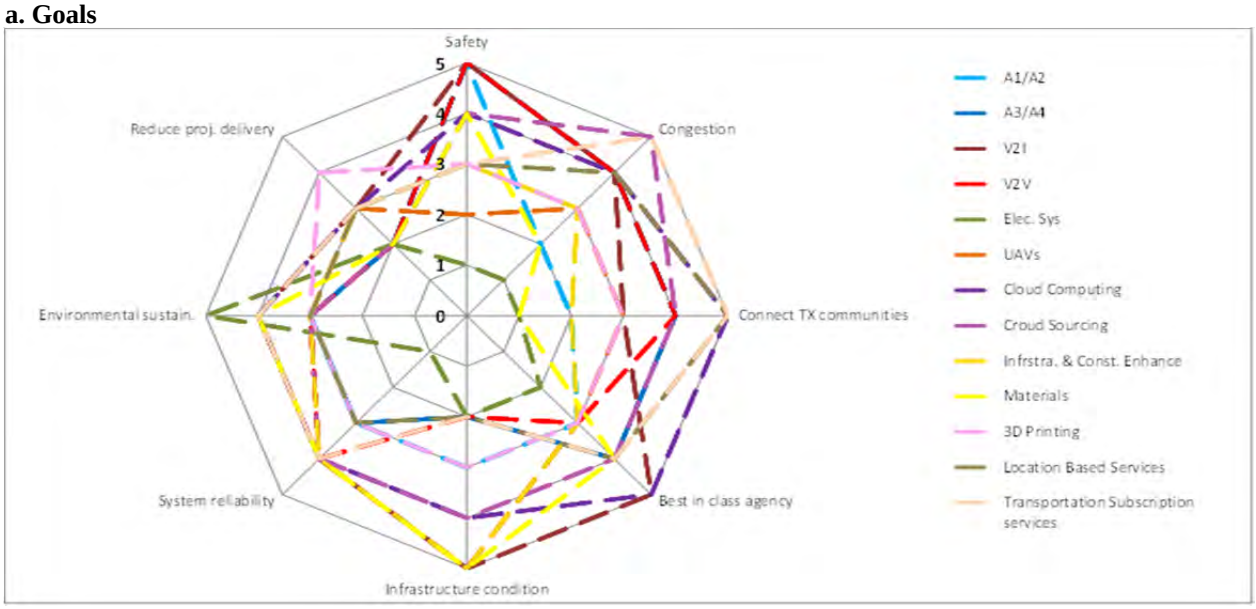
	Autonomous Vehicles		Connected Vehicles				Information and Communication						
Modal Enhancements	A1/A2	A3/A4	V2I	V2V	Elec. Sys	UAVs	Cloud Computing	Croud Sourcing	Infrstra. & Const. Enhance	Materials	3D Printing	Location Based Services	Transportation Subscription services
Surface Transportation	5	5	5	5	3	3	5	5	4	5	3	5	5
Transit	5	5	5	5	5	2	5	4	4	2	2	4	4
Freight	5	5	5	5	3	4	4	4	4	4	5	3	1
Ports, Marine, Waterways	3	4	3	4	1	2	4	2	4	3	3	1	2
Air/Aviation	3	4	3	4	2	5	4	1	4	2	2	1	2
Area Score	31.5	37.5	31.5	37.5	14.5	16.6	34.3	18.0	28.3	16.3	15.2	14.5	14.1

Ratings 0-5: 0 = No benefit to user group, 5 = Greatly benefits travel/operations for user group

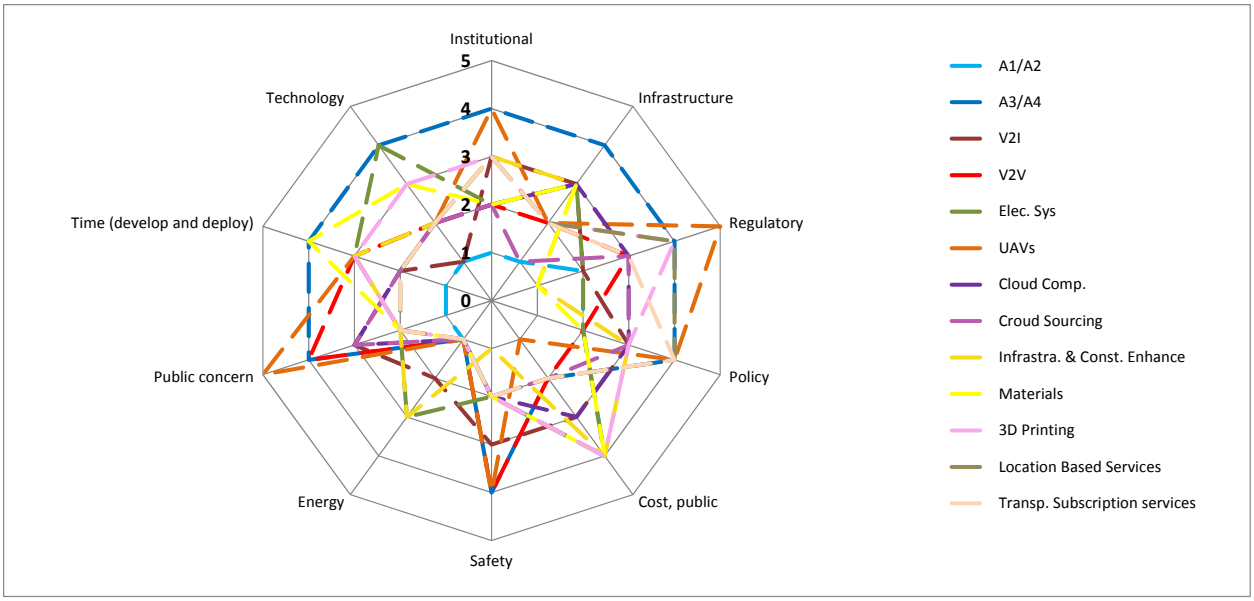
	Autonomous Vehicles		Connected Vehicles				Information and Communication						
User Group Enhancements	A1/A2	A3/A4	V2I	V2V	Elec. Sys	UAVs	Cloud Computing	Croud Sourcing	Infrstra. & Const. Enhance	Materials	3D Printing	Location Based Services	Transportation Subscription services
Freight (interregional)	4	5	4	5	2	4	4	3	3	3	3	3	2
Freight (intraregional)	4	5	4	5	2	2	4	3	3	3	4	4	3
Personal (commute)	4	4	4	5	4	1	4	5	4	4	3	5	5
Personal (Recreational)	4	5	4	5	3	2	4	5	4	4	2	5	5
Emergency	4	5	5	5	2	4	4	5	3	3	2	3	2
School/students	5	5	3	3	3	2	3	3	2	2	2	3	4
Area Score	36.8	49.5	33.6	46.0	14.8	12.7	31.1	34.6	21.6	21.6	15.6	31.8	25.5

Figure 2: Ranking matrices

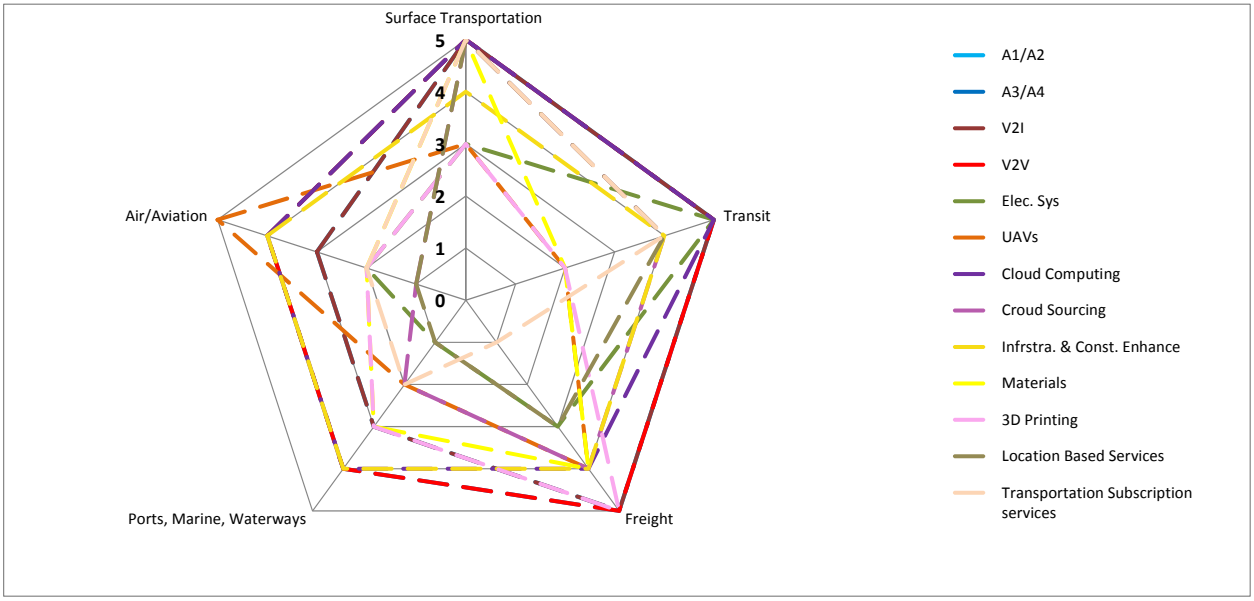
a. Goals



b. Barriers



c. Modal Enhancements



d. User Group Enhancements

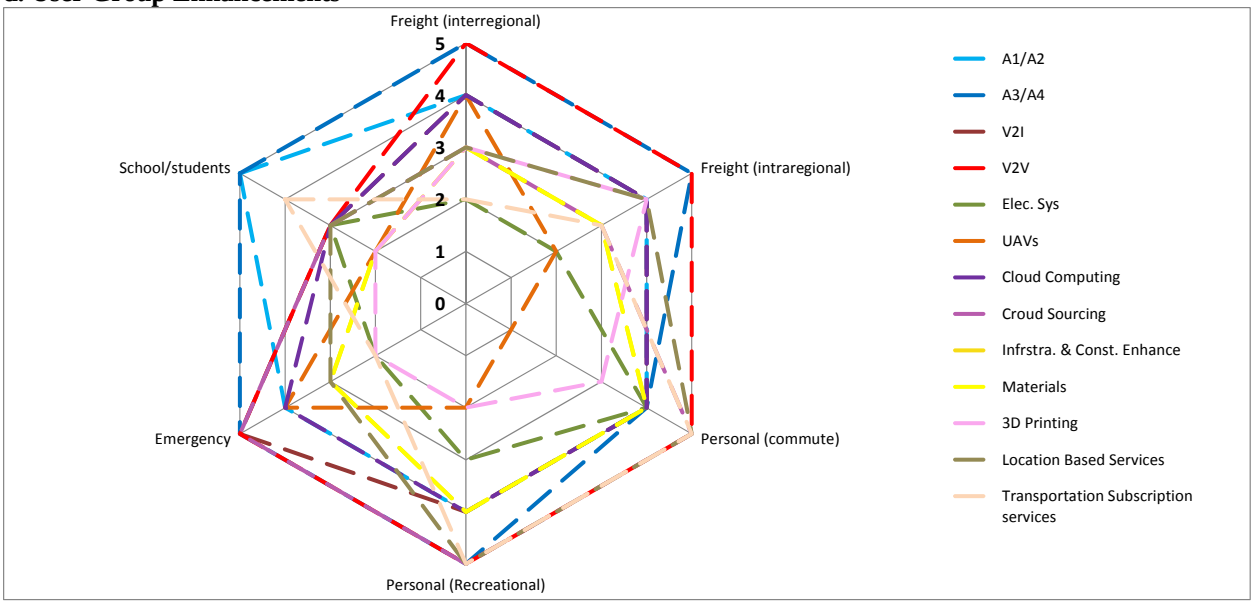


Figure 3a-d: Results of the combined rankings as radar charts

Appendix D: *White Papers* (0-6803-01-P4)

0-6803-01-P4

TEXAS TECHNOLOGY TASK FORCE WHITE PAPERS, VOLUMES 1–5:

How the Age of Technology Is Transforming Transportation Agencies

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TxDOT Project 0-6803-01: Texas Technology Task Force (TTTF)

AUGUST 2015; PUBLISHED NOVEMBER 2015

Performing Organization: Center for Transportation Research The University of Texas at Austin 1616 Guadalupe, Suite 4.202 Austin, Texas 78701	**Sponsoring Organization:** Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080
Performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.	

Understanding the Customer of the Future

White Paper

How the Age of Technology is Transforming Transportation Agencies

How can transportation agencies leverage technology to enhance the customer experience and remain relevant in the wake of major demographic, cultural, and business changes?

By viewing transportation as an interconnected experience, Texas can develop customer service strategies that ensure every touchpoint in the customer journey leads to a seamless transition to the next stage. Using data to study the customer profile, transportation agencies can better understand their customers' needs and develop personal communication strategies that will resonate with each individual.

Through customized incentives, transportation agencies can encourage customers to modify their route, time of day, and mode choices to benefit the transportation system as a whole. By developing a customer-centric mentality and prioritizing the customer relationship, transportation agencies can gain a deeper understanding of their stakeholders' interests.

Understanding the Customer of the Future

White Paper

How the Age of Technology is Transforming Transportation Agencies

KEY STRATEGIES

Study the Customer Profile

Changing demographics and cultural trends are impacting the customer base. Using the latest technology, transportation agencies can leverage relevant data to provide customers with a personal and valuable experience.

Discover the Customer Experience

When transportation agencies understand the five factors that are shaping the customer experience, they can utilize technology to strengthen customer engagement and build their brand.

Respond to Consumer Behavior

E-commerce, the shared economy, and evolving travel patterns have major implications for the transportation system. Transportation agencies will need to be prepared to respond to emerging consumer behaviors and incorporate new strategies into their planning efforts.

Exceed Customer Expectations

The transportation agency that goes above and beyond empowers the customer to become a brand advocate. By providing quality traveler information, roadway maintenance, and roadside assistance services, transportation agencies increase customer satisfaction.

Deliver Quality Customer Service

Proactively communicating important information to customers improves relationships and reduces potential dissatisfaction. By monitoring all communication channels, transportation agencies can respond swiftly and effectively, creating a consistent level of quality customer service.

Understanding the Customer of the Future

White Paper

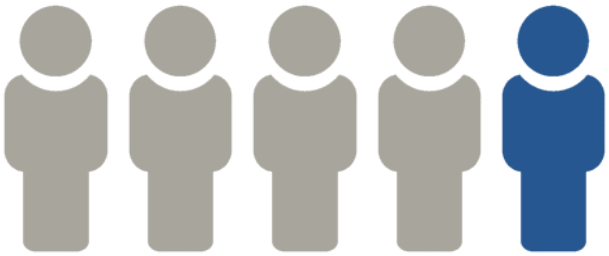
How the Age of Technology is Transforming Transportation Agencies

STATE OF RESEARCH & PRACTICE

Study the Customer Profile

Population Growth. The U.S. population is projected to increase by 80 million between 2014 and 2050, with a growth of 13.5 million occurring in Texas alone [2]. Much of the population growth in Texas is expected to come from the large urban counties of Harris, Dallas, Tarrant, Bexar, and Travis, but the fastest growth will occur in the suburban rings surrounding these counties [3]. With such rapid growth, congestion is worsening and infrastructure maintenance demands are increasing. In 1999, computer manufacturer Dell acknowledged that Central Texas traffic contributed to its decision to expand in Tennessee rather than at its Round Rock headquarters north of Austin. Transportation and urban planners will need to prepare for the state's future to ensure that Texas continues to attract rather than repel opportunities.

***Age*.** By 2050, one in five Texans is projected to be 65 and over [2].



More people will require quality public transit connections to medical and other services. Transportation agencies will also need to be aware of cultural shifts, such as reduced vehicle ownership, taking place in the millennial generation. It will be critical for transportation agencies to consider universal design principles to provide a positive customer experience for all ages.

***Diversity*.** A strong transportation system depends on a vibrant, diverse workforce that reflects the state as a whole. In Texas the Hispanic population will likely surpass the Anglo population by 2020, and comprise the majority by 2042 [3]. The Texas Department of Public Safety currently provides driver knowledge tests in English and Spanish. Supporting customer needs through outreach, signage, and information in multiple languages will continue to be crucial to public education efforts.

Since 2010, women with driver's licenses outnumber men [4]. Changing gender demographics will impact the scale and nature of vehicle demand, energy consumption, and road safety. Women are more likely than men to purchase safer and more fuel-efficient cars; drive less; and have a lower fatality rate per mile [4].

***Urbanization and Land Use*.** By 2050, emerging megaregions could absorb 75 percent of the U.S. population; rural populations are expected to continue declining [3]. Retailers, including Walmart, are accelerating small store growth as a real estate strategy to connect with urban customers. Citizens, supported by movements such as New Urbanism, are increasing pedestrian and bicycle activities. Transportation and urban planners will need to consider linking transportation and land use through mixed-use development, value capture models, and multi-modal transportation strategies.

Cultural Trends. Strategy Analytics, a research and consulting firm, forecasts that by 2020 the average person will be connected to 4.3 devices [5]. Transportation agencies will need to consider how to communicate with customers through PCs, tablets, wearables, smartphones, televisions, radio, and vehicle infotainment systems. Using the latest technology, State DOTs can leverage relevant data to provide customers with a personal and valuable experience.

Understanding the Customer of the Future

White Paper

How the Age of Technology is Transforming Transportation Agencies

Discover the Customer Experience

Safety. Roadway safety touches the lives of every person. In 2014, Texas experienced 3,534 motor vehicle traffic fatalities [6]. There was a 4% increase in the number of people killed in Texas crashes involving distracted driving. Transportation agencies need to incorporate safety concerns related to emerging technologies, such as distractions from vehicle infotainment systems and no-fly-zone restrictions for unmanned aerial vehicles, into traditional safety campaigns.

When disaster strikes, the public should be able to trust transportation agencies to work together to respond in a timely and effective manner. Emergency management plans require seamless coordination, swift communication, and good organization. When Hurricane Rita swept the Texas coast in 2005, as many as 2.5 million people were jammed on evacuation routes. Emerging technologies have a role to play in supporting emergency response efforts and protecting the public from safety threats.

Efficiency. The old adage "time is money" applies to every transportation customer. The American commuter spends on average 38 hours a year stuck in traffic, with commuters in the Houston area experiencing 52 hours of delay [7]. The IH-35 segment from US 290 N to SH 71 in Travis County takes 2.54 times as long to travel during rush hour as it does during off-peak period, costing auto commuters $196 million [7]. By incentivizing customers to alter their time of day, route, and mode choices, transportation agencies can optimize the transportation network as a whole, restoring customers' personal and family time.

Emerging technologies add value to the customer experience.

Reliability. Customers are unwilling to risk the perceived or actual reliability of driving. If buses arrive late or if traveler information is inaccurate, customers become discouraged. In a passenger perception survey, riders in San Francisco said they had reduced their use of public transportation specifically because of its unreliability, switching to other modes and adding stress to an already congested highway system [8]. By providing real-time information, transportation agencies can enable the customer to make informed decisions and adjust travel expectations accordingly.

Quality. Highway potholes, crowded buses, and lack of sidewalk infrastructure all negatively impact the customer's transportation experience. In 2012 the American Society of Civil Engineers assigned a grade of "D" to Texas roads, attributing the poor performance to declining maintenance and funding. Customers are often unaware of specific agency responsibilities, and may lay blame on the wrong public agencies [9]. Thus, transportation agencies will need to work together to provide a complete and positive customer experience.

Convenience and Choice. Emerging technologies offer conveniences and choices to the customer. Electronic toll collection systems provide a nonstop way for drivers to pay tolls through prepaid, charge, or invoice options. Toll roads in Orange County, California, save drivers over $182 million a year as a result of reduced traffic congestion during the daily peak periods [10]. Another innovative system is the Green Lane Concept proposed by Southwest Research Institute and Automated Port Solutions. If a commercial driver meets the qualifications of "trusted truck, trusted trip, and trusted trucker," the driver may proceed directly to the port without waiting in the queue [11]. Providing customers with added convenience saves them time and money and alleviates congestion during peak hours.

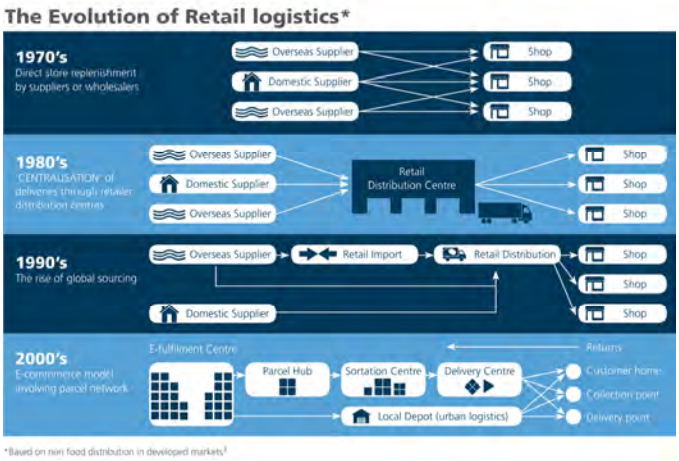
Understanding the Customer of the Future

White Paper

How the Age of Technology is Transforming Transportation Agencies

Respond to Consumer Behavior

Increased Demand for E-Commerce. Consumer habits are changing and retailers recognize e-commerce as an established business. Online shopping is driving up demand for small package home delivery, which could soon substitute for many household shopping trips. Many retailers are providing ship-from-store offers to better connect demand with inventory. Ann Taylor has converted over 300 of their stores into distribution nodes, increasing sales and gross margins by not having to mark down slow-selling items in one store that might sell at full price in another [12]. Other retailers are promoting ship-to-store offers in order to increase foot traffic and reduce greenhouse gas emissions. In 2013 Target reduced loads and miles by shipping more efficiently to CityTarget stores (which are typically smaller than traditional Target stores, customized to appeal to urban dwellers) and continuing to upgrade its transportation management systems [12]. Transportation agencies can anticipate commercial growth by remaining aware of evolving retail logistic strategies.

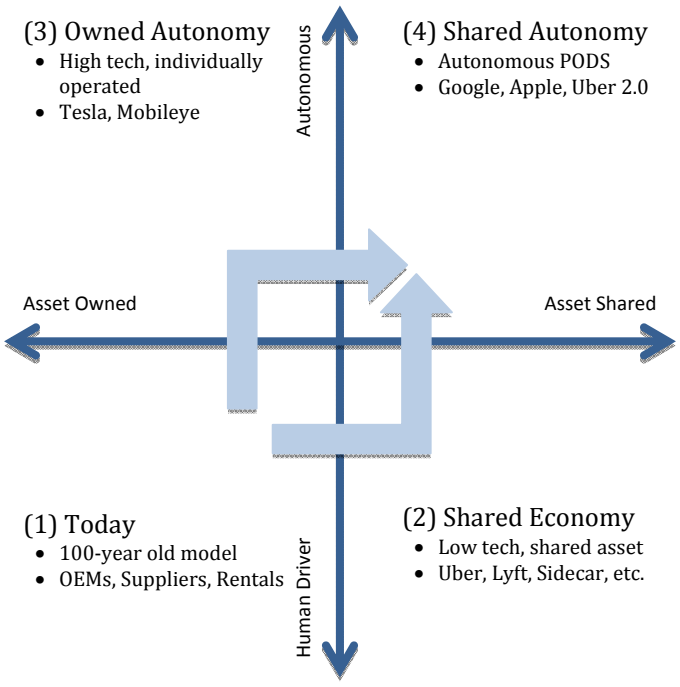


Source: [22]

Shared Economy. The sharing of goods and services is disrupting traditional business models. Its rapid growth is rooted in three factors:

- Ability to leverage space capacity and expand systems without large investment
- Exponential effect of collaborative experimentation and learning
- Ubiquitous nature of distributed capacity

A typical car lies unused for approximately 23 hours a day. Transportation network companies, such as Uber and Lyft, are taking advantage of overcapacity to satisfy a demand for mobility. From 2007 to 2011, vehicle ownership for people aged 18 to 34 fell almost 30% [2]. As a result, car manufacturers and vehicle rental companies have introduced their own carsharing services, including Daimler's Car2Go, BMW's DriveNow, and Avis's ZipCar. Businesses are also creating low-speed, shared vehicle fleets for employee use on campus and in neighborhood communities.



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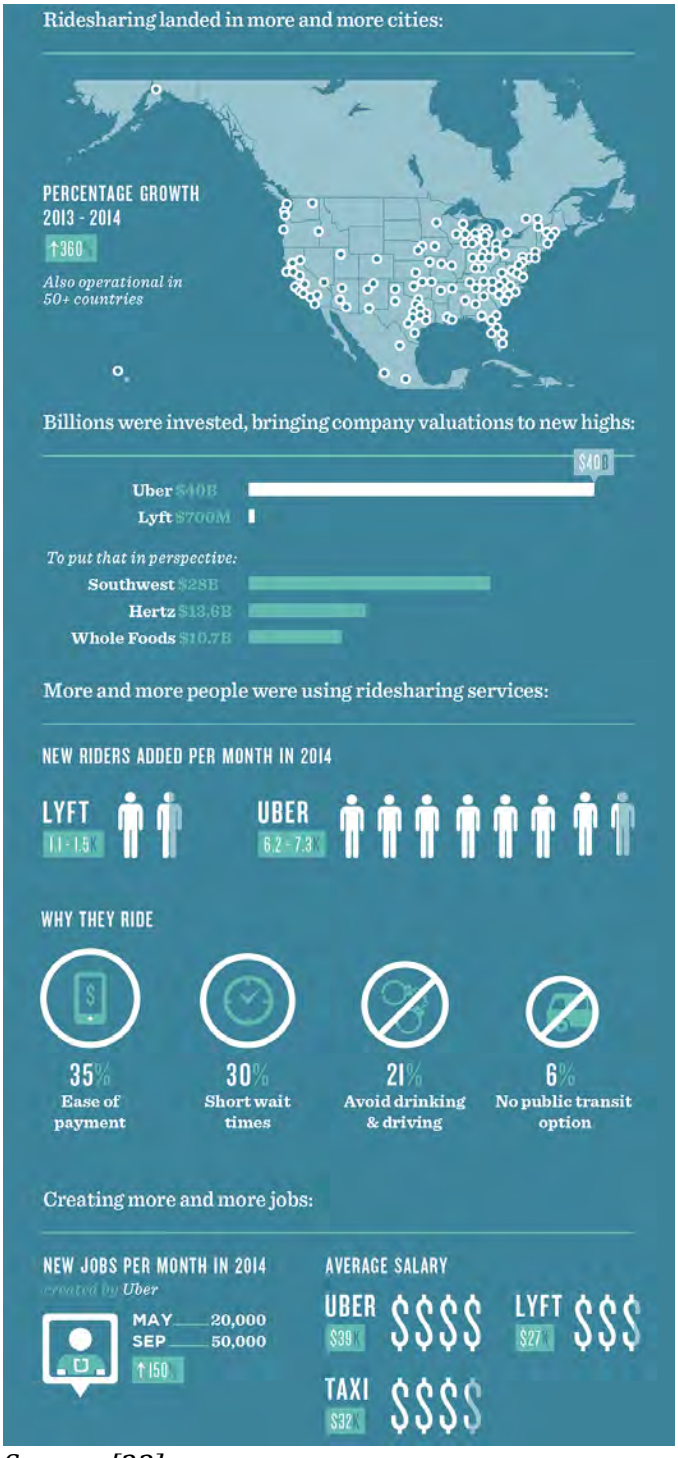
How the Age of Technology is Transforming Transportation Agencies

Travel Patterns. Customers are creatures of habit who can often become fixed in their traditional travel patterns, driving the same route to work at the same time every morning. With the introduction of new technologies and services, however, customers have begun telecommuting as well as shifting route, mode, or time of day.

Based on the American Community Survey data, telecommuting has increased 80% from 2005 to 2012, with government workers constituting the highest proportion of the total 3.2 million teleworkers [13]. Federal employees in Washington who worked from home during four official snow days saved the government an estimated $32 million [13]. As this movement grows, transportation agencies may encourage teleworking as part of the solution to peak period congestion.

Incentives are an effective means to encourage drivers to use alternative routes and times of day. Transportation corridor agencies in Orange County, California, offered $30 in free tolls to be credited to new accounts and the following month offered a promotion where motorists could try its toll roads free for an entire week [10]. The campaigns increased ridership and contributed to additional downloads of The Toll Roads app, now used to interface with over 360,000 customers.

Ride-sharing and car-sharing have increased exponentially within the last decade. Ride-sharing companies such as Uber, Lyft, Sidecar, eRideShare, and Ridester create business exchanges between drivers and passengers. Car-sharing services such as FlightCar, GetAround, and RelayRides act as brokers between people offering their cars for rent and those seeking rentals. Transportation agencies may consider partnerships with new services to provide auto-centric customer bases with an alternative to driving alone.



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Understanding the Customer of the Future

White Paper

How the Age of Technology is Transforming Transportation Agencies

Exceeding Customer Expectations

***Personalization*.** Customers are increasingly expecting a unique experience tailored to their needs and wants. Personalization is the foundation of the dynamic customer experience. For example, Pandora generates personalized music streams, Flipboard individualizes consumption of the news, and Amazon has customized online shopping. The innovative transportation agency will personalize the travel experience, providing highly contextualized information and adjusting its offerings to strengthen customer engagement.

***Speed*.** This is the era of "NOW." Customers expect services to be available 24x7 and want answers to their queries delivered on-demand. RideScout is a mobile app that shows the customer real-time information about transportation options that are available right now. Users can see transit, bus, bike, taxi, car share, rideshare, parking, and walking direction in a single view. By transforming data into valuable information, transportation agencies can provide customers with the appropriate tools to make informed decisions.

Accuracy. Inconsistent, wrong, or outdated information is unacceptable to customers. Centralizing and standardizing information ensures that answers are delivered quickly and accurately. Also, communicating at the scale of highest interest to the customer (for example, providing information about a personal route to work) allows the message to resonate. Applying a local and precise approach demonstrates a transportation agency is vested in its customers interests.

The transportation agency that goes beyond customer satisfaction empowers the customer to become a brand advocate.

Delivering Quality Customer Service

***Service-Oriented Enterprise*.** The successful transportation agencies provide services reflecting the needs of their customers. The average person travels 36 miles per day, spending about one hour in a vehicle, according to the 2009 National Household Travel Survey [14]. Managing how that time is spent determines if the customer has a positive or negative experience. By providing quality traveler information, roadway maintenance, and roadside assistance services, transportation agencies increase customer satisfaction.

Listening to the customer offers new insights, perspectives, and strategies.

***Proactive*.** Customer care cannot afford to wait for problems to arise. Proactively communicating important information to customers improves relationships and reduces potential dissatisfaction. For example, notifying travelers of scheduled construction or lane closures allows customers to identify alternative routes. Anticipating customer concerns reduces support calls and empowers the customer to become a brand advocate.

***Responsive*.** Customers need to be valued. By listening to concerns regarding brand, products, and services, a transportation agency can learn new insights, gain perspective, and adapt its strategies accordingly. For example, knowing the status of service requests reassures the customer that his or her requests are being fulfilled. Pizza Tracker is Domino's online tool that allows customers to follow the progress of their order from the time it is placed through delivery. The tool offers transparency, reduces calls regarding order status, solicits feedback, and improves customer loyalty. By monitoring all communication channels, transportation agencies are able to quickly resolve problems and improve customer relationships.

Understanding the Customer of the Future

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How the Age of Technology is Transforming Transportation Agencies

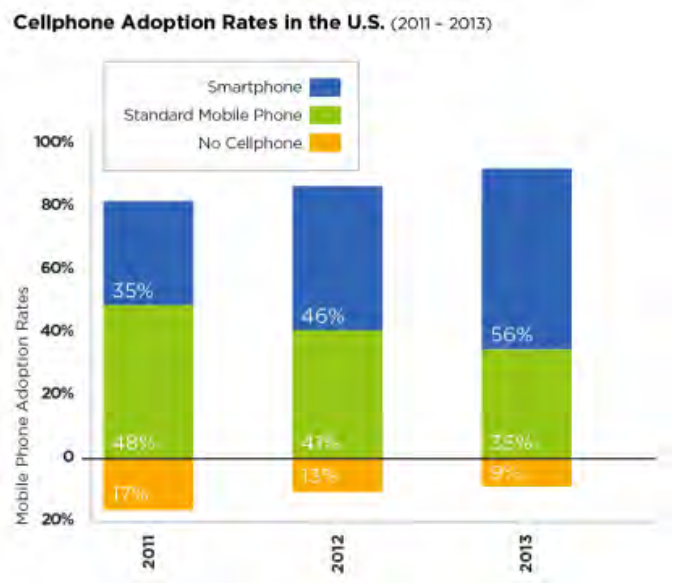
PUBLIC POLICIES & PROGRAMS

National Efforts

Beyond Traffic: Trends and Choices 2045. The U.S. Department of Transportation (USDOT) published a framework for the future of the nation's transportation system [15]. The document underscores critical decision points facing the country, by means of data-driven analysis, research, expert opinions, and public engagement. The report focuses on the following five areas:

- How will we move?
- How will we move things?
- How will we move better?
- How will we adapt?
- How will we align decisions and dollars?

In the area of emerging technologies, *Beyond Traffic* highlights connected and autonomous vehicles, 3D printing, robotics, unmanned aircraft systems, positive train control, real-time mobile access, NextGen air traffic control, and Big Data as having transformative impacts upon the customer's transportation experience.



Millennials – Shaped by Technology

There are **73 million millenials** aged 18 to 34. They are the first to have access to the internet during their formative years and will be an important engine of our future economy [15].

Income Inequality

10% of the population takes home one-third of the U.S. national income. Transportation is the second largest expense for U.S. households, accounting for nearly **20% of total household expenses** and 12 to 15% of total household income [15].

Older Americans – Redefining Longevity

About **one-third** of people over 65 have a disability that limits mobility. Their access to critical services will be more important than ever [15].

Freight – Transportation and the Economy

54 million tons of freight move across the U.S. every day. By 2040, U.S. freight volume will grow to **29 billion tons**, an increase of 45%. The value of freight is projected to grow to $39 trillion, an increase of 125% [15].

Safety – Driven by Vehicle Automation

The Insurance Institute for Highway Safety has estimated that if all vehicles had forward collision and lane departure warning, blind spot assist, and adaptive headlights, about **one in three** fatal crashes and **one in five** injury crashes could be prevented [15].

Understanding the Customer of the Future

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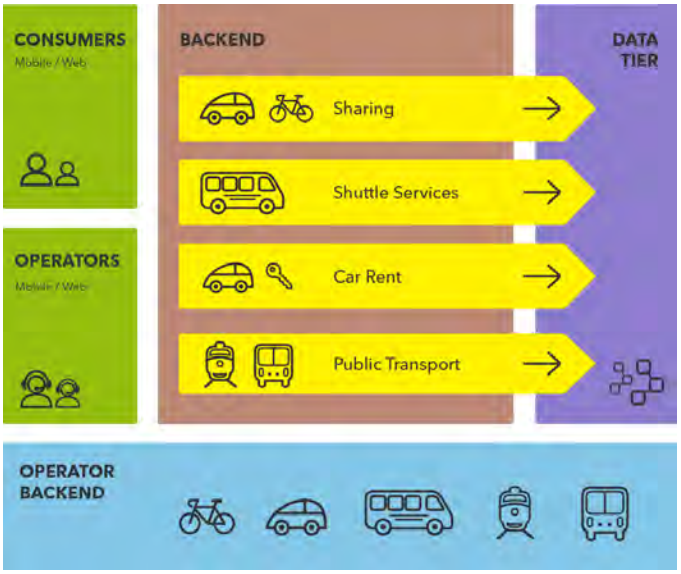
How the Age of Technology is Transforming Transportation Agencies

Mobility as a Service. What if transportation services were bundled together similar to mobile phone price-plan packages? Gaining momentum in Europe, Mobility as a Service (MaaS) is a mobility distribution model in which a customer's major transportation needs are met over one interface and are offered by a service provider [16]. User benefits include developed, personalized, and smart mobility services reflecting the customers' diverse needs; seamless, well-functioning transportation services; and easy access to mobility.

New technologies enable users to take a more dynamic, proactive role as a developer and data producer in the transportation system. MaaS may be used to develop transportation as an experience—everyone's personal 60 minutes each day. For transportation agencies, advanced data deployment improves the effectiveness of the whole system, effectively allocates resources, and improves traffic incident management.



Mobility as a Service (MaaS) Architecture:
Creating the personal transportation experience.

Activity-Based Models and MAP-21. Traditional travel demand modeling uses a trip-based approach. However, this approach does not realistically represent customer behavior and has difficulty assessing policies such as telecommuting, congestion pricing, and flexible work hours. On the other hand, the activity-based approach adopts a holistic framework that recognizes the complex interactions in activity and travel behavior, using interconnected time periods as the unit of analysis [17]. For example, an individual makes interrelated mode and time-of-day decisions based upon the activities for the whole day: dropping the children off at school, going to work, eating lunch downtown, returning to work, and running errands before arriving home.

Activity-based modeling also supports dynamic traffic assignment (DTA), which is capable of modeling more complex traffic patterns at a range of scales from the corridor level to the regional. The combination of activity-based approaches and DTA supports metropolitan planning organizations (MPOs) and other stakeholders in tracking performance measures outlined in the Moving Ahead for Progress in the 21st Century (MAP-21) Act, including safety, freight movement and economic vitality, and environmental sustainability [18]. By understanding evolving customer behavior, travel demand modelers can better represent choices made by individual travelers and improve forecasts used for planning efforts.

"The reality about transportation is that it is future-oriented. If we are planning for what we have, we are behind the curve."

- Anthony Foxx, USDOT

Understanding the Customer of the Future

White Paper

How the Age of Technology is Transforming Transportation Agencies

City and Regional Initiatives

Open Fare Payment System. Current programs to upgrade and modernize the fare collection infrastructure are underway in numerous urban areas [19]. Open fare payment systems are an architecture designed to incorporate multiple operators, multiple modes, and a central clearinghouse. New transit payment systems offer interoperability, data integrity, cash replacement, convenience, and customer service. Imagine a system where a customer could use a single rechargeable account to access bus, rail, toll roads, parking, and other transportation services in every city throughout the state.

Contactless Smart Card Fare Systems

City	*Cards (x000)*	*Transportation Access*
Atlanta, GA Breeze Card	1,400	Bus, Metro Rail, Parking
Boston, MA CharlieCard	4,000	Bus, Metro Rail, Light Rail, Parking, Ferry
Chicago, IL Chicago Card	780	Bus, Metro Rail
Houston, TX Q Card	350	Bus, Light Rail
Los Angeles, CA TAP Card	500	Bus, Metro Rail, Light Rail
Miami, FL EASY Card	1024	Bus, Metro Rail, Commuter Rail, Parking
NY/NJ SmartLink Card	350	Metro Rail
Salt Lake City, UT EFC Card	150	Bus, Light Rail, Commuter Rail
San Francisco, CA Clipper Card	800	Bus, Metro Rail, Light Rail, Commuter Rail, Parking
Seattle, WA ORCA Card	800	Bus, Light Rail, Commuter Rail
Washington, DC SmarTrip Card	1,800	Bus, Light Rail, Commuter Rail

Highway Emergency Response Operator (HERO) Program. The Central Texas Regional Mobility Authority (CTRMA) in partnership with TxDOT offer a free roadside assistance service that provides aid to stranded motorists, minimizes traffic delays, and improves highway safety along IH 35 and US 183. Services include providing traffic control, clearing damaged and disabled vehicles from roadway lanes and shoulders, removing debris, changing flat tires, and adding gasoline. Operators responded to over 10,000 roadway incidents in 2013, guaranteeing quality customer service [20].

Metropia. Metropia is an intelligent traffic management system that incentivizes communities to work together to ease city roadway congestion. Beginning September 2014, CTRMA partnered with Metropia to beta test a pilot program in Austin [21]. Users download an app that rewards commuters each time they use a suggested route or time of day. Points may be redeemed for prizes like gift cards to Amazon, Starbucks, and local restaurants.

CUSTOMER SERVICE SUCCESS STORY

"I was in Austin helping my daughter while her husband was away for military training. When I got a flat tire on I-35 it was upsetting because I was in an unfamiliar place driving my daughter's car. I was having trouble getting through to AAA when Clarence D. drove up and offered to change my tire. What a blessing he was to me. Thank you HERO Patrol!"

- Satisfied Customer

Understanding the Customer of the Future

White Paper

How the Age of Technology is Transforming Transportation Agencies

CUSTOMER SERVICE CHALLENGES

Cultural Barriers

Change. Customer trends and advances in technology can change rapidly. It is important for transportation agencies to tap into industry and academic expertise in order to remain well informed of behavioral and technological shifts. Conferences, forums, and journals are other examples of resources that leadership can leverage in order to ensure strategic plans remain relevant.

Privacy. Although transportation agencies may want to better understand their customers, many citizens are still wary of "Big Brother" and are apprehensive about providing personal information. Transparency regarding what data is collected, for what purpose, and with whom it is shared is important to maintaining public trust.

Technical Considerations

Finding the Right Technology. Emerging technologies offer valuable customer insights. The challenge lies in finding the right technology to improve the right parts of the customer experience. For example, with Big Data, it is important to understand the purpose for which the technology would be applied. Technology is not intended to replace traditional customer service, but rather serve as a tool to enable new and strengthen existing customer service strategies.

Systemizing a Customer Feedback Process. Customer feedback is an essential component required in order to benchmark and improve the customer experience. Without feedback, it is very difficult to evaluate what strategies are successful and which ones should be improved. Popular customer feedback loops include customer satisfaction surveys, quarterly business reviews, and comment boxes on the website.

"Quality in a service or product is not what you put into it. It is what the client or customer gets out of it."

- Peter Drucker

Organizational Obstacles

Creating a Customer-First Culture. Transportation agencies are not exempt from the old adage "the customer is always right." Adjusting priorities and becoming a service-oriented enterprise requires amending rewards and incentives based on the new preferred outcomes. The transition can also be catalyzed through the formation of the values the transportation agency embodies. Through effective communication, leadership can direct employees as to how they should engage, interact, and communicate with customers.

Delivering a Consistent Customer Experience. Research by Rawson, Duncan, and Jones found that customers do not care about singular touch points across the customer journey. Instead, they care about their cumulative experiences across multiple touch points and channels over time. This means customers no longer rate the service based on individual interactions; instead, they look at the experience the agency delivers as a whole.

Customer Segmentation Is Critical. When preparing educational, marketing, or communication materials, it is important to know the needs of the stakeholder. For example, a state legislator, MPO director, and member of the public are likely to be concerned about different aspects of the transportation system. Listening to the customers' needs is essential in determining which types of information should be conveyed to which stakeholder.

Understanding the Customer of the Future

White Paper

How the Age of Technology is Transforming Transportation Agencies

STRATEGIC APPLICATIONS FOR TEXAS

Develop a Seamless Customer Experience

By viewing transportation as an interconnected experience, Texas can develop customer service strategies that ensure every touchpoint in the customer journey results in a seamless transition to the next stage. Open fare payment systems are one way to create a data-rich environment that can be mined for customer insights regarding route, mode, and time-of-day information. Real-time traveler information is another service that can be used to manage customer expectations. By developing a customer-centric mentality and prioritizing the customer relationship, transportation agencies can gain a deeper understanding of their stakeholders' interests. Sharing the information and collaborating between transportation agencies can accelerate Texas towards achieving the vision of a truly interoperable transportation system

Customize and Localize Information

Knowing what information is most important to which stakeholder and why is the foundation to any good communications strategy. Performance metrics and their respective visualization tools will vary according to the user. By crafting a personal and relevant message for each customer segment, transportation agencies can ensure their message resonates.

Public Sector as an Enabler

Transportation agencies have the power to leverage technology as a platform for change. Through customized incentives, transportation agencies can encourage customers to modify their route, time-of-day, and mode choices to benefit the transportation system as a whole. Connecting people with information and opportunities enables economic growth, increased mobility, and improved service delivery.

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Revolutionizing the Global Logistics Industry

White Paper

How the Age of Technology is Transforming Transportation Agencies

How can transportation agencies prepare for 'the new normal' in supply chain management and enhance their own competitiveness in the logistics market?

With strong state growth, the connectivity of the interstate highway network, and proximity to the Mexico border, Texas could leverage state resources and conditions to appeal to logistics providers. By developing a synergistic environment that supports emerging technologies, such as 3D printing, the Internet of Things, drones, and RFID, Texas has the potential to become a leading candidate for logistics providers to perform new technology trials.

Initial planning activities should focus on providing improved intermodal connections, expanding shipping choices, conducting intermodal studies to aid local and regional economic development efforts, and facilitating the cooperative operations between mode-specific agencies. States and regions that plan for and support an increase in freight movement will enhance their own competitiveness in international and domestic markets.

Revolutionizing the Global Logistics Industry

How the Age of Technology is Transforming Transportation Agencies

White Paper

KEY STRATEGIES

Understand the Full Suite of Technologies

The future of freight and urban logistics hinges upon technology development and adoption. Understanding the suite of emerging technologies is critical for integrating them into logistics services and supply chain management.

Develop an Interface between Modes

Planning for the interface between modes will provide for the optimum use of all of the State's transportation modes for freight movement. When modes interface well, paths for goods movement increase as congestion and delay decrease.

Identify Future Markets and Influences

Growth in freight shipment has a strong connection with population growth and overall economic health and is also influenced by many other factors. Understanding trends in these areas will provide indications to transportation agencies on the amount and types of freight movement that need to be accommodated.

Revolutionizing the Global Logistics Industry

White Paper

How the Age of Technology is Transforming Transportation Agencies

STATE OF RESEARCH & PRACTICE

Understand the Full Suite of Technologies

Additive Manufacturing (3D) Printing. The idea of 3D printing or additive manufacturing (AM) as it is also know is not a new idea; however, it is only in recent years that it has become a reality. AM makes it possible for manufacturers, businesses, and individuals to print exact working replicas of parts and products using plastics, metals, resins, ceramics, paper, and wax. Already, a number of personal 3D printers can be purchased on customer sites such as Amazon for as little as $360.

In larger-scale business applications there are a number of AM technologies, each with their own strengths and weakness, that better serve manufacturing of the end product. The table below provides a snapshot of several AM technologies along with key attributes of the technology.

By understanding the range of technical capabilities, transportation agencies can develop a synergistic environment for emerging technologies.

Increasingly manufacturer and technology companies are become more involved in 3D printing and are making parts for automotive, aerospace, defense, and medical industries [2]. A list of leading AM/3D printing companies and 2014 revenues are listed below [3].

- Stratasys Direct Manufacturing $750 million (NASDAQ: SYSS)
- 3D Systems: $650m (NYSE:DDD)
- Materialise: $81m (NASDAQ:MTLS)
- ExOne: $43.9m (NASDAQ:XONE)
- Arcam: $39m (Stockholm Stock Exchange, STO:ARCM)
- SLM Solutions: $36m (XETRA: AM3D)
- Alphaform $30m (ETR:ATF)
- voxeljet: $17m-18m (NYSE:VJET)

AM could have a lasting impact on freight and logistics for a number reasons, but primary reasons include onsite production or the ability to print products anywhere, particularly the customer's business location, and the idea that printing on location is faster than shipping from remote supplier and traditional manufacturers. Replacement or unique parts that traditionally require expensive offsite new manufacturing can be scanned and printed same day.

Summary of Printing Technologies

Process	General material used	Material deposited or on bed?	Material fused by what process?	Popular Process/Brand	Select Companies with Process
Material Extrusion	Thermoplastic	Deposited	Nozzle	FDM	SSYS; DDD
Material Jetting	Photopolymer/Wax			PolyJet/ProJet	SSYS; DDD
Vat Photopolymerization	Photopolymer	Bed	Laser	SLA	DDD; EnvisionTEC
Binder Jetting	Powders		Bonder	3DP	DDD; XONE; VJET
Powder Bed Fusion			Laser/EBM	SLS/DMS	DDD; ARCM; EOS
Directed Energy Dep.		Deposited		DM	Trumpf; Optomec
Sheet Lamination	Paper		Bonder	LOM/UAM	Mcor Technologies

Source: Pacific Crest Securities estimates

Revolutionizing the Global Logistics Industry

White Paper

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Internet of Things (IoT). A number of factors are driving the rise of the IoT, including the widespread availability of broadband Internet, Wi-Fi capable devices (especially smartphones) and sensors, and the overall decrease in the cost of connecting. In short, IoT allows devices to communicate with one another using communication infrastructure, absent human intervention. Devices include everything from smartphones, household appliances, wearable devices, and components of machines such as vehicle engines, and much more. Ultimately the IoT will become a massive network of connected things with connections between people-people, people-things, and things-things. The application of IoT to future freight and logistics is expected to increase speed, decrease waste, and reduce costs.

Example IoT applications possible through connected sensors and devices for urban freight and logistics include the following [4].

- Waste management—detection of trash container levels provides information for the optimization for waste management routes.
- Traffic congestion—monitoring of vehicles, cyclists, and pedestrians to optimize delivery vehicle routing.
- Shipment quality—monitor container vibrations, hits, and openings to indicate potential quality issues.
- Item location—query of individual items in large areas like warehouses or harbors.
- Storage incompatibility detection—monitor and warn of emissions from containers storing inflammable goods near others containing explosive material.
- Fleet tracking—monitor routes followed for delicate goods like medical drugs, jewels, or dangerous merchandises.

IOT Challenges

Security – Keeping data secure is a big issue when considering millions or billions of devices being connected together. Transportation agencies and original equipment manufacturers should consider strategies for keeping information secure.

Privacy – The IoT also opens up companies and customers to more security threats, which also threatens their privacy. Agencies will need to find ways to monitor their databases, limit access, properly encrypt data, or use other strategies to ensure privacy of data.

Data Management – With massive, connected networks, the amount of data that devices will produce will be enormous. Agencies will need to figure out how to store, query, analyze, and use the immense amounts of data that will be generated.

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Drones. Consumer purchasing and delivery is changing largely in part due to online shopping—customers are increasingly interested in click-and-buy shopping on mobile devices. Soon, the way that goods reach the consumer's door could change with on-demand, last-mile delivery options. Same-hour bicycle delivery and vehicle delivery (like Uber) are becoming options, but the truly transformational technology that may be a reality in the future is delivery drones. Large, reputable companies like Amazon and Google have already made known their plans for delivery drones in the U.S. with programs called Amazon Prime Air and Project Wing. Delivery companies FedEX and UPS have also indicated research activities in the area of drones [5]. International delivery giant DHL is already testing drone based delivery in Europe [6].

In all of these schemes, small unmanned aerial vehicles (UAVs), or drones, weighing less than 55 pounds would be used at a maximum flight level of 400 ft above ground. The few operational details released by Amazon include plans for 30-minute-or-less delivery, a 10-mile flying radius from launch point, and 30-minute battery life [7]. Each UAV could carry a package of up to five pounds, which applies to about 80 or 90 percent of all items Amazon sells [8].

Current regulation issued by the U.S Department of Transportation's Federal Aviation Administration (FAA) does not allow for testing of commercial delivery schemes like Amazon's proposal. Restrictions regarding drone operations (such as the mandate for full line of sight, prohibition of flying over people, etc.) make it impossible to test delivery drones in urban areas. Until urban deliver trials are allowed on a small scale, U.S. transportation agencies should watch Amazon Prime Air approvals and trials in others countries for lessons learned.

***Robotics and Automation*.** Although these two ideas are closely related, their applications differ in the context of freight and logistics. One application of automation is the autonomous, or partially autonomous, freight truck. Such vehicles would allow for computer takeover of driving tasks in large semi trucks. Daimler has already announced the trial of such a concept and said that the company will begin testing on public roadways in Nevada [9]. Automated trucks offer safety and operational benefits because autonomous systems can react faster than human drivers and adjust driving according to real-time vehicle information. This capability not only increases safety on the road, but also increases operational efficiencies by enabling truck platooning. Similar trials in Sweden have resulted in millions of gallons in fuel savings from autonomous systems that optimize driving under continually monitored driving conditions.

At ports, automation or robotics may be used for loading and unloading, automated container transport, and automated container storage using autonomous guide vehicles, autonomous stacking cranes, or ship-to-shore cranes [10]. Benefits of these could include reduced costs and increased productivity. Empirical evidence from global ports using automation shows improvements like increased productivity and efficiencies. For example, Hong Kong, Singapore, and Taiwan, which have highly automated ports, are able to undertake 46 crane moves per hour, making them 13 percent more efficient than Middle Eastern ports and 43 percent more efficient than North American ports in unloading cargo [11].

Automated truck platooning offers safety and operational benefits. Trials in many states are already underway.

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Radio Frequency Identification (RFID). RFID is an automated identification and data collection technology that is found in items such as access cards and toll tags. It allows an object to be tracked by identifying it with a transponder or tag. Periodically, the tag transmits its unique ID number through radio frequency or an RFID reader requests that the tag to broadcast its data. The reader receives tag data and sends it to middleware that filters, aggregates, and formats the data for business applications. RFID comes in a various forms, although the most common are passive (no battery) and active (with battery) forms [12]. RFID technology can be used in the freight and logistics for the following applications.

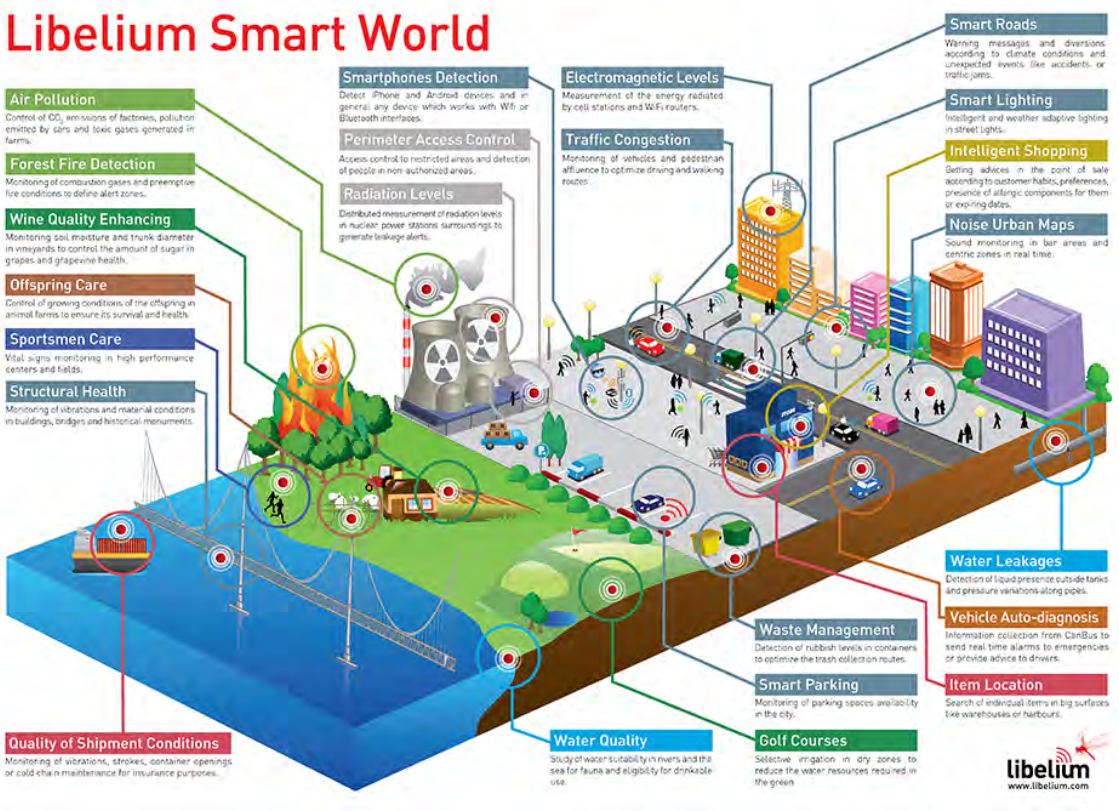
RFID Applications

Network Asset Visibility – RFID can be used to track containers and trucks across many supply chain modes.

Operational Control – RFID can allow monitoring of automated processes within terminal or ports.

Safety – This technology can help to ensure safety of personnel and equipment through nearly continuous monitoring within a terminal or port.

Security – RFID can aid in control and securing assets in the inventory.



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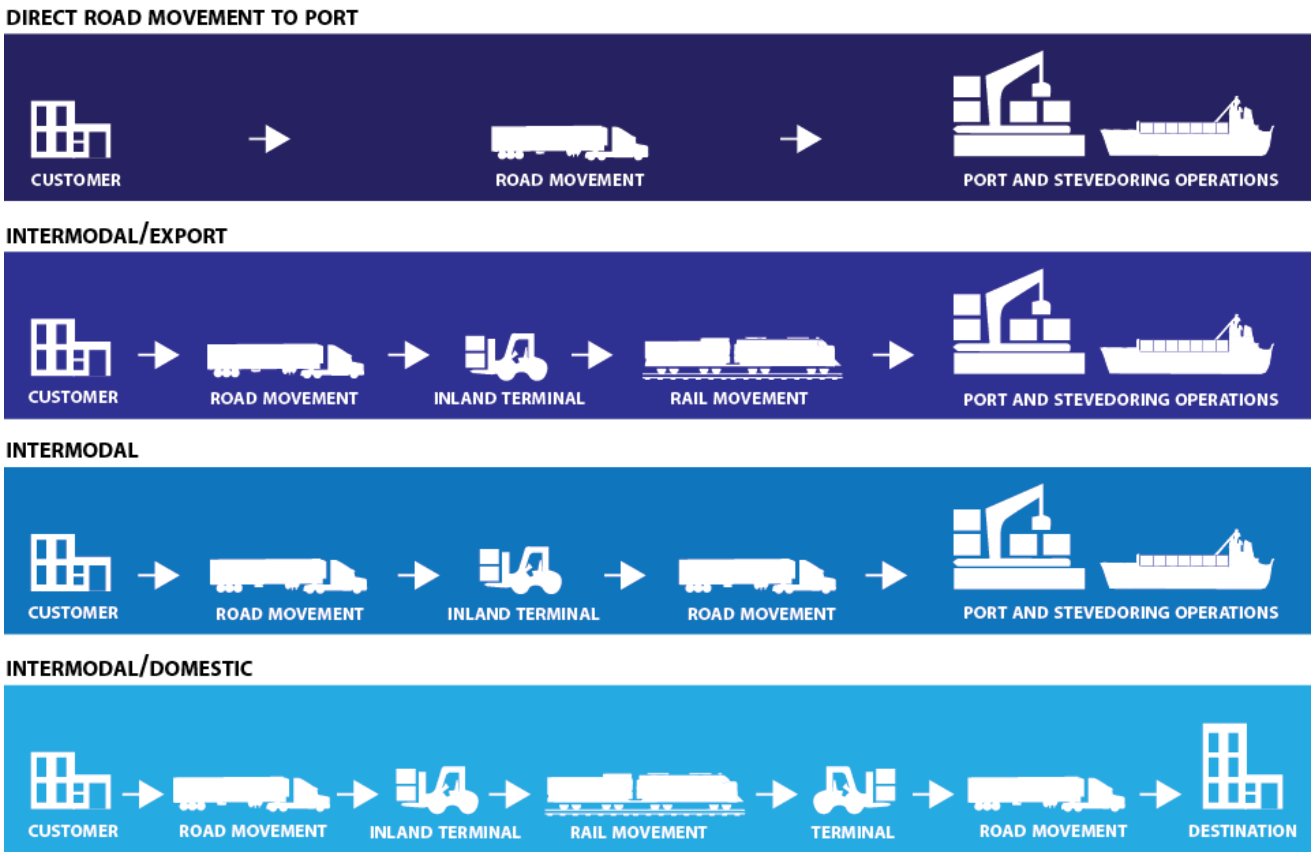
Develop an Interface between Modes

Intermodal. Goods shipment requires more than one mode. It requires a combination of ships, trains, trucks, ports, rails, and roads, and demands a support structure for intermodal operations so that the economy of the U.S. continues to thrive. Since goods movement takes place in an interconnected, complex system, the impact of increased freight on one mode impacts other modes. For example, more efficient water ports may be capable of handling bigger ships with larger loads and at a quicker turnaround time, too. But if those goods cannot be efficiently moved to trucks and rail, then waterways will become congested and backed up rendering larger ships ineffective.

Intermodal efficiency is critical and to be planned for at high levels with coordination among agencies that traditionally have interest in a single mode (e.g., aerospace, rail, surface transportation, etc.). Public and private sectors stakeholders alike have an interest in identifying the most efficient combination of modes for shipments across the supply chain since revenue is tied to efficiency. Where there are inefficiencies at modal interfaces, solutions must be made to relief congestion and delays. The Port of Savannah, for example, has built two freight rail lines located in terminals for long-distance or heavy cargo, and has also built a direct three-mile roadway link to Interstate 95 at a cost of $73 million in order to save 11 minutes to and from the port [13].



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Identify Future Markets and Influences

Consumer Purchases. The demand for goods movement will ultimately be driven by customer purchases. To that end, the Census Bureau has estimated that that the U.S. population will increase 20% by 2040, which translates to roughly one additional person every 12 seconds who needs and wants consumer goods [14]. Further, the Boeing Company previously released worldwide projections for the global air freight market, which is expected to double in the next 20 years. This is supported by the notion that there will be a continuing, strong need to transport air goods to North America from Asia. To meet demand, Boeing predicts that carriers will buy nearly 840 new freight planes over the next two decades at an estimated value of $240 billion with an annual global rate of air freight growth of 4.7 percent [14].

Freight and logistics companies and transportation agencies should also be aware of a number of other market factors that will impact their operations and bottom line, such as fuel prices, alternative energy advances, demand for personal travel that impacts road network performance, labor and personnel availability and training, and more.

The global air freight market is expected to double by the year 2035.

American Trucking Association Projections for the U.S.

Overall freight tonnage will grow 23.5% from 2013 to 2025 and freight revenues will increase by 72%.

Growth in overall freight volume is pegged at 2.8% per year from 2014 to 2019, and then it tapers off to 1.0% during the next six years through 2025.

Trucking's share of freight tonnage will increase from 69.1% in 2013 to 71.4% in 2025

Rail intermodal tonnage will grow 5.5% annually through 2019 and 5.1% a year through 2025—yet the rail market share will shrink from 14.5% of all tonnage in 2013 to 13.8% in 2025.

OPPORTUNITIES FOR TEXAS

Leverage Natural State Resources

Texas could leverage state resources and conditions that are appealing to logistics providers. Strong state growth, the interstate highway network, proximity to the Mexico border, and other factors make Texas a prime candidate for logistics providers to perform new technology trials.

Facilitating Intermodal Planning

Initial planning activities should focus on providing improved intermodal connections, expanding shipping choices, conducting intermodal studies to aid local and regional economic development efforts, and facilitating the cooperative operations between mode-specific agencies. States and regions that plan for and support increase in freight movement will enhance their own competitiveness in international and domestic markets.

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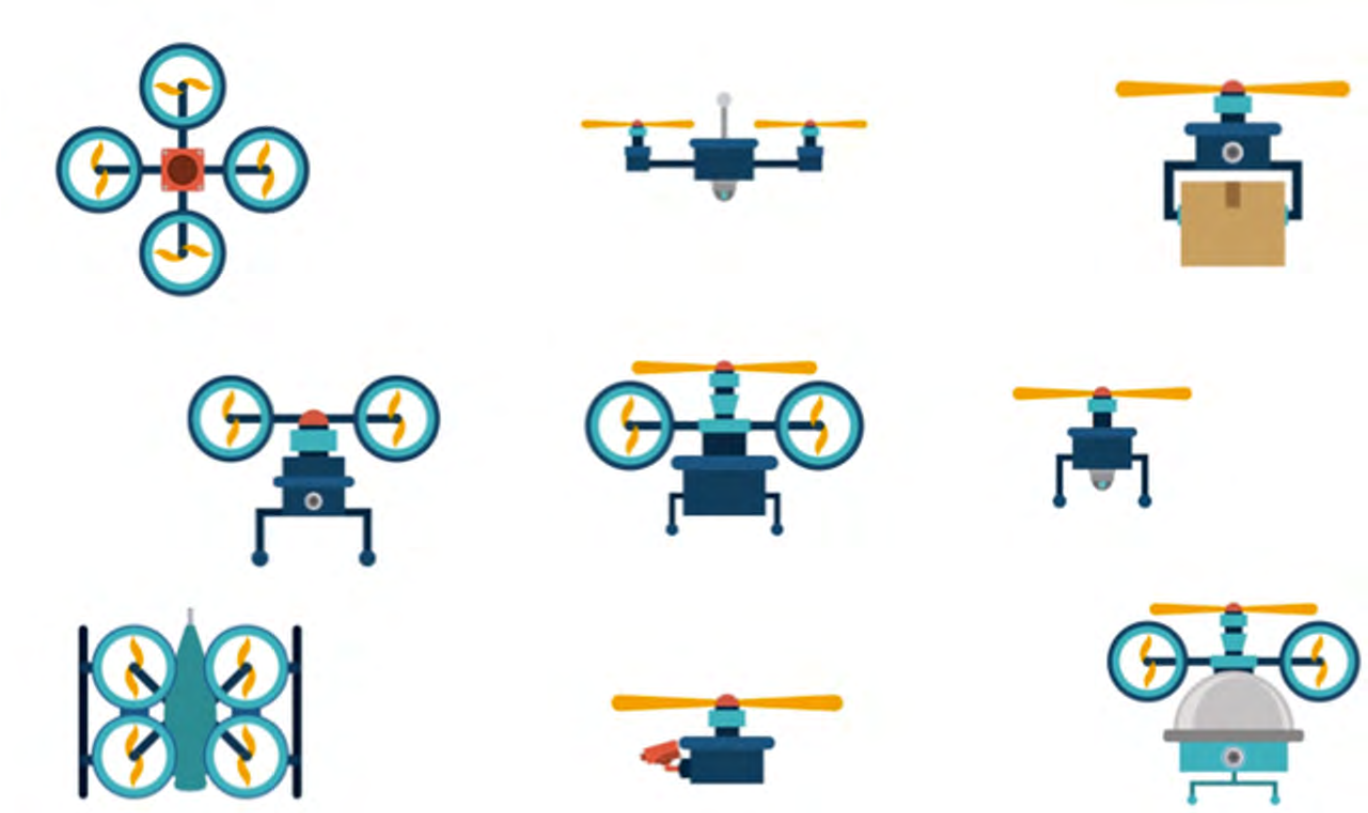

How are drones changing the way transportation agencies do business and does Texas have the potential to become a leader in this space?

Potential commercial and civilian uses of small unmanned aerial vehicles (UAVs), also known as drones, offer many beneficial applications in the areas of emergency response, structure inspections and safety, traffic monitoring and investigating, delivery and logistics, and more. Transportation agencies at all levels can get creative with proposed drone applications, which will offer safety, cost savings, and operational efficiency gains. In order for these benefits to be realized, transportation agencies should be proactive in planning by staying informed of FAA rules and regulations, understanding technological and operational barriers, and planning to mitigate citizen concerns through strategic initiatives. Transportation agencies can also support UAV integration by taking steps to provide the necessary support infrastructure, personnel, and programs.

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KEY STRATEGIES

Develop an Ecosystem to Support UAV Integration

The introduction of UAVs to support transportation operations across all modes requires consideration and provision of a full, supportive ecosystem for safely managing them in our airspace.

Monitor FAA Rulemaking and Regulations

The FAA is expected to issue updates to rules governing commercial and civil uses of drones in late 2016 or early 2017. Transportation agencies should watch for these updates and take advantage of other key initiatives for UAV integration supported by the FAA.

Identify Commercial and Civil Applications

Already a number of commercial uses of UAVs have been proposed by companies across the U.S. Transportation agencies can monitor these proposals in order to plan for their operations, learn from those trials, or partner with the private sector for their own trials.

Discover and Mitigate Operational Obstacles and Barriers

Many barriers and obstacles exist, which will slow the introduction of UAVs for commercial and civil uses. Transportation agencies should anticipate these barriers and have a mitigation plan in place to increase the safe integration of UAVs.

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STATE OF RESEARCH AND PRACTICE

Develop Ecosystem to Support UAV Integration

Unmanned Aircraft (UA). The Federal Aviation Administration (FAA) states that a UA, also known as a drone, is one component of the larger system that is necessary to operate such an aircraft. The UA is a flying aircraft that is piloted through a ground control system, or autonomously through on-device computers and also using information transmission devices. The larger UA system (UAS) is made up of components such as control stations, data networks and transmission devices, navigation equipment, etc. UAVs offer a number of commercial and civil uses that could enhance surface transportation, provide economic benefits, and promote U.S. competitiveness.

Small UAVs. Small UAVs are defined as those that weigh less than 55 lb (25 kg) and fly at an altitude of under 400 ft (122 m) above ground level. This class of UAVs is typically powered by rechargeable batteries or small internal combustion engines (ICEs) and flown either manually via a remote controller or autonomously using an automated program in the UAV. Federal rules governing the use of drones vary depending upon the use class—recreational, commercial, or government. While there are a large number of drone applications, most can be described as delivery operations; utility operations; or surveillance, photography, or imagery operations.

Small UAVs come in a variety of shapes, sizes, and styles—each with unique benefits and applications.

General UAV Characteristics. Small UAVs come in a variety of shapes, sizes, and styles. With each style and body variation comes unique benefits and drawbacks that make the aircraft more or less appropriate for a particular application. Ultimately a UAV pilot (also called the operator) is required to match a best-fit vehicle with an application based on understanding key attributes. Currently there are two broad categories of UAVs—fixed wing and rotary wing. Each of these two categories can be further broken down into subclasses, with their own unique characteristics and advantages and disadvantages. The following section describes two broad UAV styles and corresponding characteristics. A discussion of other technological components follows.

Fixed Wing Small UAVs. This type of UAV has a rigid (fixed) wing with a predetermined airfoil that makes flight possible by causing lift of the vehicle using forward airspeed. Lift requires forward thrust generated by propeller and electric or internal combustion engine. Fixed wing UAVs can be broken into subclasses; for example, a fixed wing UAV can be high wing, mid wing, low wing, and flying wing. The aircraft is controlled by wing surfaces with control components (i.e., elevator, ailerons, and rudder). These components permit the vehicle to rotate around three axes that are perpendicular to one another and joined at the vehicle's center of gravity. Each component controls movement for each axis—for example, the elevator controls the pitch (lateral axis), ailerons control the roll (longitudinal axis), and the rudder controls the yaw (vertical axis) [1].

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***Rotary Wing*.** Rotary wing small UAVs have two to three rotor blades that rotate around a fixed, center mast—the rotor. These UAVs come in a number of setups, such as helicopters with one rotor, tripcopters with three masts, quadcopters with four rotors, hexacopters with six rotors, etc. Like fixed wings, rotary wing UAVs can be broken into subclasses that offer their own unique advantages and disadvantages for a flight mission. Rotor blades work exactly the same way as a fixed wing; however, constant aircraft forward movement is not needed to produce airflow over the blades. Instead, the blades themselves are in constant movement, which produces the required airflow over their airfoil to generate lift.

Fixed Wing versus Rotary Wing. Overall the fixed wing UAV is a simpler structure compared to a rotary wing UAV. Due to its simplicity, maintenance and repair is typically less expensive and complicated, resulting in more fly time at a lower cost. In addition, fixed wings offer more efficient aerodynamics with the advantage of longer flight times at higher speeds, making them a competitive option for applications such as surveying and mapping where larger areas per flight can be realized. Fixed wing UAVs also offer natural gliding (no power) capabilities (a feature rotary wings lack), meaning that they are able to carry greater payloads for longer distances on less power.

The disadvantages of fixed wings are the need for a runway or launcher for takeoff and landing. They also require air moving over their wings to generate lift and must stay in a constant forward motion, meaning they do not have stationary capabilities. Thus, fixed wing UAVs are not practical for stationary applications such as inspection work, where hovering is necessary.

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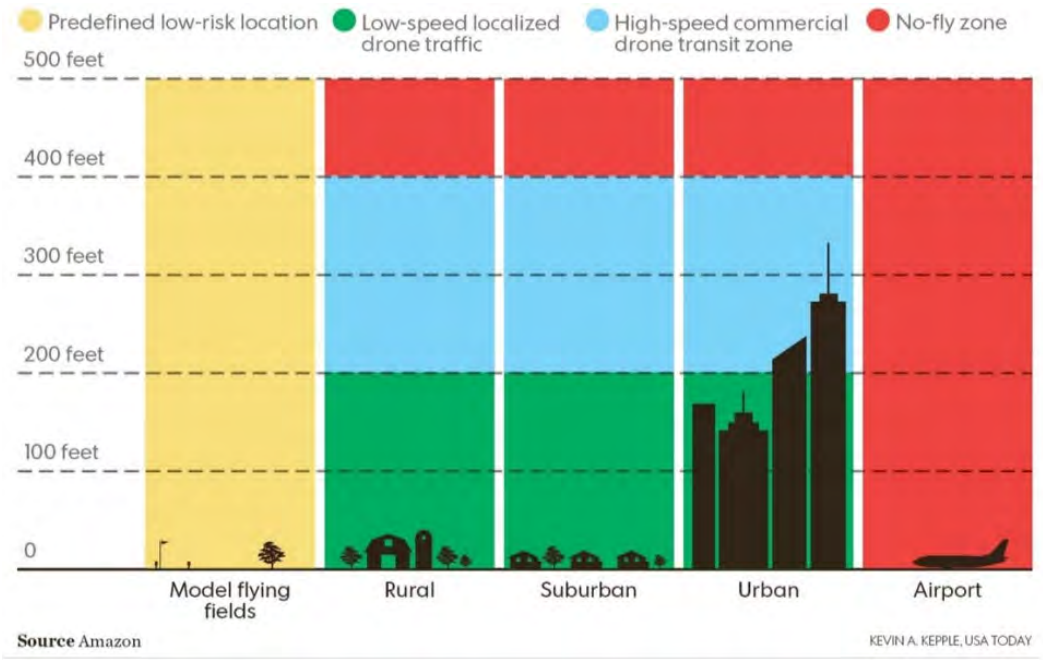
Energy and Propulsion System. Small UAVs typically have one of two engine technologies—internal combustion or electric. ICE and electric engines present distinctly different advantages (and disadvantages) for flight missions. ICEs provide for longer endurance flights that may be good for mapping and surveying, and electric engines provide for quiet operations, which may be ideal for missions in and around populated areas.

***Controllers and Onboard Technology*.** A controller is needed in order to take flight. Controllers come in many forms, including gamepad-like devices and smartphone and tablet apps. The controller allows a pilot to launch, navigate, and land the UAV, typically through 2.4 gigahertz radio waves [2]. UAVs have a variety of onboard technologies as well. For example, GPS chips for relaying location and navigation, gyroscopes for determining the reference system for the navigation, altimeters for monitoring altitude useful for hovering, etc.

Small UAS Ecosystem. According to the Institute of Electrical and Electronics Engineers (IEEE), UAS will present greater communication needs compared to current manned aircraft partly due to issues like communication bandwidth—or the rate at which data can be sent over a communication link. Many small UAS applications necessitate fast response times in locations where permanent supporting communication infrastructures do not exist [3]. Current approaches that use long-range or satellite communications require equipment that is too large and expensive for small aircraft, whereas smaller radios limit the small UAS operational envelope in terms of range, altitude, and payload. Much research and planning is needed to understand the full ecosystem of hardware and software needed to safely integrate more UAVs into the airspace. In addition, the FAA will need to work with the FCC regarding the communications frequencies used by UAVs, and with the government and Congress on privacy issues to support the ecosystem.



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Monitor FAA Rulemaking and Regulations

Federal Aviation Administration (FAA). The FAA under the U.S. Department of Transportation oversees operations of any aircraft in the national airspace and requires that aircraft are certificated and registered, are operated by a licensed pilot, and have operational approval.

Current Rules. General and current rules for small UAVs are described below and vary depending on use. Uses are divided into three categories: recreational, business, and public.

- UAV flights must be below 400 feet and remain clear of surrounding obstacles
- UAVs shall remain within visual line of sight at all times
- UAVs must stay well clear of manned aircraft operations
- UAVs cannot fly within 5 miles of an airport without contacting the airport and control tower beforehand
- UAVs cannot fly near people or stadiums
- UAVs cannot fly an aircraft that weighs more than 55 lbs
- Operators cannot be careless or reckless with the UAV

The FAA does allow the flight of small UAS for commercial or business purposes on a case-by-case basis. Operators are prohibited from flying for commercial purposes without the express permission of the FAA. There are two ways to obtain such permission. Operators can apply for an exemption (see description of Section 333 to follow) from the FAA to operate commercially or obtain an FAA airworthiness certificate and operate pursuant to FAA rules. In either case the operator needs an FAA Certificate of Waiver or Authorization (COA).

Finally, public entities, including publically funded universities, law enforcement, fire departments, and other government agencies, can apply for a COA from the FAA for the use of small UAS in public aircraft operations. For both commercial and public uses, the FAA will thoroughly evaluate each COA application and determine the safety of proposed use. COAs will be used for a specific period of time (typically two years) and include special provisions unique to each proposal, such as a defined block of airspace or the time of day the UAS can be used.

***Proposed Rules*.** Earlier in 2015 the FAA provided notice of rulemaking for small UAVs, known as "Small UAS Notice of Proposed Rulemaking," which was followed by a required 60-day public comment period ending on April 24, 2015. Comments were solicited for the FAA's proposed framework of regulations for the routine use of small UAVs in the national airspace. Next, the FAA will review the public comments and make any necessary changes to proposed rules. The FAA has not announced an expected completion date for the changes. The proposed rules apply to non-recreational operations and non-model aircraft and further addresses operational hours, visual-line-of-sight requirements, height restrictions, operator certification, optional use of a visual observer, and aircraft registration and marking. Until a final rule is issued, no part of the rule will be in effect and current regulations will continue to apply. Until the new rules are issued, commercial operators must request and receive a Section 333 grant of exemption.

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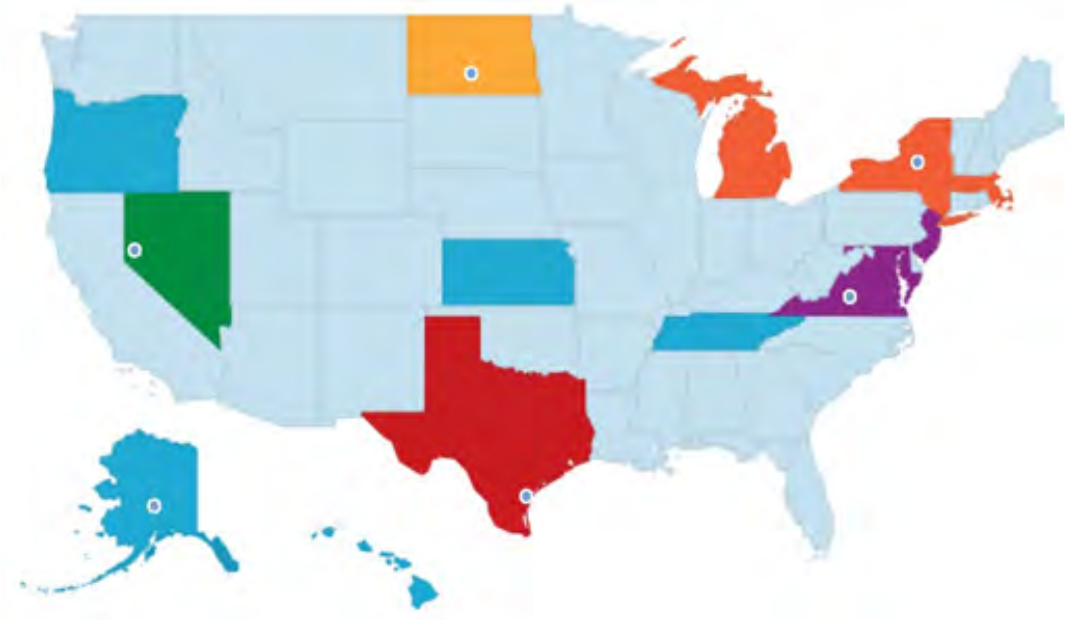
Highlights of the "Small UAS Notice of Proposed Rulemaking" include provisions for operator certification and responsibilities such as passing an initial aeronautical knowledge test and provisions for aircraft requirements (aircraft markings, registration, inspection, etc.). In addition to rule making, the FAA is currently engaging in a number of key initiatives designed to research and plan for the integration of UAVs into the national airspace. An overview of such initiatives is provided below.

Test Sites. The FAA has chosen six UAS sites across the country for research and testing. Each of the six sites is in partnership with a university and has been chosen for its geography, climate, proximity to ground infrastructure, research needs, airspace use, safety, aviation experience, and risk. These sites combined represent cross-country geographic and climatic diversity in order to help the FAA meet its UAS research needs. The sites are congressionally mandated and will complete critical research that will inform the certification and operational requirements needed to safely integrate UAS into the national airspace in coming years.

Summary of FAA UAS Test Sites

Location	Approval Date	Research Area
University of Alaska (includes test ranges in Hawaii, Oregon, Kansas, and Tennessee)	May 5, 2014	Wildlife surveys: demonstrating how UAS can accurately locate, identify, and count large wild animals UAS safety: collect safety-related operational data needed for UAS integration
State of Nevada	June 9, 2014	Airport safety: verifying UAS can operate safely at the airports Standards and operations: UAS standards and operations as well as operator standards and certification requirements
New York's Griffiss International Airport (includes test range locations in Massachusetts and Michigan)	August 7, 2014	Safety: integration of unmanned aircraft into the national airspace Agriculture: detection of insects, weeds, diseases, crop characteristics, crop biomass and background soil characteristics farm fields
North Dakota Department of Commerce	February 11, 2015	Precision Agriculture: UAS check of soil quality and the status of
Texas A&M University – Corpus Christi	June 20, 2014	Multiple areas: safety of operations and data gathering in authorized airspace, UAS airworthiness standards, command and control link technologies, human-factors issue for UAS control-station layout, and detect-and-avoid technologies
Virginia Polytechnic Institute and State University (Virginia Tech) (includes test ranges in New Jersey and Maryland)	August 13, 2014	Agriculture: spray equipment testing, Standards and Operations: development of aeronautical procedures for integration of UAS flights in a towered airspace and developing training and operational procedures for aeronautical surveys of agriculture



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Center of Excellence. The FAA chose Mississippi State University, through a competitive process, to house the UAS Center of Excellence (COE). The COE will focus on education, research, and training necessary for the successful and safe integration of UAS into the national airspace. Research focus areas include detect and avoid technology; low-altitude operations safety; control and communications; spectrum management; human factors; compatibility with air traffic control operations; and training and certification of UAS pilots and other crewmembers, in addition to other areas [4]. While these are initial focus areas, the research program is expected to change and evolve as the program grows, with activities commencing in September 2015 and evolving to a fully operational and robust research agenda by January 2016.

The COE operates in partnership with 15 of the nation's leading UAS and aviation universities, which are listed below.

- Drexel University
- Embry Riddle Aeronautical University
- Kansas State University
- Kansas University
- Mississippi State University
- Montana State University
- New Mexico State University
- North Carolina State University
- Ohio State University
- Oregon State University
- University of Alabama, Huntsville
- University of Alaska, Fairbanks
- University of Kansas
- University of North Dakota
- Wichita State University

Section 333 (Commercial & Business Applications). "Section 333" refers to the provisions of Section 333 of the FAA Modernization and Reform Act of 2012 titled "Special Rules for Certain Unmanned Aircraft Systems." This section will ultimately allow for commercial or business operations in low-risk, controlled environments. Currently, UAVs that are flown for purposes other than recreation or hobby (commercial or business) are required to obtain FAA authorization via Section 333 and a grant of exemption, until new rules are issued by the FAA.

The following items are needed for commercial or business operations, including the Section 333 grant of exemption:

- Section 333 grant of exemption,
- Certificate of Waiver or Authorization (COA),
- Aircraft registered with the FAA, and
- Pilot with an FAA airman certificate

More information on Section 333 exemptions can be found online on the FAA Section 333 webpage [5]. In addition, granted exemptions can be found online on the Authorizations Granted Via Section 333 Exemptions page, which gives details on the petitioners and proposed UAV uses [6]. At the time of this paper, over 1200 petitions had been granted.

Focus Area Pathfinders. The FAA supports an initiative designed to work in partnership with UAV industry partners to consider next steps in UAV operations and integration not included in the draft small UAS rule it published in February. To date, three industry partners have asked the FAA to partner for work in specific focus areas. Each partnership and focus area is described below and more information can be found on the FAA's Focus Areas Pathfinder webpage [7].

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FOCUS AREA PATHFINDERS

Partner: CNN

Work: Visual line-of-sight operations in urban areas considering how UAS might safely gather news in populated areas

Partner: PrecisionHawk

Work: Exploration of crop monitoring in precision agriculture operations beyond visual line of sight in rural areas

Partner: BNSF Railroad

Work: Exploration of command-and-control challenges beyond visual line of sight in rural areas to inspect rail system infrastructure using UAS

UAS in the Arctic. The FAA Modernization and Reform Act of 2012 Section 332 also charged the FAA with the task of developing a plan to designate permanent areas in the Arctic where small UAVs could carry out research and commercial operations. An Arctic Implementation Plan for such activities is available on the FAA's Key Initiatives webpage [8].

UAS Roadmap. The previously mentioned FAA Modernization and Reform Act of 2012, Public Law 112-95, mandated the creation and publication of a five-year roadmap for UAS research and integration. It gives a broad timeline for tasks and considerations needed to enable UAS integration, such as research, regulations, policies, procedures, guidance, and training plan development. Revision is completed annually in partnership with other relevant national agencies. The first and latest version of the UAS plan can be found on the FAA's UAS Roadmap website [9].

Identify Commercial and Civil Applications

Delivery Applications. Amazon has gone public with its plans for a customer delivery scheme that is said to delivery packages in under 30 minutes. Amazon has not officially released details of the intended delivery UAV, but early images suggest a rotary wing octocopter. Amazon CEO Jeff Bezos has stated that the octocopter would have a 10-mile radius limit from launch point due to battery limitations, which means that customers in urban areas may be better delivery candidates. Payload limit would not exceed 5 pounds—86% of all amazon deliveries [10].

DHL is already using its 'parcelcopter' for initial operations for research purposes in Europe and is completing regular flights to the North Sea island of Juist. Operational flights are completed with DHL's university and industry partners at the same time every day and are used to deliver emergency medications and urgently needed goods. This is the only UAV operation in Europe where UAVs are authorized to fly outside the operator field of vision [11].

Disaster Aid and Emergency Response. Google's UAV scheme, called Project Wing, envisions using drones for disaster relief, i.e., delivery of emergency supplies to areas in need [12, 13]. Google's concept aircraft has four electrical propellers; a wingspan of nearly five feet; weighs just less than 19 pounds (22 pounds with payload) and can take off and land without a runway. The UAV is controlled through computer programs with operator-override capabilities when necessary [14].

The FAA expects that 7,500 small UAVs will be operating in the U.S. by 2018. The market for UAVs could exceed $1 billion by 2020.

***Utility*.** Although this is not a small UAV application, Facebook is using larger drones to beam internet signals in remote places. With a wingspan of a Boeing 737, this UAV will be launched into the sky using a large balloon that will carry it into the stratosphere. It will hover at altitudes between 60,000 and 90,000 feet where it will not interfere with commercial airline flights and will remain above inclement weather. The UAV will be fitted with solar panels and an electric motor, which jointly will allow it to remain in the sky for 3 months uninterrupted [15].

The Revell Texter Helicopter is a rotary UAV that allows users to upload via USB a basic text message or image to be displayed in LED lighting [16]. Such a drone could be used for emergency messaging in remote or inaccessible areas.

Surveillance, Photography, Imagery. A number of applications exist for the use of UAVs with imaging, photography, and video equipment. A short list of applications and uses for illustrative purposes is provided below [17].

- Shell Oil Company uses UAVs to monitor and inspect oil and gas facilities that are unsafe or difficult for in-person inspectors to access.
- Engineers at the Polytechnic University of Catalonia in Barcelona have developed a drone that could be used to catch rhino poachers in national parks in Africa by making use of thermal vision technology.
- Network Rail's ORBIS project in the UK will use drones to get better images of the rail's transport networks.
- BBC and Al Jazeera have begun using drones for aerial filming.
- Budget airline EasyJet uses drones for safety inspections on its aircrafts.

Discover and Mitigate Operational Obstacles and Barriers to UAV Integration

Theft and Civilian Take-Down. There are already many cases where civilians have shot down drones due to privacy concerns. Concern exists regarding the opportunity for theft of surveillance and camera equipment or customer goods.

***Privacy*.** UAV deployment before proper regulation and policing causes great concern for privacy. Drones equipped with facial recognition software, infrared technology, and microphones capable of monitoring personal conversations could cause unprecedented invasions of privacy rights. Interconnected drones could enable tracking of vehicles, and finally, micro drones could go largely unnoticed while peering into the windows of unauthorized places.

Managing Traffic in National Airspace. With the unprecedented number of drones that could join the national airspace if commercial operations are allowed, there is concern about crowding and airspace management.

Safety. There is concern about UAVs flying over urban areas because a drone could potentially fall from flight onto people or moving traffic. In addition, children or pets could become injured by the rotary blades when trying to retrieve packages from rotary UAVs.

Weather Restrictions. Drones fly well in reliable weather but not able to withstand unreliable or inclement weather. Precipitation would obscure sensors, and more research is needed in this area.

OPPORTUNITIES FOR TEXAS

Identify Beneficial Uses of UAVs

UAVs for Civil Uses. A starting place for planning for the introduction of UAVs for civil uses should include an investigation into how they could be used to improve civil operations, followed by developing a list of applications of interest. Civil uses would likely take advantage of UAV cameras and sensors, as in the following examples of potential uses.

Traffic Monitoring. Small UAVs could be used to collect data on and manage peak period traffic.

Emergency and Disaster Response. UAVs could be launched to monitor dangerous conditions presented by events such as wildfires, flooding, or hurricanes. Real-time traffic conditions for evacuations during these events could also be provided by UAVs.

Law Enforcement. Border patrol and criminal activity investigation, especially in remote areas, could benefit from UAV surveillance.

Utility. Hovering UAVs with cameras could perform remote inspection and sensing of civil infrastructure like transmission lines, pipelines, bridges, etc.

Partner with UAV Test Sites for Safe Trials

The UAS test sites supported by the FAA have the expertise to safely and properly conduct UAV trials, and Texas has one of these six sites in Corpus Christi. Partnering with one of these sites for UAV trials would provide public agencies and industry partners alike with the technical expertise and regulatory knowledge needed for successful operations within the FAA allowable rules.

Identifying Opportunities and Challenges of UAVs

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Managing Customer Relationships Using Big Data

White Paper

How the Age of Technology is Transforming Transportation Agencies

How can transportation agencies develop a data-rich environment that generates valuable information for all of its stakeholders?

Texas has the potential to develop a truly interconnected transportation system by utilizing data as a platform for engaging with its customers. Empowering the customer with a voice and listening to his or her concerns are small steps that can have large impacts on the transportation network. Big Data can also be transformed into an effective decision-support tool. The key is to match the right tool to the right problem in order to effectively communicate to the decision-maker in a timely manner the best course of action. By making a commitment to data-driven decision-making, transportation agencies can take advantage of improved efficiencies, effective resource management, and cost savings across the state.

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KEY STRATEGIES

Capture Data

By viewing data as a core asset, transportation agencies move beyond reactive and silo-based approaches to proactive and integrated management strategies. Collecting real-time data and relaying information to the customer can inform travel decisions that generate immediate value.

Integrate Silos of Information

Shifting from a single source to a multi-source, multi-modal approach creates a comprehensive, data-rich environment from which state, regional, and local agencies can draw valuable information about their customers.

Analyze for Insight

Matching the right tool to the right problem enables the transportation agency to effectively communicate to the decision-maker the best course of action for the customer. Improvements may be achieved in efficiency, resource management, and cost savings.

Measure Performance

Developing a system of key performance indicators (KPIs) monitors the health of the enterprise and evaluates whether a transportation agency is achieving the goals it defined. Benchmarks and milestones are useful tools for establishing a concrete direction for the agency.

Leverage Data to Create Value

Knowing the customer helps the agency to better serve the customer and the public as a whole. Equipped with information, transportation agencies have the potential to offer incentives encouraging customers to shift to an alternative route, time of day, or mode.

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STATE OF RESEARCH & PRACTICE

Capture Data

What is Big Data? Big Data is a relative term describing a situation where the volume, velocity, and variety of data exceed an agency's storage or computational capacity for accurate and timely decision-making [2].

***Data Types*.** There are generally two types of data: structured and unstructured. Structured data, such as traffic counts and customer records, refer to information with a high degree of organization, are readily searchable, and may be easily stored in database management systems. On the other hand, unstructured data, such as text and multimedia content, require different architecture, technologies, and analytics. Since up to 85 percent of an agency's data can be unstructured, it is important to find ways to incorporate the unstructured data into quantitative analysis and decision-making.

***Data Sources*.** A successful Big Data strategy must take into account data generated from both traditional and nontraditional sources [2].

- Traditional Enterprise Data – includes customer information, transactional ERP (enterprise resource planning) data, and web store transactions
- Machine-Generated/Sensor Data – includes smart meters, manufacturing sensors, and traffic counts
- Social Data – includes customer feedback streams, micro-blogging sites like Twitter, and social media platforms like Facebook

Understanding existing data sources is the first step in identifying gaps between known and unknown information.

***Internet of Things*.** The Internet of Things (IoT) is an enabler of Big Data and falls under the second data source category of machine-generated/sensor data. Imagine a world in which a transportation agency is collecting traffic information from connected vehicles, bridge stress and strain information from embedded sensors, and commercial vehicle size and weight information through roadside infrastructure. Combined with traditional data collected through pavement testing and new photographic information supplied through social media, transportation agencies now have the ability to optimize maintenance schedules and improve response times to customer requests.

The Real-Time Factor. "Real-time" data is defined based on two considerations: frequency and latency. The first is the data capture interval or how often data is collected. The second is the time lag between when data is collected and when it can be shared with users [3]. Collecting real-time data, such as weather and travel times, and relaying route information to the customer can inform travel decisions, generating immediate value.

***Ownership, Storage, & Maintenance*.** With the increasing use of technology for data acquisition, developing policies for ethical data management is crucial. Grasping the full implications of a Big Data policy requires answering these questions: Who owns the data—public sector, private sector, or the individual? How often should data be collected and how long should data be stored? Who is best equipped to maintain the data and does the agency have sufficient in-house expertise? The answers to these questions will vary depending upon the data and its purpose. By viewing data as a core asset, transportation agencies can move beyond reactive and silo-based approaches to proactive and integrated management strategies.

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Integrating Silos of Information

Single-Source to Multi-Source, Multi-Modal. Most data environments are single-source: they capture one type of transportation data, such as vehicle crashes, roadway inventory, or travel times. These data sets, however, are rarely integrated with other pertinent information and consequently provide an incomplete view of field conditions. With Big Data analytics, it is now possible to understand the relationships between traffic delays and their correlation to traffic counts, crash history, and weather conditions [4].

Data integration may also be improved across modes. In order to enhance the freight network, it is imperative to incorporate travel information throughout the supply chain. The Freight Advanced Traveler Information System (FRATIS) is one such concept that includes shipment schedules, port queue lengths, highway route restrictions, container disposition, and intermodal connection updates [5]. Another example is a Port Community System, which is an electronic platform connecting multiple systems operated by a variety of organizations that make up a seaport, airport, and inland port community [6].

Center of Excellence. Transportation agencies are embracing a holistic, enterprise view that treats data as a core asset. In addition to the usual array of internal data—such as demographics, campaign responses, sales, revenues, and other customer data—Chico's now integrates information about customer online behavior, the competitive landscape, and the local trade area into its customer data warehouse [2]. By applying the same principles, a state DOT could better understand a consumer's willingness to carpool, public transit needs, and attitudes towards toll roads, roadway maintenance standards, and tolerance of traffic congestion.

Types of Database Architecture. Two main types of databases are currently used in the transportation environment: Relational Database Management Systems (RDBMS) and Not Only Structured Query Language (NoSQL).

RDBMS is the traditional architecture that places data within well-defined tables, fields, and records. Most RDBMS support Structured Query Language (SQL) and are simple to understand, allow multiple users, and minimize redundancy. Its primary disadvantages, however, are inadequate performance and limited scalability at high volumes and variety of data.

NoSQL was created to overcome the shortcomings of RDBMS for the storage of Big Data. NoSQL systems are designed to capture all data, structured and unstructured, without categorizing and parsing it upon entry. The dynamic data structures are extremely scalable and support high throughput for data processing. On the other hand, the system has limited functionality and the complexity of NoSQL requires additional knowledge and skills [7].

Transportation agencies are embracing a holistic, enterprise view that treats data as a core asset.

Teamwork and Collaboration. Data are usually collected by a number of different agencies and are not necessarily compatible. Federal, state, regional, and local agencies need to work together towards a common goal to improve the overall efficiency of the transportation system. Gathering stakeholder input is critical to developing an effective Big Data strategic plan. Through meaningful collaboration, transportation agencies can break down data silos to build a unified view, deliver quality services, and ultimately improve the customer experience.

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Analyze for Insight

***Data Relevance*.** Data relevance is the intersection of data content and user interest. It is based upon enterprise context and determines which data should be included in analytical processes. Data alone are abstract pieces of information; in other words, data may be considered a "what." The transportation agency provides a "why," a motivation or problem statement requiring a solution. By marrying the "what" with the "why," transportation agencies can develop a Big Data strategy that arms data with a purpose.

Types of Analytics. Analytics are designed to economically extract value from Big Data and may be categorized in five general classes:

Descriptive – Summarizes what happened by digesting Big Data into smaller, more useful nuggets of information.

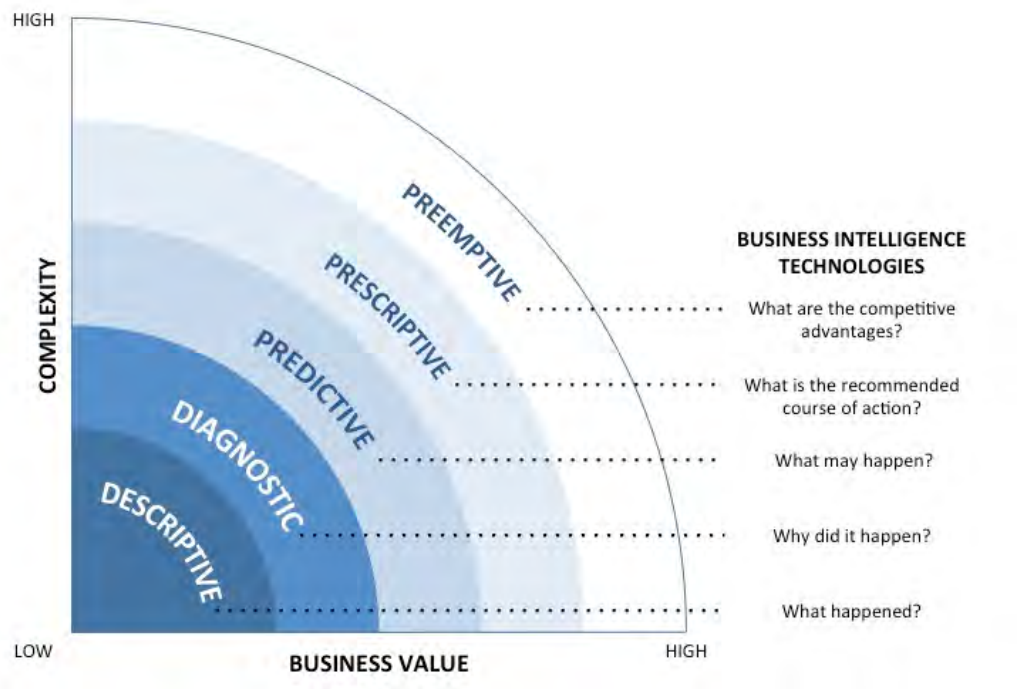
Diagnostic – Identifies the primary and secondary causes for why something happened.

Predictive – Models potential future events using data mining, statistical methods, and machine learning techniques.

Prescriptive – Recommends a course of action based on outcome probabilities using actionable data and a feedback procedure.

Preemptive – Reveals the competitive advantages for a tactical course of action throughout a business ecosystem.

Decision-Support Tools. Executives need to make different types of decisions based upon an understanding of the past (hindsight), present (insight), and future (foresight) of the enterprise. Examples include queries, reports, online analytical processing (OLAP), dashboards, scorecards, and other visualization tools [3]. The key is to match the right tool to the right problem in order to effectively communicate to the decision-maker in a timely manner the best course of action.



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Measure Performance

Key Performance Indicators. A key performance indicator (KPI) is a business metric used to evaluate factors crucial to the success of an organization [8]. KPIs monitor the health of the enterprise and determine whether an agency is achieving its defined goals. The following framework outlines the basic process for developing KPIs:

1. Define the Goal – What is the agency trying to achieve?
2. Establish Performance Measures – How will the agency make progress?
3. Identify the Target – How does the agency define success?
4. Allocate Resources – What does it take to get where the agency wants to go?
5. Monitor and Publish Reports – How successful is the approach and do changes need to be made?

Milestones and Benchmarks. To evaluate whether a program is successful, milestones and benchmarks may be used as targets to provide concrete direction to the agency. *Milestones* are interim achievements that celebrate the progress of a program up to that point; *benchmarks* represent the end result that the agency is striving to achieve.

SAMPLE KPI ELEMENTS

Goal: Improve EMS response time

Performance Measure: Time to reach incident

Target: Eight minutes or less 90% of the time

Resources: Traffic signal preemption

Reports: Dashboard to track performance

Leverage Data to Create Value

Data-Driven Decision-Making. It is not enough to create a Big Data strategy; rather, the agency must commit to data-driven decision-making. To realize organizational gains, Big Data will entail a new culture of management, requiring agencies to educate their leadership, acquire additional talent, and encourage the organization to embrace innovation. In 2012 the MIT Center for Digital Business, in partnership with McKinsey (a management consulting firm), found that companies in the top third of their industry using data-driven decision-making were, on average, 5% more productive, and 6% more profitable than their competitors [9]. Fortunately, many agencies are already data-oriented, and need only exercise the will and leverage the data to create value.

Knowing the customer helps the agency to better serve the customer and the public as a whole.

Customer Relationship Management. Big Data can be used as a Customer Relationship Management tool to coordinate an agency's interaction with current and future customers. By increasing engagement with customers throughout the customer lifecycle, agencies can improve business relationships, strengthen customer loyalty, and boost the positive visibility of the organization.

Incentivize Customer Behavior. Knowing the customer helps the agency to better serve the customer and the public as a whole. Equipped with information, transportation agencies now have the potential to offer incentives encouraging customers to travel during off-peak hours, try other routes, shift to a new mode, or telecommute more frequently. Compounding moderate changes in customer behavior have the potential to create large impacts on the transportation network.

PUBLIC POLICIES & PROGRAMS

National Efforts

Research Initiatives. To accelerate the deployment of innovative practices and realize tremendous operational efficiencies, the White House and six Federal departments and agencies announced in March 2012 a "Big Data Research and Development Initiative" with more than $200 million in new commitments. This initiative promised to greatly improve the tools and techniques needed to access, organize, and glean discoveries from huge volumes of digital data [10].

TechAmerica Foundation's Big Data Commission published a report in October 2012, offering a comprehensive roadmap for the use of Big Data by the Federal government and a set of policy recommendations and practical steps agencies can take to get started on Big Data initiatives. The report envisions that distributed sensors on handheld devices, vehicles, and roadways can provide real-time traffic information that is analyzed and shared [11].

Researchers at the Royal Institute of Technology of Sweden (KTH) wanted to better manage congestion by gathering a wide array of real-time data that might affect traffic patterns. Data from vehicle GPS devices and radar sensors on roadways were collected, along with data on congestion pricing, weather, and visibility; these datasets were channeled into a unique software analytics tool. The data was then used to intelligently identify current conditions and estimate travel times between points within Stockholm, offer travel alternatives, and improve traffic in the metropolitan area. The result was a decrease in traffic congestion and accidents. KTH is now looking to expand the capability to support routing of emergency service vehicles [12].

United States Department of Transportation. Since 2010, the USDOT Intelligent Transportation Systems Joint Program Office (ITS JPO) has been engaged in assessing the potential for systematic and dynamic data capture from vehicles, travelers, and the transportation system infrastructure to enhance current operation practices and transform future surface transportation systems management [13]. The Data Capture and Management Program offers a set of guiding principles and identifies key issues for transforming the federal role. The following candidate applications have been identified as part of the Dynamic Mobility Applications (DMA) Program and are intended to make travel safer, smarter, and greener:

- Enable Advanced Traveler Information System (EnableATIS)
- Freight Advanced Traveler Information Systems (FRATIS)
- Integrated Dynamic Transit Operation (IDTO)
- Intelligent Network Flow Optimization (INFLO)
- Multi-Modal Intelligent Traffic Signal Systems (MMITSS)
- Response, Emergency Staging and Communications, Uniform Management, and Evacuation (RESCUME)

Other Success Stories. The federal government has taken a leadership role in applying Big Data analytics to achieve small and large successes. For example, the U.S. Department of Agriculture reduced the rate of food stamp fraud by 60% using data analytics that quickly identify merchants who traffic them illegally. In the field of imagery, NASA has implemented an online records management tool that benefits the public through state-of-the-art image archiving.

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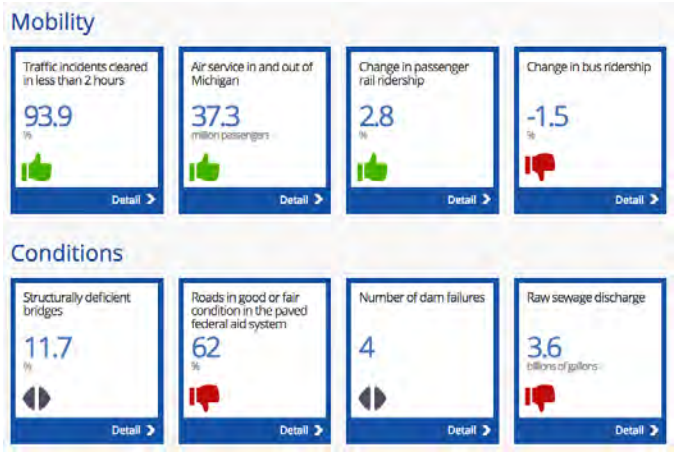
State Movements

Dashboards. A business intelligence dashboard is a data visualization tool that displays the current status of metrics and KPIs for an enterprise. Dashboards consolidate and arrange the most important information in a single view to effectively communicate with the target audience. Customizing the dashboard to address a stakeholder's specific needs is a strategy for strengthening the agency's engagement with the community.

Utah Department of Transportation (UDOT). In March of 2015, UDOT selected Rolta to design and deliver the next-generation Enterprise Data Warehouse for the organization. UDOT will build upon its current dashboard system to communicate information about current interstate travel times, fatalities, construction projects, pavement conditions, and bridge conditions [14].

Virginia Department of Transportation (VDOT). To better connect with the public, VDOT created a performance reporting system for projects and programs. Among typical highway performance metrics, the dashboard includes a unique feature: a citizen survey results section that evaluates how the public views VDOT in terms of roadway maintenance, emergency response, and other categories [15].

***Open Michigan*.** Michigan's dashboards were implemented by Governor Rick Snyder as part of the Open Michigan initiative to provide a quick assessment of the state's performance in key areas, including economic strength; health and education; value for money government; quality of life; infrastructure; and public safety. The infrastructure dashboard includes metrics describing economic growth, safety, accountability, mobility, and conditions [16].



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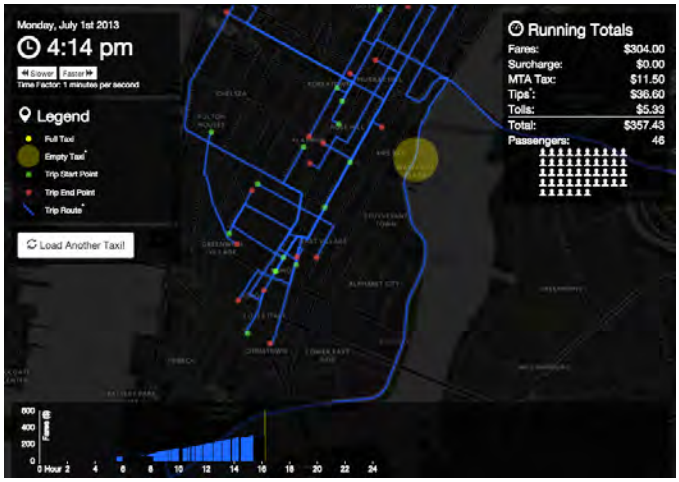
City Initiatives

Open Data Portals. The open data portal is a platform that offers consumers a better way to access and use public information. In an effort to improve transparency, accountability, and interoperability, cities are releasing government-produced, machine-readable data sets through centralized repositories. By engaging with the community, public agencies are enhancing quality of life and the delivery of government services.

The LouieStat Model. Local leadership is acting as a catalyst to jumpstart the open data movement. Led by Mayor Greg Fischer and the chief of the Office of Performance Improvement, Theresa Reo-Wever, Louisville has positioned itself to use data in transformative ways [17]. Fischer signed into law an executive order mandating that data is open by default and launched the LouieStat open data portal in 2012. As a result of the program, drop-off policies were revised and Emergency Management Services delivered 18,000 more patients to the hospital between September and December of 2013 as compared to the same time period in 2012.



Mining Toll Data. Data generated by the E-ZPass toll-paying system is being used to feed other traffic management and analytics applications across New York City [18]. Midtown in Motion is a traffic management program announced by the mayor's office in 2011 that utilizes 100 microwave sensors, 32 video cameras, and E-ZPass readers at 23 intersections to highlight traffic choke points and adjust traffic light timing. The total cost for installation was $1.6 million, with $1 million in city funding and $600,000 in funding from the Federal Highway Administration. NYDOT states the system resulted in a 10% improvement in travel speed and reduced pollution in its first year.

Hackathons. In April 2015, the NYC Taxi and Limo Commission and NYU Rudin Center for Transportation hosted a hackthon. Data scientists, policymakers, and community activists were invited to analyze the 174 million taxi trips from 2013, discover underlying patterns, and collaborate on solutions to local challenges [19]. In particular, several recommendations to address the rush hour taxi problem were proposed, inciting a conversation that resonates in the heart of every New Yorker.

THE POWER OF VISUALIZATION

A new visualization by civic hacker Chris Whong gives users a glimpse into the daily journeys of New York City taxi drivers. The tool traces the route of a random cab as it travels across the boroughs, totaling how many passengers are carried and how much money is earned [19].

BIG DATA CHALLENGES

Financial and Political Barriers

Cost. Enabling Big Data requires hardware, software, and skilled resources. Storage costs are significant and proportional to the volume of the Big Data. The real cost, however, is in the operation and overall management or integration of Big Data within an existing ecosystem.

***Security, Privacy, and Regulatory Compliance*.** Preserving data integrity and public trust are essential for building a Big Data foundation. As part of a vehicle-miles-traveled (VMT) user fee pilot program, the Oregon Department of Transportation (ODOT) created multiple options for drivers to share their mileage. Participants could choose to submit their information through a smartphone app, a GPS device, a reporting device without GPS capabilities, or official inspection [20]. By offering the customer a voice in the data sharing process, ODOT was able to collect vital information at the respective comfort level of the customer.

In order to harness the power of Big Data, agencies need to invest the time to define, learn, and capitalize on valuable information.

Technical Considerations

***Need for Speed*.** Improving hardware systems to explore Big Data volumes and gain business insights in near real-time will enable agencies to remain competitive. Some vendors are using increased memory and powerful parallel processing, while others are putting data in memory using a grid computing approach.

***Data Quality*.** Cleaning or scrubbing data requires time to detect and correct a data set's corrupt or inaccurate information that would otherwise cause errors or skew analytics.

Legacy Systems. Transitioning from traditional database management systems can involve complex and timely processes. Data migration, new workflows, and retraining are some considerations that need to be addressed in order to facilitate Big Data adoption.

Organizational Obstacles

Lack of Organizational Support. Championing the importance of data and embracing new technologies, processes, and workflows are critical to overcoming institutional inertia [21].

***Vague Mission and Goals*.** Developing a unity of purpose is important, helping people to identify the right data and determine how best to use it.

***Unclear Metrics*.** Defining concrete and measurable indicators can minimize ambiguity, focusing the agency's energy on the most important metrics.

Required Expertise. Educating, training, and recruiting executives with a deep understanding of Big Data analytics can transform the way the agency perceives and leverages data for valuable information. With the shortage of technically skilled workers, public agencies will need to invest in developing and diversifying their talent base.

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OPPORTUNITIES FOR TEXAS

Gain Customer Insights

Texas has the potential to gain new insights from data that is already being collected. First, Texas has one of the most sophisticated toll road networks in the country. Can data collected through TxTag, TollTag, and EZ Tag be integrated and shared with local traffic management centers to improve statewide congestion while still ensuring the privacy of its users? Can this information be used to better understand customer travel patterns in order to incentivize behavioral shifts, such as suggesting an alternative route, time of day, or mode choice? Second, TxDOT is already active in social media and collecting information about consumers' interests. Can Facebook, Twitter, and feeds from other platforms be mined in order to improve marketing campaigns and delivery of quality services? Finally, several cities throughout Texas already have open data portals, including Dallas, Houston, Austin, San Antonio, and Denton. Can Texas integrate data from disparate federal, state, and local sources to advance the state economy, education, public safety, energy, and infrastructure?

Embrace Data-Driven Decision-Making

Developing a series of key performance indicators and effectively communicating successes and challenges to stakeholders is a core area in which Big Data can be transformed into information. Dashboards, scorecards, and other visualization tools are effective means for providing executives, policymakers, and the public with valuable information in a format that makes Big Data easy to understand. Equipping decision-makers with timely and accurate information will lead to improved efficiencies, resource management, and cost savings across the state.

Engage with the Community

Empowering the customer with a voice and listening to his or her concerns are small steps that can have large impacts on the transportation network. Beyond traditional methods, civic hackathons are a great forum to invite citizens to collaborate with policymakers, engineers, and software developers and propose solutions to significant challenges. By tapping into the community, transportation agencies can ensure that citizens have a role in shaping the future of their state.

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Formulating a Communications Strategy

White Paper

How the Age of Technology is Transforming Transportation Agencies

How does a transportation agency connect with each of its customers while developing a message that resonates with its stakeholders?

A successful strategic plan requires stakeholder engagement in order to facilitate adoption and implementation. Developing customized communications strategies tailored to specific interests ensures that each stakeholder's contribution is valued. By defining its main objectives, Texas can prioritize its stakeholders and craft a relevant message for each of its audiences.

Transportation agencies can relate to customers on a personal level by identifying everyday transportation challenges that can be improved with technology. By providing valuable and quality customer service in each of these micro-moments, transportation agencies empower their stakeholders to become brand advocates. Developing a clear communications strategy is a first step in signaling that Texas is on the move again, leading the transportation of people, goods, and information.

Formulating a Communications Strategy

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KEY STRATEGIES

Know the Stakeholders

A successful strategic plan requires stakeholder engagement in order to facilitate adoption and implementation. Developing customized communications strategies tailored to specific interests ensures that each stakeholder's contribution is valued.

Build the Agency Brand

Transportation agencies portray themselves through the style represented in their brand, logo, and organization identity. Policies and guidelines on applying brand identity ensure that materials used in all stakeholder communication channels convey a coherent message.

Engage through Multiple Channels

By viewing the transportation experience through the eyes of the customer, transportation agencies can orchestrate the customer experience across all layers so that it is seamless, integrated, and consistent.

Embrace Digital Marketing

Transportation agencies can use digital marketing to strengthen brand awareness, improve engagement, and empower customer advocates. Content marketing in particular can be designed to encourage customers to adjust their travel patterns and behaviors.

Empower Champions of Change

Highlighting current successes and recognizing leaders who are improving the mobility of people, freight, and traveler information for the benefit of all develops a culture of which people feel proud to be a part.

Formulating a Communications Strategy

White Paper

How the Age of Technology is Transforming Transportation Agencies

STATE OF RESEARCH & PRACTICE

Know the Stakeholders

Identify Stakeholders. A successful strategic plan requires stakeholder engagement in order to facilitate adoption and implementation. When identifying stakeholders, it is better to be inclusive rather than exclusive. Below are examples of key stakeholders when considering the advancement and integration of emerging technologies:

- Transportation Officials – USDOT, state DOTs, MPOs/COGs, regional mobility authorities, city engineers
- Policymakers – Federal, state, and local legislators and government officials
- Businesses – Industry leaders, major employers, small business owners, startups, professional societies
- Research Institutions – Universities, private research institutions, public test sites
- Community Organizations – Citizen groups, neighborhoods, and community activists

Each stakeholder may be viewed as an audience. Developing customized communications strategies tailored to specific interests ensures that each stakeholder's contribution is valued. Although this requires additional time, benefits of personalized messages include constructive feedback, emotional connections, effective education, diverse perspectives, proactive problem solving, improved decision making, and engaged stakeholder development.

Developing customized communications strategies tailored to specific interests ensures that each stakeholder's contribution is valued.

***Plan Engagement Activities*.** Effective stakeholder engagement requires advanced planning to ensure the appropriate input to programs and projects is obtained. There are generally three levels of engagement:

- Level 1 – Requires little planning effort; email, word of mouth, newsletters, social media, infographics, promotional items
- Level 2 – Requires some planning effort; press releases, radio, newspaper, television
- Level 3 – Requires detailed planning effort; billboards, charrettes/workshops, websites, mobile applications, major events

Developing the proper meeting format and tools depends on the desired levels of dialogue and interaction amongst participants, as well as the types of outcomes desired.

Strengthen Stakeholder Relationships. Listening is the simplest way to connect with a stakeholder. There are many insights a transportation agency can gain by empowering each stakeholder with a voice. Through interaction and open dialogue, transportation agencies can convey a positive and receptive attitude.

***Deliver and Follow Up*.** It is important to remember that stakeholder engagement does not end at the conclusion of the design phase. Demonstrating that concerns have been genuinely addressed engenders confidence and trust between the stakeholder and the transportation agency. Soliciting feedback is another way to follow up with stakeholders throughout the project process. Learning from positive and negative experiences develops a culture of continuous improvement. Feedback allows a transportation agency to evaluate the overall effectiveness of its efforts and apply that knowledge to future initiatives.

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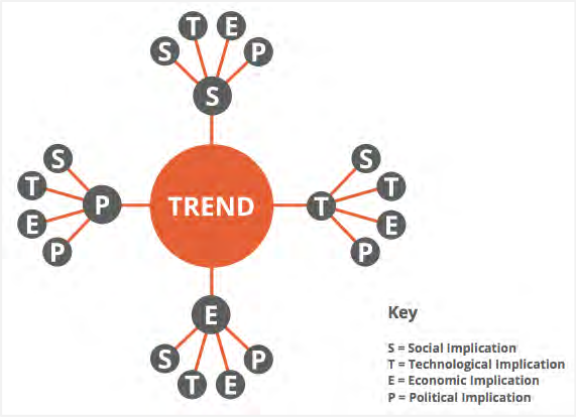
Build the Agency Brand

Brand Recognition. Transportation agencies portray themselves through the style represented in their brand, logo, and organization identity. A brand is more than a logo—it is a promise an organization makes to its customers that must be delivered with every interaction [2]. A consistent use of graphic standards is critical for unity and recognition. Developing policies and guidelines on applying brand identity ensures that materials used in all stakeholder communication channels convey a coherent message.

Unified Campaign. First, the **statement of purpose** is a simple directive that describes the overarching objective of the communications strategy. Next, it is critical to understand the **current strategy** to know what has been successful or unsuccessful in the past. Applying some of the following **analysis tools** can assist in identifying communication challenges and opportunities [3]:

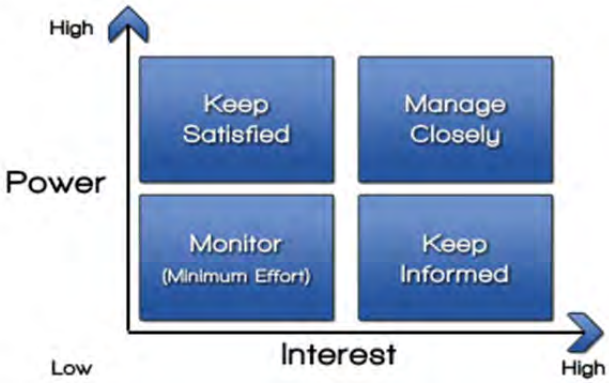
- STEP Analysis – Involves listing the Social (S), Technological (T), Economic (E), and Political (P) factors that may influence the agency's work
- SWOT Analysis – Involves listing the Strengths (S), Weaknesses (W), Opportunities (O), and Threats (T) to the agency's work
- Competitor Analysis – Identifies main competitors and ranks them according to specified criteria, such as strength of brand, media presence, etc.
- Stakeholder Map – Assesses the stakeholders' level of influence with respect to their interest in the agency

Finally, transportation agencies should prioritize their stakeholders and **craft a relevant message** for each of those audiences.



STEP Analysis

SWOT Analysis



Stakeholder Map

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Engage through Multiple Channels

OmniChannel. By viewing the transportation experience through the eyes of the customer, transportation agencies can orchestrate the customer experience across all layers so that it is seamless, integrated, and consistent [4]. OmniChannel anticipates that customers may start in one channel and move to another as they progress to a resolution. Facilitating the transitions so that they are fluid for the customer develops continuity within the communications strategy.

***Website*.** Developing an online presence through an agency website is critical as the basis for a, permanent digital relationship with the customer.

***Search*.** The next digital layer emerged from the development of powerful search engines such as Google. Focusing on the customer's discovery process, transportation agencies can align customers to their desired services and information.

Social Media. Social networks generate another layer of communications and present a new way to connect with customer service. Transportation agencies can take advantage of the opportunities to advertise safety campaigns, promote commerce, and provide service options.

Mobile. Combined with social media, mobile presents an unprecedented opportunity to focus on utility. By providing stakeholders with valuable information in real time, customers can receive traffic alerts or evacuation information and make effective decisions in a timely manner.

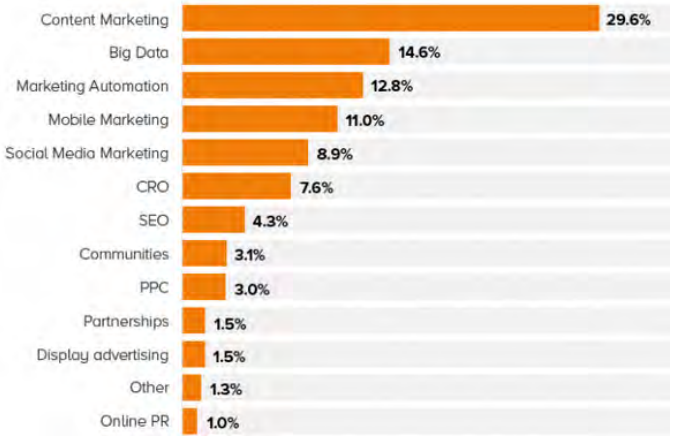
Wearables. Augmented reality, wearable technology, and advanced filters increase the bond between customers and their technology. As individuals become more health conscious, transportation agencies can leverage the trend to promote pedestrian and bicycling initiatives.

Embrace Digital Marketing

Strengthen Content. Content marketing is a strategic marketing approach focused on creating and distributing valuable, relevant, and consistent content to attract and retain a clearly defined audience and, ultimately, to drive positive customer action. B2C Content Marketing found that although social media content is rated the most popular tactic, in-person events are proving the most effective [5]. Transportation agencies can use content marketing to strengthen brand awareness, improve engagement, and empower customer advocates.

***RACE Planning*.** The RACE digital marketing process comprises the following components [6]:

- Reach – Connect with customers to build brand awareness and maximize multiple interactions using different touchpoints
- Act – Encourage website visitors to take the next step by discovering more about the agencies products and services
- Convert – Convince customers to adjust their travel behaviors and alleviate congestion for the whole system
- Engage – Develop a long-term relationship with customers to strengthen stakeholder support and promote open dialogue



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Empower Champions of Change

Celebrate Successes. Highlighting employee, project, departmental, and agency achievements is a positive way to convey success to stakeholders. A good communications strategy will use past success in order to generate momentum to do more in the future. By providing support and encouragement to employees, transportation agencies can develop an organizational culture of which people are proud to represent.

Capture the Micro-Moment. In 2011, Google released an ebook, *Winning in the Zero Moment of Truth*, that helped those in the advertising, search, social, and marketing fields succeed in the early stages of discovery [7]. In 2015, Google followed up by asking, "Right now people all over the world are trying to make the most of every moment—are you there? [8]" Mobile has forever changed the way people live and has forever changed what is expected of brands. The consumer journey has been fractured into hundreds of real-time, intent-driven micro-moments. Transportation agencies should view each one as a critical opportunity for their brand to shape a customer's decisions and preferences.

Achieve Recognition. In October 2015 the USDOT and the White House Office of Public Engagement will host a Champions of Change event focused on "Beyond Traffic: Innovators in Transportation for the Future" [9]. The public is invited to help recognize leaders who are advancing change that will benefit the nation's transportation system at the local, regional, and/or national level. The nominees, to be submitted by August 1, 2015, will be considered for their work in improving the mobility of people, the mobility of freight, overarching strategies for enhancing the transportation system for moving things better, and response to a changing environment.

Immediate Action

Smartphones allow us to act on any impulse at any time. We take immediate action whenever we want to learn, find, do, or buy something [10].

Demand for Relevance

When we act on our needs in-the-moment, our expectations are high and our patience is low. This makes the quality, relevance, and usefulness of marketing more important than ever [10].

Loyal to Needs

Our preferences and behaviors are shaped in these micro-moments. Ultimately, the brands that do the best job of addressing our needs in each moment will win [10].

What is a micro-moment?

A micro-moment is a real-time, intent-driven scenario. For example, people who want to find directions to a local restaurant may reference Google Maps or estimate traffic conditions using Waze. People who want to know which bus to take or when it will arrive may access CapMetro's mobile app. Someone preparing to drive from Laredo through Dallas may follow the @I35Travel Twitter feed for information regarding construction and lane closures. Designing for these new opportunities will prepare transportation agencies to remain relevant in the age of technology.

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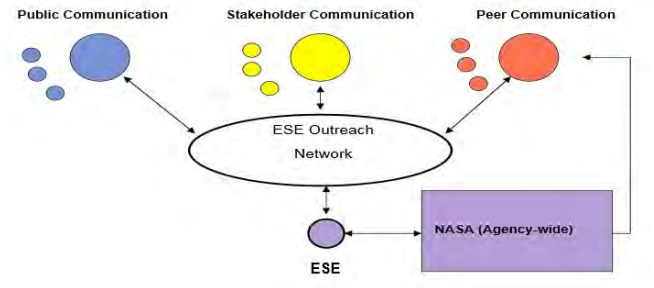
PUBLIC POLICIES & PROGRAMS

National Efforts

Publicly available full communication plans from federal agencies are not abundant, although some do exist. For example, the food and drug administration (FDA) as well as the National Aeronautics and Space Administration (NASA) both publish their complete communication plan [11, 12]. Common content in these plans include identification of agency internal and external stakeholders, lists of communication channels, and primary content to communicate to each stakeholder. The FDA plan also identifies "key trigger events" or events that warrant communication with stakeholders through identified channels. As an example, these include:

- Project/program milestone dates (e.g., initiation, progress, completion)
- External request for agency information or a meeting requiring coordinated and consolidated input from several internal offices or departments
- Agency-wide meetings
- Industry meeting milestones to present updates
- Formation of new teams of divisions
- Updates to standards
- Charter updates

The NASA plan is more oriented toward engaging and communicating with the public rather than focusing on industry stakeholders. It's a cross-department oriented plan that links communication strategies with furthering agency goals and objectives. Communication-specific goals are laid out for each identified target audience (i.e., public, stakeholder, and peer).



The NASA plan also lists each division or center within the agency and identifies the content each is in charge of communicating to the public. The plan recognizes how important public affairs are to its mission and has a section dedicated to coordination with the NASA Public Affairs Office. Conferences are recognized as a special forum for spreading messages from the agency. The plan has a dedicated section for handling communications at conferences. Finally, there is an inventory of current communication programs, channels, or activities.

In the transportation area, the U.S. Department of Transportation does not have a publicly available communication plan; however, the Federal Highway Administration (FHWA) has its own Policy Communications team that manages the FHWA briefing process for department leadership, including the Secretary, Deputy Secretary, and Administrator. The team has developed and maintains an electronic library containing briefing materials. Maintaining this library ensures accessibility and consistency for data and information. This team is also tasked with oversight of the Office of Public Policy and public outreach effort and ensuring quality control for agency reports to Congress, and assists the Congressional affairs team at need.

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State Strategies

State agencies or other large agencies engaging in public communication and outreach will find that NCHRP Synthesis 413 is a helpful resource [13]. This report synthesizes effective strategies that transportation agencies have used to addresses challenges and impacts of construction projects in congested urban corridors. An important finding of the study is that stakeholder communication is a critical component of every urban construction project and that the use of the media has become commonplace in these projects. The report provides strategies for stakeholder and public involvement (speaking, branding, targeting stakeholders, etc.) in Chapter 6 and for Media Relations in Chapter 7 (speaking, media relationships, etc.).

Agency-wide communication strategies may be difficult to come by, but successful project-specific strategies used by transportation agencies are readily available. One example is Arizona, which has a communication and outreach strategy for work zone safety and mobility public information [14]. Another example is the Illinois DOT (IDOT) and its use of many social media outlets to provide information on the reconstruction of Willow Road from IL 93 to IL 94—a multimodal improvement project. IDOT created a project-specific web site, a blog, a Facebook page, a Twitter feed, and an Instagram account to share information and project photos [15].

City Initiatives

The Interstate I-405 full closure in Los Angeles is another notable public information and outreach example. This project dealt with the full closure of both directions of a 10-mile stretch of the I-405 Freeway in West Los Angeles on the weekend of July 16–17, 2011 for 53 hours—an event deemed "Carmageddon." Motorists were warned well in advance of the need to plan ahead, stay home, or avoid the area through English and Spanish public service announcements starring celebrities, coordinated celebrity tweets, news releases and fact sheets, and a count-down clock. It was a joint effort of the Los Angeles Police Department, Los Angeles Fire Department, California Highway Patrol, Los Angeles Department of Transportation, Metro, and Caltrans [16].

COMMUNICATION CHALLENGES

Financial and Political Barriers

A comprehensive public outreach process can be very time consuming, expensive, and require many organizational resources, but a well-executed process can provide many benefits. These include monetary savings, such as reduced user cost through congestion savings, and customer support for projects. Before undertaking a full public outreach process, agencies are advised to complete a cost-benefit analysis that assesses the full cost of the outreach plan and expected benefits due to improved communications.

Technical Considerations

Before embracing digital media for communication and outreach, agencies should consider the user experience across the many devices that consumers use—especially mobile devices. Once users have a bad experience at a site on their mobile device, their likelihood to return may decrease. In addition, agencies should consider how the audience varies at each digital outlet. For example, Twitter users are only 23% of internet users, which is low when compared to Facebook users, who comprise 71% of all internet users [17].

Organizational Obstacles

Getting a message to the public can be difficult when working with reporters outside the organization. Often reporters seek to find controversy or conflict in stories and events as a method for grabbing audience attention. The desire of transportation agencies is to provide positive, inclusive messages through collaboration with outside channels. Smart collaboration requires developing and using shared key messages about agency activities, and cultivating trusted leaders within the organization to be credible spokespeople. The agency will need to maintain working relationships with reporters to create interesting news angles that do not conflict with agency goals.

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OPPORTUNITIES FOR TEXAS

Statement of Purpose

Texas should formulate a communications strategy focused on emerging technologies to achieve the following three objectives:

- Build awareness and engage with key stakeholders
- Improve the customer experience as a service-oriented enterprise
- Become a leader in interconnected and innovative transportation systems

"On the Move Again" Proposal

What do your morning commute, grocery shopping, and directions to the nearest gas station have in common? These are everyday transportation challenges that can be improved with technology.

***Texas Moves People*.** Texans in the state's four most populous cities are spending over 40 hours every year sitting in traffic. That's one full workweek that could be better spent enjoying time with family, having dinner with friends, or reading that book your coworker recommended. Texas transportation agencies are committed to relieving congestion and giving you back your time, but they need your help. Every person, every car makes a difference. So the next time you are preparing to brave the morning commute, instead take advantage of the incentive program and try a different route, take the Express Bus, go in an hour later, or even talk to your employer about working from home once a week. By making these small shifts, you can do your part to improve the transportation system as a whole. In return, transportation agencies will reward you with points at major stores, toll roads, and local restaurants. The greatest benefit though is once again having your time back to do the things that you want. Why sit in traffic if you don't have to?

Texas Moves Goods. Ever wonder how your groceries get to the local grocery store? Supermarkets rely on several distributors to fill their stores with meat, produce, dairy products, baked goods, and other staples. Regional distributors act as "middle men" to provide consistency and ease, ensuring that the shelves are well-stocked and goods are delivered from the inventory warehouse at the exact level of ripeness desired by you, the customer. Many grocers are also experimenting with urban kiosks and delivery services that make shopping even more accessible.

Underlying the operations of a grocery store is a complex logistics network. When there is a traffic accident, icy road conditions, or a hurricane approaching the Gulf Coast, transportation agencies work with distributors and businesses to maintain a quality level of service and to guarantee just-in-time delivery of your goods. By supporting the freight industry through the use of technology and infrastructure, transportation agencies make it possible for distributors to deliver groceries at your convenience.

***Texas Moves Information*.** Have you found yourself driving around downtown searching endlessly for parking? Or looking for the right bus stop to take you home? Through the open data portal, transportation agencies now have the capability to communicate real-time traveler information and answer your most pressing questions. If you find yourself stuck in traffic, mobile notifications will inform you of better options to get you on the move again.

Texas is on the move again, leading the way in the transportation of people, goods, and information.

Formulating a Communications Strategy

White Paper

How the Age of Technology is Transforming Transportation Agencies

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Appendix E: *Update to the Work Plan for the Completion of Strategic Business Plan* (0-6803-01-P5)

0-6803-01-P5

UPDATE TO THE WORK PLAN FOR THE COMPLETION OF STRATEGIC BUSINESS PLAN

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TxDOT Project 0-6803-01: The Technology Task Force

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Performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.	

Table of Contents

WORK PLAN

1. Background

The Texas Department of Transportation's (TxDOT) mission is to provide a safe and reliable transportation system for Texas, while addressing congestion, connecting Texas communities, and becoming a best-in-class state agency. In an effort to help TxDOT achieve its mission, the Texas Technology Task Force (TTTF) was established. The TTTF was formally created in February 2013. After General Appropriations Bill, S.B. No. 1, 83rd Legislature, item 44, VII-31 (2013) was passed, TxDOT and the Task Force were directed to oversee a study on transportation technology. Through guidance from a technology industry expert panel, the TTTF has developed a vision for the future Texas transportation system that furthers these goals via technology-based solutions. The TTTF met from March to August of 2013 (Phase I) to develop a set of recommendations for continuing work in a second phase of a technology study. The recommendations from Phase I are provided in this section; subsequent sections synthesize and discuss work completed in Phase II.

1.1 Phase I of the Texas Technology Task Force

Three objectives were established for Phase I:

1. **Assemble a panel of subject matter experts (SME) drawn from industry and the public sector.** This panel became the TTTF, which ultimately identified key emerging technologies likely to impact transportation over the next 5 to 20 years. Three in-state meetings were held with members between April and July 2013 where they worked to develop a vision and recommendations for furthering emerging technologies.

2. **Convene the Task Force to identify key emerging technologies and outline a path to implementation, addressing policy, economic, and institutional barriers.** Results from the completion of this objective included a list of the key emerging technologies the state should immediately address, preparation of a preliminary analysis of policy, economic, and institutional barriers to be addressed in order to enable and encourage development and adoption of the emerging technologies while minimizing potential negative impacts, and an assessment of the steps necessary to position TxDOT to develop strategies that leverage technology to make transportation safer and more efficient. Based on guidance from the Task Force, three white papers were developed on identified emerging technologies and included details on the state of identified technologies, their applications in Texas, and critical areas for further investigation.

3. **Obtain recommendations for an initial program of work for a public-private consortium and next steps.** The result from objective three included recommendations of initial program of work for public-private consortium that would be supportive of emerging technologies based on findings from first two tasks. It also included recommendation of next steps, continuing research, and further potential legislative and/or policy recommendations.

The following implementation strategies were the Task Force's final recommendations (from Phase I's third objective) and are intended to lay a framework for moving forward toward the vision for emerging technologies in Texas.

- **Incubator** – Create an organization to act as a technology incubator focused on disruptive transportation technologies. The key differentiator for this incubator is the public partnership with TxDOT, where ideas and innovations can be tested and proven in a real-world environment. Technology support services and resources may be offered to emerging technology partners.
- **Public-Private Partnership (PPP)** – Use a range of approaches to create an organizational structure that facilitates economic development in emerging industries via collaboration and coordination among the public, private, and not-for-profit/academic sectors. Such partnerships will create intellectual capital and technology that can be shared to the common benefit or focus on bringing new and evolving technologies to market.
- **Pilot Program** – Conduct a pilot program within Texas to encourage and enable the development of new transportation technologies. The pilot program would collect specific data through testing for evaluating alternatives to the regulations, or create innovative approaches to enhancing safety and ensure that the safety performance goals of the regulations are satisfied for a preselected technology.
- **Legislative and Regulatory Changes** – Identify regulatory and legislative barriers to emerging transportation technologies, and provide guidance on addressing them.

1.2 Phase II of the Texas Technology Task Force

Recommendations from Phase I support the establishment of partnerships and other efforts, which would provide continued support in the pursuit of emerging technology goals. A first step toward partnership and goals is a strategic business plan. Phase II's sole task was to start initial work to create a business plan that would ultimately facilitate partnerships between public and private participants in technology. Such partnerships will be integral to enabling TxDOT's vision of providing a safe and reliable transportation system for Texas, while addressing congestion, connecting Texas communities, and becoming a best-in-class state agency. Phase II of the TTTF project focused on the initial work toward a strategic technology business plan for the state. Additionally, Phase II saw the completion of initial background work for the establishment of the strategic business plan following recommendations from Phase I. The intention is that in later phases of the technology study, the strategic business plan will be completed to fully demonstrate how public and private partners can collaborate in the creation of an economic roadmap to diversify and strengthen the state economy and transportation system though transformative emerging technology adoption. Final contents of the plan will provide an analysis of the state's transportation, information, and communication technology industries, establish state goals and objectives, develop an action plan for implementation, and articulate investment priorities and funding sources.

Preliminary work completed in Phase II includes the following tasks:

- Review of technology development plans
- Development of the work plan to create the strategic business plan
- Environmental scan
- SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis
- Vision and strategy development

1.3 Phase III of the Texas Technology Task Force

The third phase focused on technology discovery and broadening the portfolio of emerging technologies to encompass newly developed ones and those that apply across multiple modes. This phase was conducted over the period of September 2014 to August 2015 with primary tasks including reconvening the Task Force to review and revise Phase I and II work and expanding the list of other highly transformational technologies or integrated systems. New technologies in the portfolio were evaluated using the framework developed in Phase I and new SMEs joined the Task Force to provide insights on new technologies. Using Task Force guidance, critical topics for white paper development were selected and five detailed papers were developed on the following.

1. The Customer of the Future
2. Global Freight and Logistics
3. Small Unmanned Aerial Vehicles
4. Big Data
5. Strategic Communication Planning

Finally, additional work toward the establishment of the Strategic Technology Business Plan was completed and a transition plan for continuing phases was developed.

2. Existing Transportation Technology Strategic Plan

Research and planning activities conducted or ongoing at the national level were reported in Phase I. The most notable federal planning efforts stemmed from partnerships from key agencies, such as the USDOT (U.S. Department of Transportation) and its sub-organizations that include the ITS-JPO (Intelligent Transportation System-Joint Program Office), NHTSA (National Highway Traffic Safety Administration), FHWA (Federal Highway Administration), and RITA (Research and Innovative Technology Administration). New developments arising from national efforts are reported in the next section. In addition, new developments from other states undertaking similar, coordinated efforts to develop an implementation plan for new transportation technologies are reported. And finally, new developments and activities from industry are provided.

2.1 New Developments at the National Level

The NHTSA and the USDOT released a plan for connected vehicle research for vehicle-to-vehicle (V2V) safety application in October 2011 *(1)*. Under this research plan a pilot program in Ann Arbor, Michigan, was established with nearly 3,000 vehicles communicating on public roads using dedicated short-range communications (DSRC) technology, which was a key focus of the pilot program. At the end of the pilot program, which was planned for the end of 2013, the NHTSA stated that it would release a decision on whether to start putting DSRC technology into production cars, or to do more research. Recently the pilot program received a 6-month extension to continue research but has stated that this extension will not change the original plan to release a decision by the end of 2013. NHTSA Administrator David L. Strickland stated that a decision regarding DSRC would still be made in 2013 *(2)*. The decision will come in two parts: the first will relate to DSRC for light-duty vehicles and the second will follow in 2014 and relate to DSRC for heavy-duty vehicles. The decision will state whether it will begin the rule-making process to mandate V2V communication technologies in newly manufactured cars. The implication of such a decision is that it may be the first step towards fully automated vehicles that navigate by internal sensing and communication electronics linked to transportation infrastructure, and communication and database systems.

In December 2013, the ITS-JPO stated that it has organized a new affiliation of DSRC infrastructure device makers, operators of vehicle-to-infrastructure (V2I) installations, and developers of applications that use V2I communications *(3)*. The newly announced affiliation will provide a common technical platform for connected vehicle technology and expand test bed options for users. Its establishment is intended to help ensure that all future connected vehicle applications are based on common implementations of the communications technology. Goals of the new affiliation include the following:

- Exchanging information
- Sharing deployment lessons learned
- Developing a common technical platform
- Expanding test bed options for users

The following seven public, private, and academic institutions have entered into a memorandum of agreement with RITA to be involved in the affiliation of test beds:

1. Arada Systems
2. Southwest Research Institute
3. Detroit Department of Public Works
4. Security Innovation
5. Siemens Industry Inc.
6. Cohda Wireless America LLC
7. University of Michigan

Finally, the Government Accounting Office (GAO) released a report in November 2013 titled "Intelligent Transportation Systems Vehicle-to-Vehicle Technologies Expected to Offer Safety Benefits but a Variety of Deployment Challenges Exist" *(4)*. This report investigated the benefits that could be realized with the adoption of connected vehicles and identified five major areas where challenges exist; these challenges need to be addressed before adoption. Finally, the GAO revealed that a current and ongoing cost analysis is being completed that will look at V2V costs in-vehicle and for the communication security system.

2.2 U.S. State Strategic Plans and Activities

Two notable state efforts are underway: one in Michigan and the other in Florida. The Michigan Department of Transportation, in partnership with the Center for Automotive Research (CAR), completed the Michigan Connected and Automated Vehicle Technology Strategic Plan in July 2013 to leverage testing and research that is ongoing in the state. The plan outlines the motivation for and overview of previous activities and research on emerging transportation technologies, and the state's mission, vision, and goals for autonomous and connected vehicles. The plan laid out measures and strategies, divided into the following themes or focus areas: leadership, safety, customer service, partnerships, system linkages, and efficiency. The plan describes how technologies further the goals of strategic plan and state goals. The appendices contain technical information and other useful and references materials; included are two sections from the *Line of Business Strategy for Vehicle Infrastructure Integration*—Part I: Strategic and Business Plan; and Part II: Specific Goals and Activities *(5)*.

In Florida, the Department of Transportation (FDOT), Tampa-Hillsborough Expressway Authority (THEA), and Center for Urban Transportation Research (CUTR) partnered to host the Florida Automated Vehicles Summit in November 2013. The summit explored issues related to autonomous vehicles and facilitated discussions helpful for creating a framework for implementation of automated vehicles in Florida that will ultimately save lives and enhance mobility. Key focus areas of the summit were automated vehicle technology and prediction of implementation roadmaps, engagement of public and private partners, key regulatory issues to enable the safe deployment of automated vehicles, and the identification of a framework for multi-phased implementation of automated vehicle systems in the state. The summit brought together scholars, elected officials, automobile manufacturers, equipment manufacturers, transportation professionals, trade and industry organizations, and public agencies to create partnerships for moving forward *(6)*.

2.3 Private Sector Technology Strategic Plans and Activities

No official plans from auto manufacturers have been made available, but information about company plans and involvement related to emerging technology has become available through conference proceedings, press releases, and interviews. The following provides an overview of new developments, activities, and announcements from private sector technology and automobile companies.

- Ford *(7, 8)*: Ford Motor Company revealed a glimpse of its newest research vehicle, a Fusion Hybrid designed to test out new autonomous driving technologies. The vehicles reportedly are using a combined Lidar system and 360-degree cameras, similar to Google's technology. Ford also revealed that it is part of the testing effort in Michigan along with State Farm insurance company.
- Volvo *(9)*: Volvo announced a plan that is more aggressive than its competitors' plans: a partnership with Swedish authorities to initiate trial runs of its self-driving cars, which Volvo is calling Drive Me. One hundred specially selected drivers will be given self-driving vehicles, and their commentary and diagnostic information will be fed back to the company for further development of autonomous vehicles. The Drive Me project will be run on every type of roadway, from congested urban center streets to fast-moving freeways, in order to test the cars in all driving scenarios. For Volvo, 2014 will see the introduction of a new user interface and cloud functionality, and a projected rollout is set for 2017.
- Nissan *(10)*: Nissan announced that it will bring multiple self-driving cars to market by 2020. Nissan also announced that the company is relying on partnerships between its own engineers and a number of universities, including Stanford, MIT, Oxford, Carnegie Mellon, and the University of Tokyo, to help create its autonomous driving technology.
- Mercedes and Nokia *(11)*: Nokia has teamed up with Mercedes-Benz to develop smart maps intended to spur the development of self-driving cars.
- IBM *(12)*: IBM entered into a connected vehicle collaboration agreement with Continental, an automotive supply company, to jointly develop fully connected mobile vehicle solutions for car manufacturers around the world.

3. Implications for Texas Transportation Technologies Strategic Business Plan

The review of the current state of the practice in emerging transportation technologies reveals several critical insights for the state of Texas. Table 1 summarizes the status of different technology development aspects, policy, legislation, R&D (research and development), standards, licensing, pilot studies, market and business development, and testing environment.

As indicated in Table 1, the development of emerging transportation technologies has attracted joint efforts from public, private, and academic sectors, investigating many different aspects. These technologies are currently at varying development stages, and not all aspects have been intensively covered in the existing efforts, leaving opportunities and challenges for the state of Texas.

- **Policies and legislations**: The policy and legislation development for the emerging transportation technologies has been primarily led by USDOT and state DOTs. Although the research and development of technology policies and legislations has been an ongoing process in federal and state government, developing a series of promotional policies and legislations for the state of Texas is crucial to the process of eliminating some of the existing institutional barriers facing the development of emerging transportation technologies.
- **Standards and licensing**: Standards and licensing procedures are prerequisites for successfully implementing and managing new transportation technologies. Some of the technologies themselves are still in their development stages and there have been multiple efforts at federal and state levels to design standards and licensing procedures. For Texas, it may be necessary not to initiate the development of a new set of standards and licensing procedures; a preferred method would be to monitor the existing efforts and adopt "well-accepted" standards and procedures. Such a strategy can help avoid the potential compatibility issues seen in the existing electronic toll systems.
- **Technology development**: One mission of the TTTF is to promote technology development and implementation in the state of Texas. These technologies might not have been originally invented or researched in Texas. Meanwhile, many states have deployed technology test sites or testbeds as a strategy of promote technology development in their state. For Texas to stand out among other states in promoting emerging transportation technologies, the real opportunity is to provide an open and supportive environment for technology developers or industry R&D, addressing some of the key barriers that exist in other states (such as lack of financial support, economic instability, legislative barriers to testing technologies, and the lack of data, infrastructure, and facility support).
- **Market and economic development**: A unique mission of TTTF, in addition to promoting technology R&D in Texas, is to spur economic and market development, taking advantage of the vibrant economy, technology foundation, investment opportunities, and the consumer market. Most existing market and economic development strategic plans for emerging transportation technologies have been proposed and executed by private sectors. If TxDOT and state government can facilitate and collaborate with the private sector in creating a healthy, sustainable, and

economically viable environment, Texas will be in a prime position to promote and lead the efforts in technology development.

In response to the current state of the practice, the task force will develop a strategic business plan to provide a roadmap, strategies, and initiatives for future transportation technology development in Texas.

Table 1. Summary of the Representative Efforts in Technology Development Aspects

	Autonomous Vehicles	Connected Vehicles	Electric Systems	Crowdsourcing and Cloud Computing
Policies	USDOT/ NHTSA policy	Under development	Part of US government green energy/ energy security policies *(13)*	U.S. Department of Commerce policy *(14)*
Legislations	3 states passed, 8 states under consideration, 5 states failed	Upcoming USDOT legislative decisions (CV-DSRC)	State and federal promotion legislations	Under development
Technology R&D	Google cars, automobile industry	CV-cellular led by private sectors and academia, CV-DSRC led by USDOT and academia	Battery technologies, electric charging systems	Private industry
Standards	Under development	Safety message communication standards (CV-DSRC), no standards yet for CV-cellular	Under development by the EVSP of ANSI *(15)*	Under development by IEEE, ITU, and NIST *(16)*
Licensing	Under development	Security network framework, under development	Under development with user fee charging strategies	Non-transportation licensing agency: FedRAMP *(17, 18)*
Pilot Studies	Google cars in CA, FL, and NV *(19)*	6 testbeds, 6 safety clinics *(20)*	Charging system pilot studies; highway electrifications pilots	Limited in planning and transportation agencies
Market Development	Private sector efforts	Joint private and public sector efforts	Established EV market	Efforts led by IT companies and private industry
Consumer Products	In 3–5 years by Google *(21)*	Full-CV products under development	Charging and electrification systems	IBM and Cisco system, WAZE mobile app

Acronym Guide:

- CV-DSRC: connected vehicle using DSRC; CV-cellular: connected vehicle using cellular technology; Full-CV: fully connected vehicle; EV: electric vehicle
- EVSP: Electric Vehicles Standards Panel, ANSI: American National Standards Institute, IEEE: Institute of Electrical and Electronics Engineers, ITU: International Telecommunication Union, NIST: National Institute of Standards and Technology; FedRAMP: Federal Risk and Authorization Management Program

4. Work Plan for Developing TTTF Strategic Business Development Plan

The work plan for developing the TTTF strategic business plan includes three major research stages: background research, strategy development, and roadmap and execution plan. Each phase consists of several subtasks to produce the corresponding sections in the final business plan.

4.1 Background Research

The background research for business plan consists of a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis, industry impact analysis, economic analysis, and environmental scan.

Task 1: SWOT Analysis

SWOT analysis is a structured planning method used to evaluation the strengths and weaknesses of, opportunities for, and threats to a project or business venture. It involves identifying both internal and external factors that are favorable or unfavorable to the objective of a project.

- **Strengths**: *The characteristics of a business or project that give it an advantage over others.* In the case of this project, the strength analysis will focus on the major advantages possessed by the state of Texas, TxDOT, and the related transportation and information technology industry compared with other states.
- **Weaknesses**: *The characteristics that may position a project or business at a disadvantage.* TTTF will focus on analyzing the existing barriers for technology development such as technology limitations, organizational issues, funding and resource limitations, institutional barriers, and public relations and education.
- **Opportunities**: *Elements that the project or organization may take advantage of.* In the context of transportation technologies in Texas, TTTF will explore key opportunities in different aspects of transportation technology development such as policy, legislative, funding, and collaborative opportunities.
- **Threats**: *Elements in the environment that may bring trouble for the business or project objective.* TTTF will focus on identifying existing efforts by the USDOT, other state DOTs, and private sector entities so that Texas does not waste resources repeating the previous efforts. Meanwhile, external factors such as federal policies, legislation, regulations, and compatibility with technologies in other states may also be evaluated for potential threats.

Since emerging transportation technologies are at varying maturity levels and have significantly different development needs, individual SWOT analyses are required for each targeted transportation technology.

Task 2: Industry Impact Analysis

This task evaluates the industry and economic impact of developing new transportation technologies in Texas. The targeted industries include but are not limited to the transportation, automotive, energy, information technologies, telecommunication, logistics, and financial services industries. The industry impact will be evaluated in the following steps:

- Needs assessment for emerging transportation technologies.
- Related outcomes/products/services by emerging transportation technologies
- Transportation technology development scenario projection
- Impact assessment under different scenarios
- Summary of the overall impact and strategies

More specifically, the industry impact may include the contributions of new transportation technologies to the advancement of technologies, knowledge, and experiences, operational efficiency, new consumer products, and new market development.

Task 3: Economic Impact Analysis

The economic impact analysis produces a critical section in the strategic business plan. Based on the outcomes of Task 2, the economic impact analysis further quantifies the impact of different emerging transportation technologies on the Texas economy. To account for the potential direct, indirect, and induced impact of new transportation technologies on Texas economy, the following indicators may be used in economic impact analysis:

- Budgeting and forecasting
- Return of investment
- Job creation and employment
- GDP (gross domestic product) contribution
- Market creation and expansion
- Production cost savings
- Congestion cost savings
- Life/property damage savings
- Energy savings

Tools and methodologies to be used for economic impact analysis can be classified into two major categories: transportation economic impact assessment toolboxes and general economic impact analysis tools. The USDOT and the FHWA have developed multiple transportation economic impact analysis tools, such as STEAM, BCA.NET, and MicroBENCOST *(22)*. In the economics sphere, generalized economic impact analysis tools such as RIMS II *(23)* are also available.

Task 4: Environment Scan

As an extension of the SWOT analysis, the environment scan identifies several lists of stakeholders and resources that influence the internal and external factors found in SWOT analysis. In this project, the task force is interested in identifying the following entities and resources related to new transportation technology development.

- Internal Environment:
    - In-state transportation or non-transportation government agencies that may affect or contribute to the development and implementation of emerging transportation technologies
    - In-state private companies with potential interest in joining the development program
    - In-state funding and investment companies and organizations interested in technology development
    - In-state academic institutes interested in contributing to the state of research and practice of new transportation technologies
- External Environment:
    - National and federal government agencies and organizations that lead or promote new transportation technologies
    - Out-of-state DOT research centers and organizations
    - International technology development organizations or government agencies

By identifying those specific resources and entities, the task force can most fully address and assess the benefits, opportunities, and challenges in new transportation technology development within the context of the business plan.

4.2 Strategy Development

With the background research conducted in the previous phase, the main purpose of this phase is to complete the sections in the business plan regarding technology development strategies, which includes the development of vision, goals, and detailed strategies.

Task 5: Vision, Mission, and Goals Development

The key of this task is to develop the vision, key missions, and goals for the proposed technology development program in Texas. The vision should incorporate the perspectives from latest long-term highway authorization, MAP-21(Moving Ahead for Progress in the 21st Century) *(24)*, as well as the state and TxDOT strategic goals. The key missions will be developed closely related to the specific visions developed. Program goals will be developed by specifying criteria for determining the success of the transportation technology development.

Task 6: Strategy development

Based on the outcome of Task 5, this task will result in detailed development strategies. Strategic areas to be considered may include funding and investment strategies, organizational structures and procedures, PPP strategies, service offering strategies, client selection strategies, evaluation and pilot testing strategies, legislative- and policy-supporting strategies, and public relation and education strategies. The strategic development will lead to key business initiatives and subsequent policy research to be conducted in future phases of this project.

4.3 Roadmap and Execution Plan

With the completion of strategic development in the previous phase, in this phase the task force will focus on creating roadmaps and a work plan towards achieving the established vision and goals of transportation technology development in Texas.

Task 7: Roadmap and Work Plan

In this task, the task force will develop short-term, mid-term, and long-term roadmaps that consider the inherent uncertainty in resource availability and technology innovations. The short-term roadmap will focus on achieving the most urgent tasks and initiatives to jumpstart the transportation technology development in Texas. The medium-term roadmap will cover the strategic steps towards the large-scale testing and pilots. The long-term roadmap will provide perspectives on addressing the implementation and preparation for new technology breakthroughs. The overall work plan also includes specific work plans for key initiatives, such as creation of the public-private consortium and testing platforms.

Task 8: Organizational Structure and Staff Plan

To ensure the execution of the developed work plan in future phases of the project, the development of an efficient organizational structure and staff plan is critical. The task force will specify the detailed organizational structures, staff requirement, internal boards and responsibilities, work flows, legislation and bylaws, and other aspects to ensure the key initiatives of the project can be carried out.

5. Timeline and Schedule

The development of the strategic business plan is expected to require 18 months. The detailed timeline is summarized in Table 2.

Table 2. Timeline of the TTTF Strategic Business Plan Development

FY	FY 13			FY 14		
Month	**1–2**	**3–4**	**5–6**	**7–8**	**9–10**	**11–12**
Task 1*						
Task 2						
Task 3						
Task 4						
Task 5*						
Task 6*						
Task 7*						
Task 8*						

*Indicates tasks with preliminary research conducted in the previous and current phase of the project.

APPENDIX I. Business Plan Creation Process

PRELIMINARY BACKGROUND RESEARCH

SWOT (Strengths, Weaknesses, Opportunities, Threats) Analysis

The preliminary SWOT analysis for Texas transportation technology development focuses on general social needs as well as economic, policy, legislative, and funding aspects. The task force attempted to identify the unique characteristics that differentiate Texas from other states. The insights of the general SWOT analysis form the basis for the more detailed, technology-specific SWOT analysis to be conducted in the next phase of the project.

Strengths

- **Innovation propelled by transportation needs:** Texas is the second-most populous state in the U.S. with four major metropolitan areas. The state suffers from the ever-increasing travel demand that leads to significant safety, congestion, and energy issues in transportation systems. The land use limitations in urban areas make it impossible to address those issues by simply expanding the existing transportation infrastructures. The state calls for new technological innovations that can alleviate those issues by maximizing the potential capacities in the existing infrastructures.
- **Economic strength:** The Texas economy stayed strong during the recent economic recession. The strong economy makes Texas attractive to investors and start-ups looking for sites with long-term economic stability. This stability is crucial for developing new transportation technologies such as autonomous vehicles, connected vehicles, and electric vehicles that need not only a large consumer base but also a sustainable economy that can support technological innovations.
- **Technology development:** Texas is the home of high technology companies such as Dell, Texas Instruments, AT&T, AMD, Google, Apple, Samsung, etc. NASA's Johnson Space Center and Lockheed Martin's *(25)* aeronautics division are both located in Texas. Texas has also provided generations of researchers and engineers through its large and successful university systems.
- **Government strength:** The state government in Texas has tremendous leadership and solid organizational structure. As one strong component of the state government, TxDOT has a vital interest in investing in transportation infrastructures and is aggressive in addressing transportation issues. Meanwhile, the distributed structure of TxDOT ensures that transportation issues can be addressed with localized methods and solutions.
- **Tradition of funding and investment:** Texas has a tradition of supporting technology innovations, transfer, and commercialization. Texas has multiple technology incubator and accelerator programs that have assisted many young talents in converting their ideas into successful business.

Weaknesses

- **Decline in public funding:** Due to the conservative taxation policies and the increase of automobile fuel efficiency, Texas highway funding continues to decline even though the infrastructure and operational needs are increasing over the years.
- **Decentralized government structure:** Although the decentralized organizational structure provides flexibility for each district in addressing local transportation needs, it does create barriers to the testing and implementation of new transportation technologies across the state.
- **Auto-centric society:** Texas has long been an automobile-centric state with passenger vehicles dominant among other, more sustainable public transportation modes. Although this scenario provides a robust testing environment for vehicle-based technologies such as connected and autonomous vehicles, it can create barriers to the testing and implementation of emerging sustainable transportation solutions inspired by new transportation technologies.
- **Resource limitations:** With the increasing population, Texas also faces resource limitations, especially in terms of water and energy. Such limitations may discourage certain technology development that relies on those resources.

Opportunities

- **National and international technology trend:** TTTF was established in light of the latest wave of innovative transportation technologies triggered by the progress in information, communication, and automobile technologies. If appropriately positioned, Texas can take advantage of the current wave and be among the leading states in developing and implementing those new technologies.
- **Forward-thinking government:** The state government's willingness to promote new technologies and innovative funding strategies, such as PPPs, drives the development and implementation of new transportation technologies.
- **Outbreaks of transportation issues:** Traffic congestion issues in Texas cities over the recent years have significantly worsened and drawn a lot of attention from the general public. Such attention can serve as strong motivations for the introduction and adoption of emerging transportation technologies.
- **Stakeholder support:** The initial conversations between the task force and stakeholders in transportation technology development—including the public, private, and academic sectors—revealed strong interest in participating in and contributing to the program.
- **Economic development in technology development:** A unique opportunity for Texas to excel in the technology development is the ability to combine technology development with long-term economic development. By combining these two aspects, Texas can be at a prime position to attract technology developers, investment, and collaborations.

- **Existing USDOT efforts:** The USDOT has been leading the research, pilot, and policy development for DSRC-based connected vehicle technologies. The NHTSA has also been leading the legislative efforts towards the implementation of connected vehicle devices and the testing of autonomous vehicle technologies. Those efforts can provide the foundation for Texas to develop its own technology development strategies.
- **Lessons learned from other state DOTs:** Many state DOTs have also pursued technologies such as autonomous and connected vehicle technologies and made available significant documentation of the lessons learned in promoting those technologies. Texas can take full advantage of the past experiences and identify a feasible and suitable path for technology development.

Threats

- **Duplication of existing efforts by the USDOT, other state DOTs:** These entities have devoted a great deal of resources to technology research, testing, standardization, and policy research. Texas should not try to replicate those efforts.
- **Private industry R&D development:** Many private companies in the automobile or IT industries have their own R&D agenda and facilities. They are not necessarily interested in collaborating with public agencies if the TTTF cannot significantly assist with their R&D agenda.
- **Legislative barriers:** At the national/federal level, the USDOT may create legislative or policy barriers if milestone decisions, such as the enforcement of DRSC devices and the promotion of public testing of autonomous vehicles, are made according to the original agenda *(2)*. Meanwhile, the related legislative decisions from other state DOTs may also cause confusions and debates for similar technology-related decisions in Texas.
- **Compatibility issues with other states:** Another potential threat is related to the R&D of major emerging transportation technologies: simultaneous technology development efforts may lead to compatibility issues among different systems, similar to the issues that have arisen with electronic tolling systems.

Technology Evaluation Matrices for Preliminary SWOT Analysis

Since transportation systems are complex and embody varying goals and barriers across various modes and user groups, a multidimensional evaluation framework is needed to understand how technologies could impact the system across multiple dimensions and is an initial step for the SWOT analysis. It begins by assessing performance of transportation systems, which requires consideration of safety, mobility, environment dimensions, etc., and along each dimension, measurable and quantifiable indicators are needed. The remainder of this section focuses on a framework that allows for an analysis of the technology across multiple dimensions.

Step 1. Framework Definitions: This framework starts off by defining all technologies within the portfolio in need of evaluation in the SWOT analysis.

- ***Autonomous Vehicles,*** which may include specific applications in the following areas: autonomous freight technology, platoons, and pilots; personal autonomous vehicles including neighborhood/low speed and non-neighborhood vehicles; commercial uses (taxis); and autonomous parking in urban cores. For the evaluation process, these are broken into two categories: levels one and two automation and levels three and four automation.
- ***Connected Vehicles,*** including current and prospective applications, trials, and pilots; V2I implementation/wrong-way driver detection; and studies of human behavior and driver interface with CV applications. For the ranking process, these are broken into two categories: vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) technologies.
- ***Electric Vehicles and Systems,*** including smart highways, solar highways, or roadway energy storage and transmission; battery technology; distributed nuclear energy; alternative fuels, inductive charging or wireless energy transfer; DC fast charging systems, and smart grids.
- ***Unmanned Aerial Vehicles (UAV)*** including surveillance applications and logistics.
- Information and communication technologies, including ***cloud computing*** with big data, distribution and analysis (automotive cloud), and super-fast computing for V2I, and ***crowdsourcing****, which* includes smartphone applications and surveillance or emergency management examples and applications.
- ***Infrastructure and construction technologies,*** including infrastructure enhancements such as fiber optics and ITS technologies, and construction techniques and equipment (such as truss sliding and vacuum consolidation).
- ***Materials,*** including self-healing pavements and nanotechnologies.
- Additive manufacturing for vehicles and infrastructure (***3D printing***).
- Service-based technologies, which are divided into the following: ***location-based services*** (e.g., ridesharing and social networking applications for transportation) and ***transportation subscription services*** (e.g., shared vehicle fleets).

These technologies are carried forward into Step 2, which is described in the next section.

Step 2. Technology Assessment: Step 1 resulted in an initial technology list, which became the initial technology portfolio. Step 2 was designed to assess individual technologies, as a basis for comprehensive evaluation for selecting preliminary critical technologies for further inspection. The assessment focuses on four primary dimensions:

- **Strategic Goal Alignment:** Ability to meet or further national and state transportation goals, which mainly consists of safety, congestion, and environment.
- **Deployment Barriers:** Presence of barriers to adoption and implementation, which include the regulatory, cost-effectiveness, and safety aspects.

- **Mode-Specific System Enhancement**: Ability of technology to improve transportation in different modes, which cover not only highway traffic, but also bicycle/pedestrian, freight, transit, aviation, port, etc.
- **User Group Enhancement:** Ability of technology to enhance or improve transportation user group experience. User groups will closely align with trip purpose and mode combinations. For example, passenger vehicle travel for home-based work trips may use technologies differently than passenger vehicle trips for leisure travel, or interregional freight travel may receive benefits from technologies that are different for intraregional freight travel.

For each evaluation, each member of the research team was asked to rank technologies in matrix of technologies across columns against each evaluation dimension (rows) on a scale from zero to five. Each integer on the ordinal scale corresponded to each individual's belief about how each dimension represents each technology, with lower values indicating less relevance in a dimension and higher values indicating more relevance. For example, when considering the benefits that lower levels of vehicle automation could have on travel, a rank of zero would indicate no benefit and a rank of five would indicate a monumental impact on travel. A full summary of assessment along these four dimensions and corresponding factors considered are listed in Tables 1a-d. After individual rankings, results from each team member are to be combined to form one final set of evaluation matrices to reflect the consensus of the team.

The final combined rankings will be used to inform a trade-offs analysis to compare technologies along common dimensions. The final evaluation (radar chart) allows for the assessment and comparison of technologies along various dimensions so that a final set of critical technologies may be chosen for further analysis in subsequent steps. A diagram of this full ranking and combining process is shown in Figure 1.

Table 1a: Factors in ranking considerations for goals evaluation

Proposal Goal	Factor Consideration
Economic development	• Quantity and quality of jobs directly created in Texas
Safety	• Crash frequency reduction • Crash severity reduction
Congestion	• Decreased hours of congested travel • Improved traffic flows during congestion • Improved travel time reliability
Connect Texas communities	• Enhanced access to goods and services • Increased Texas gross state product • Public relations and dissemination of information to Texas communities
Best in class agency	• Agency able to deploy resources more efficiently
Infrastructure condition	• Direct improvement to infrastructure condition • Indirect improvement to infrastructure condition
System reliability	• Improved system efficiency
Environmental sustainability	• Reduced fuel and energy consumption • Reduced air pollutant emissions, to meet EPA standards
Reduce project delivery	• Reduced project delivery delays due to shortened time during construction

Table 1b: Factors in ranking considerations for barriers evaluation

Proposal Issues & Concern	Factor Consideration
Institutional	• Internal public transportation agencies changes • Potential new agency positions and duties • Technology standardization and coordination • Cross-agency and private institution collaboration
Infrastructure	• Extent of new infrastructure required • Existing infrastructure repurposed
Regulatory	• Legislative regulatory changes (may be helpful or necessary) • Administrative regulatory changes (may be helpful or necessary)
Policy	• Public agency direction and support
Cost, public	• Direct public agency costs
Safety	• New crashes or incidents otherwise avoidable • Increased crash or incident severity • Electronic security vulnerabilities
Energy	• Energy consumption of new technology greater than potential savings
Public concerns	• Disparate impacts across income groups • Privacy concerns • Neighborhood concerns • Other non-safety or energy concerns
Cost, private	• Consumer technology purchase costs • Corporate technology development costs
Time (develop & deploy)	• Timeframe required to complete phase after entering
Technology	• Technical barriers technology development

Table 1c: Factors in ranking considerations for modal enhancement evaluation

Mode	Factor Consideration
Surface Transportation **Transit** **Freight** **Ports, marines, waterways** **Air/Aviation**	• Increased safety • Increased mobility • Decreased cost on system • Operations and maintenance benefits

Table 1d: Factors in ranking considerations for user group enhancement evaluation

Mode	Factor Consideration
Freight (interregional) **Freight (intraregional)** **Personal (commute)** **Personal (Recreational)** **Emergency** **School/students**	• Increased safety • Increased mobility • Decreased cost on system • Operations and maintenance benefits

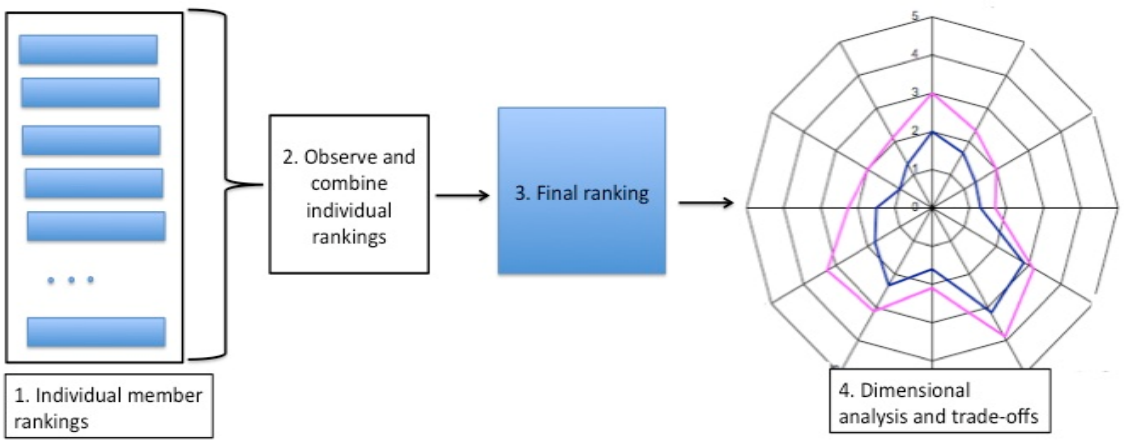


Figure 1: Overview of technology assessment

Step 3. Portfolio Assessment: This third and final step, which will be carried out during the next stage with the help of the TTTF, will take a deeper, more technical look into the technologies and build on Step 2. Due to resource limitations, agencies need to strategically allocate the available resources to technologies under consideration. As a final step, a comprehensive portfolio assessment framework will be used next to gain a deeper, more technical understanding of the technologies. The key difference between this step and the previous ones lies in a more comprehensive perspective—based on the attributes of and forecasts for individual technologies, we consider the technology life cycle; short- and long-term institutional, technological, and economic uncertainties; and the synergy of technologies. To be specific, we will examine the following aspects:

- **Technology Life Cycle:** This analysis will provide a better understanding the development phases and trajectory of technologies, and highlight opportunities for synergy. Life cycle curves will be used to visualize the evolution phases of technologies.
- **Scenario Generation:** The team will forecast possible technology adoption scenarios for the analysis of portfolio benefits in safety, congestion, and environment.
- **Technology Synergy:** This analysis will formally analyze the synergy effect that can be realized by pairing technologies. The possibility of synergy and potential benefits will be analyzed together.
- **Performance Metrics:** Different portfolios will be compared to select and prioritize individual technologies within the portfolio. Three sub-steps will be taken:
    - Convene the Task Force and use Delphi-like process to further rank the technology portfolio and obtain feedback from TTTF members.
    - Combine individual Task Force input to support development of critical list.
    - Select technologies based on highest rankings among technology-dimension intersections weighed against Task Force member input.

The above steps constitute a tentative evaluation framework to apply to the technologies in the portfolio. The framework is intended to be illustrative, as it will become refined continuously based on Task Force guidance. The completion of this analysis will inform the final SWOT analysis.

Observations from Application of Step Two: Technology Evaluation

Observations on strategic goal alignment

For each of the technologies on the radar chart, the total area was calculated with the idea that technologies that align more closely with goals would have larger coverage areas. The total area (area score) is shown in the final row of each matrix. The technologies with the highest area score were ***vehicle-to-infrastructure technologies*** (47.7), ***cloud computing*** (48.4), ***crowd sourcing*** (40.3), ***transportation subscription services*** (40.0***), location-based services*** (32.9), and perhaps ***automation levels three and four*** (32.2). Electric systems technologies show the lowest alignment with goals overall even though it ranked the highest in the environmental sustainability dimension.

Observations on deployment barriers

The results of technology barrier rankings are shown in Figure 2a-d. In the interest of minimizing barriers for transformative technologies, those with low area scores are highlighted. The lowest scores were for ***automation levels one and two*** (10.3), ***crowd sourcing*** (14.5), ***materials*** (18.7), ***transportation subscription services*** (19.8) and ***vehicle-to-vehicle technologies*** (19.1). Note that crowd sourcing, transportation subscription services, and location-based services showed high goal alignment and simultaneously low barrier to implementation. Note that technologies that are less transformational and unlike any existing technology have higher barriers to overcome, whereas technologies with marginal enhancements over existing ones face lowers barriers to adoption and diffusion.

Observations on mode-specific system enhancements

Results from the modal enhancement analysis show that ***automation of all levels***, connected vehicles (***V2V and V2I***), and ***cloud computing*** provide the most benefit across modes with area scores as follows; automation levels one and two (31.5), automation levels three and four (37.5), V2I (31.5), V2V (37.5), cloud computing (34.3). For surface transportation, location-based services and transportation subscription services would also greatly enhance travel. For transit, the same is true. For freight, automation and connected vehicles showed the most enhancements along with the diffusion of 3D printing, which could have great impact on freight travel. For ports, marines, and waterways, the greatest enhancements could come from automation levels three and four, vehicle-to-infrastructure technologies, cloud computing, and infrastructure and construction enhancements. Finally, the single largest impact on air and aviation could be seen from UAVs/drones.

Observations on user group enhancements

Results of the user group enhancement rankings show that all levels of ***automation, connected vehicles, cloud computing, crowd sourcing, and location-based services*** have the greatest ability to enhance travel across user groups with area scores as follows; automation levels one

and two (36.8), automation levels three and four (49.5), V2I (33.6), V2V (46.0), cloud computing (31.1), crowd sourcing (34.6), and location-based services (31.8).

Ratings 0-5: 0 = Does not address goal, 5 = Disruptively beneficial solution

		Autonomous Vehicles		Connected Vehicles			Information and Communication							
Goals		A1/A2	A3/A4	V2I	V2V	Elec. Sys	UAVs	Cloud Comp.	Croud Sourcing	Infrastra. & Const. Enhance	Materials	3D Printing	Location Based Services	Transp. Subscription services
Texas Goals	Safety	5	5	5	5	1	2	4	4	3	4	3	3	3
	Congestion	2	4	4	4	1	3	4	5	3	2	3	4	5
	Connect TX communities	2	4	3	4	1	3	5	4	2	1	3	5	5
	Best in class agency	3	4	5	3	2	3	5	4	3	4	3	4	4
Other National Goals	Infrastructure condition	3	2	5	2	2	5	4	4	5	5	3	2	2
	System reliability	3	3	4	4	1	4	4	4	4	4	3	3	4
	Environmental sustain.	3	3	4	3	5	3	4	3	3	4	3	3	4
	Reduce proj. delivery	2	2	3	2	2	3	3	2	3	2	4	3	3
Area Score		22.3	32.2	47.7	31.8	9.5	30.4	48.4	40.3	30.4	30.4	27.6	32.9	40.0

Ratings 0-5: 0 = No Barrier, 5 = Barrier likely insurmountable in

	Autonomous Vehicles		Connected Vehicles				Information and Communication						
Barriers	A1/A2	A3/A4	V2I	V2V	Elec. Sys	UAVs	Cloud Comp.	Croud Sourcing	Infrastra. & Const. Enhance	Materials	3D Printing	Location Based Services	Transp. Subscription services
Institutional	1	4	3	2	2	4	2	2	3	2	3	3	3
Infrastructure	1	4	3	2	3	2	3	1	3	3	2	2	2
Regulatory	2	4	2	3	2	5	3	3	1	1	4	4	3
Policy	2	4	3	2	2	4	3	3	3	2	3	4	4
Cost, public	4	2	3	2	4	1	3	2	4	4	4	2	2
Safety	2	4	3	4	2	4	2	2	1	2	2	2	2
Energy	1	1	2	1	3	1	1	1	3	1	1	1	1
Public concern	1	4	3	4	2	5	3	3	2	2	2	2	2
Time (develop and deploy)	1	4	2	3	3	3	2	2	3	4	3	2	2
Technology	1	4	1	2	4	2	2	2	2	3	3	2	2
Area Score	10.3	42.4	24.4	19.1	23.0	31.5	21.2	14.5	21.6	18.7	25.1	21.9	19.8

Ratings 0-5: 0 = No benefit to mode, 5 = Greatly benefits travel/operations on mode

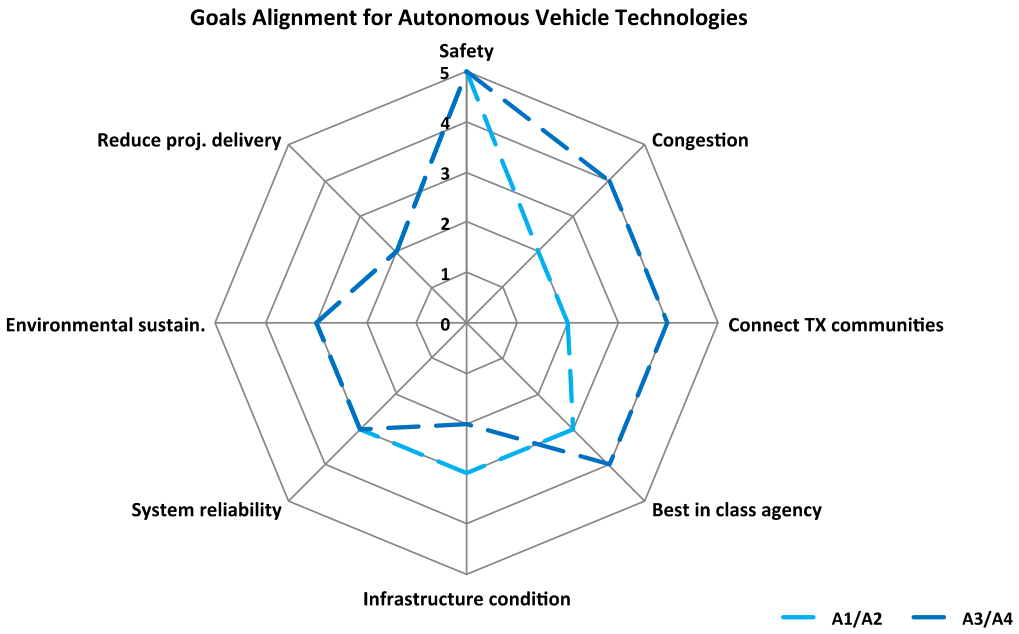
	Autonomous Vehicles		Connected Vehicles				Information and Communication						
Modal Enhancements	A1/A2	A3/A4	V2I	V2V	Elec. Sys	UAVs	Cloud Computing	Croud Sourcing	Infrstra. & Const. Enhance	Materials	3D Printing	Location Based Services	Transportation Subscription services
Surface Transportation	5	5	5	5	3	3	5	5	4	5	3	5	5
Transit	5	5	5	5	5	2	5	4	4	2	2	4	4
Freight	5	5	5	5	3	4	4	4	4	4	5	3	1
Ports, Marine, Waterways	3	4	3	4	1	2	4	2	4	3	3	1	2
Air/Aviation	3	4	3	4	2	5	4	1	4	2	2	1	2
Area Score	31.5	37.5	31.5	37.5	14.5	16.6	34.3	18.0	28.3	16.3	15.2	14.5	14.1

Ratings 0-5: 0 = No benefit to user group, 5 = Greatly benefits travel/operations for user group

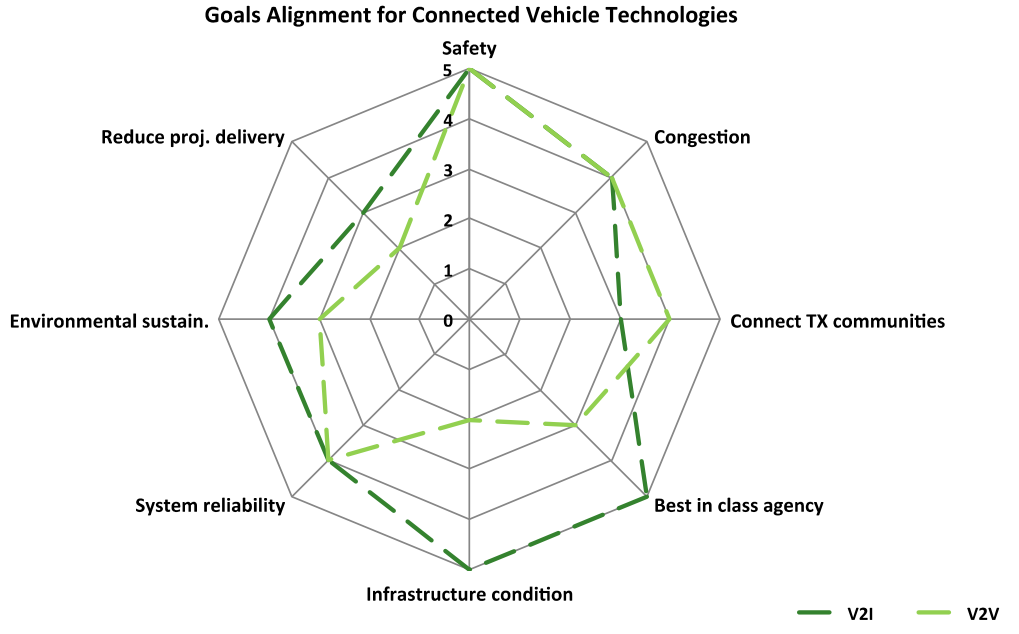
	Autonomous Vehicles		Connected Vehicles				Information and Communication						
User Group Enhancements	A1/A2	A3/A4	V2I	V2V	Elec. Sys	UAVs	Cloud Computing	Croud Sourcing	Infrstra. & Const. Enhance	Materials	3D Printing	Location Based Services	Transportation Subscription services
Freight (interregional)	4	5	4	5	2	4	4	3	3	3	3	3	2
Freight (intraregional)	4	5	4	5	2	2	4	3	3	3	4	4	3
Personal (commute)	4	4	4	5	4	1	4	5	4	4	3	5	5
Personal (Recreational)	4	5	4	5	3	2	4	5	4	4	2	5	5
Emergency	4	5	5	5	2	4	4	5	3	3	2	3	2
School/students	5	5	3	3	3	2	3	3	2	2	2	3	4
Area Score	36.8	49.5	33.6	46.0	14.8	12.7	31.1	34.6	21.6	21.6	15.6	31.8	25.5

Figure 2 (a-d): Matrix Evaluation Results for Four Dimensions

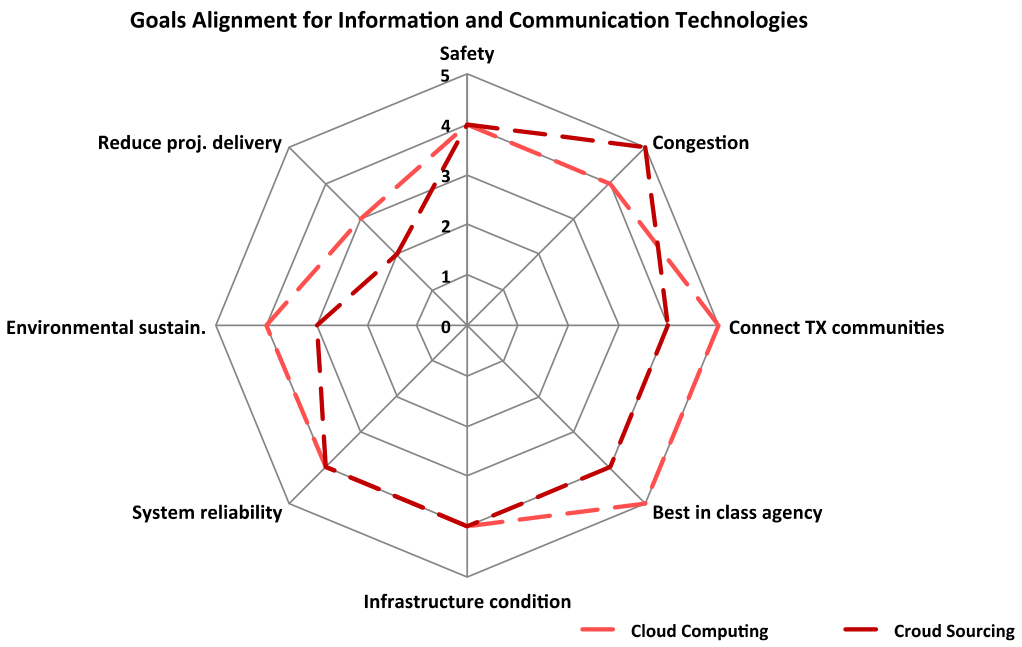
Figures 3 through 6 provide the trade-off results.


Goals Alignment for Autonomous Vehicle Technologies
Safety
Congestion
Connect TX communities
Best in class agency
Infrastructure condition
System reliability
Environmental sustain.
Reduce proj. delivery
0
1
2
3
4
5
A1/A2
A3/A4

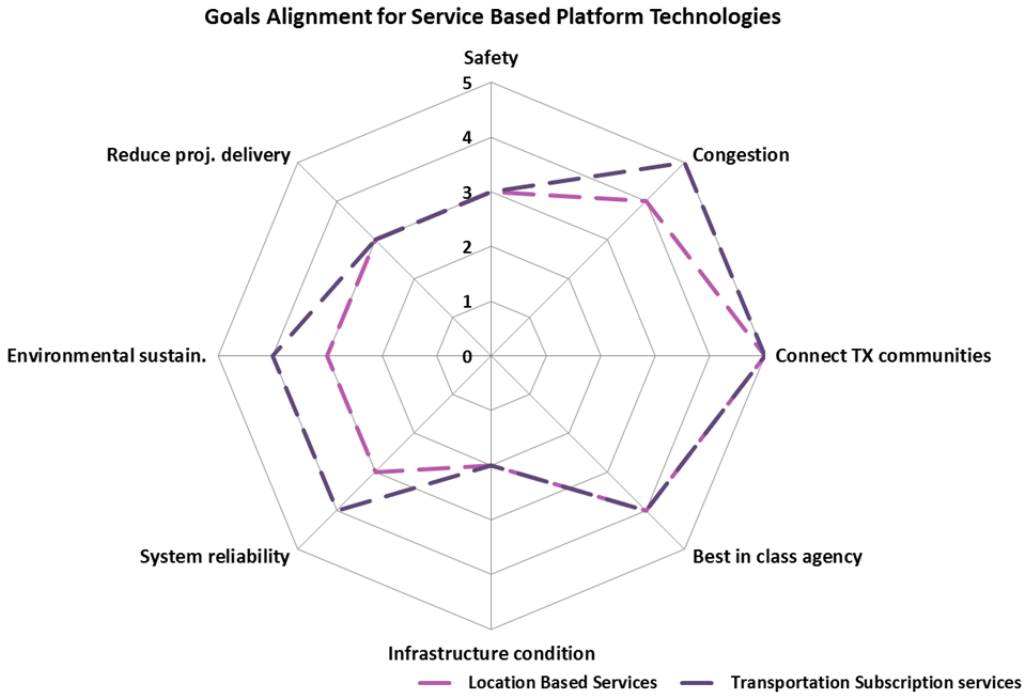
3(a)


Goals Alignment for Connected Vehicle Technologies
Safety
Congestion
Connect TX communities
Best in class agency
Infrastructure condition
System reliability
Environmental sustain.
Reduce proj. delivery
0
1
2
3
4
5
V2I
V2V

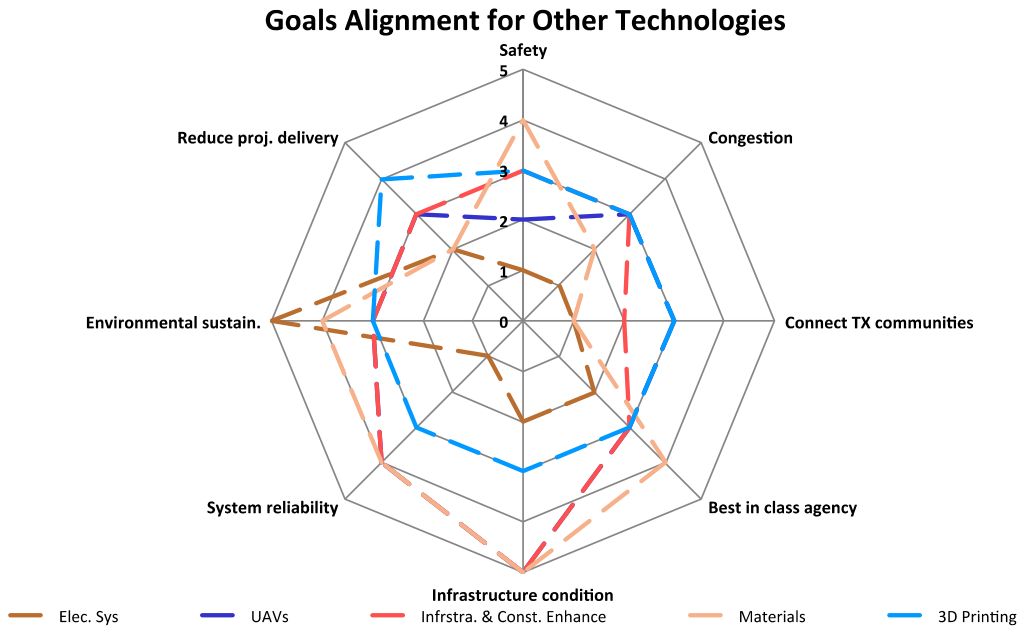
3(b)


Goals Alignment for Information and Communication Technologies
Safety
5
4
3
2
1
0
Congestion
Connect TX communities
Best in class agency
Infrastructure condition
System reliability
Environmental sustain.
Reduce proj. delivery
Cloud Computing
Croud Sourcing

3(c)

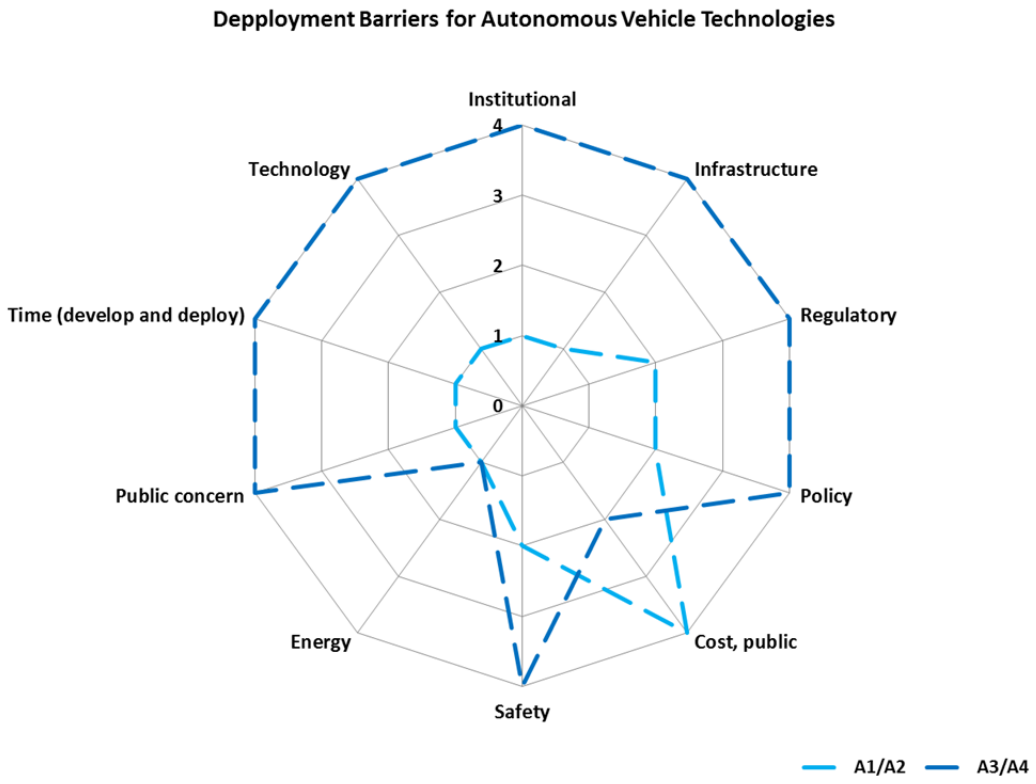

Goals Alignment for Service Based Platform Technologies
Safety
5
4
3
2
1
0
Congestion
Connect TX communities
Best in class agency
Infrastructure condition
System reliability
Environmental sustain.
Reduce proj. delivery
Location Based Services
Transportation Subscription services

3(d)

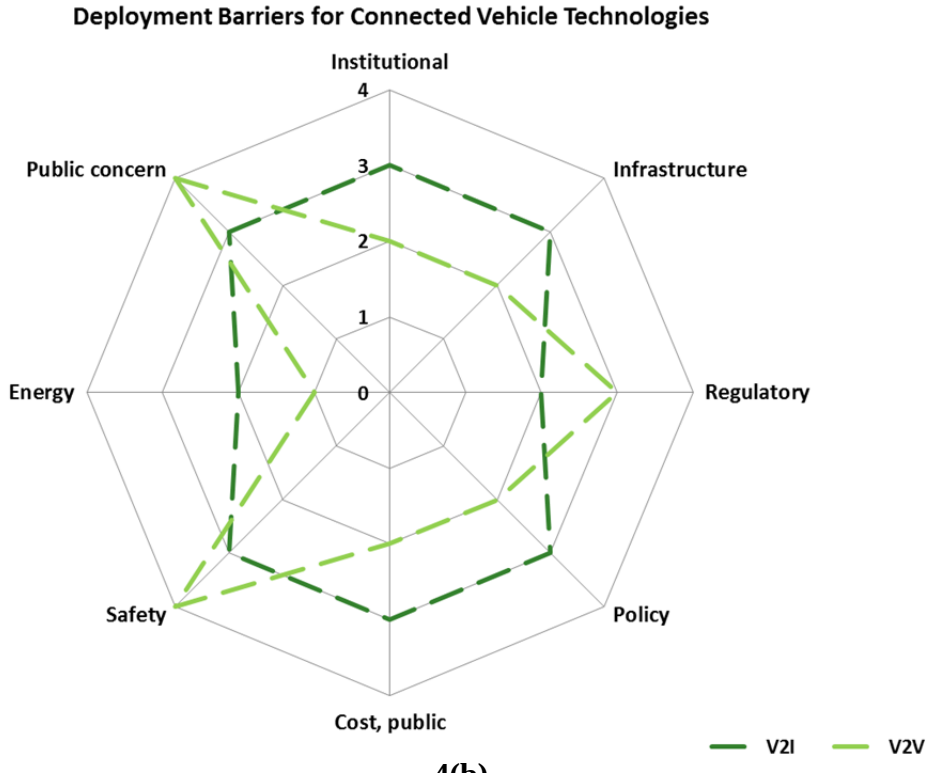


3(e)

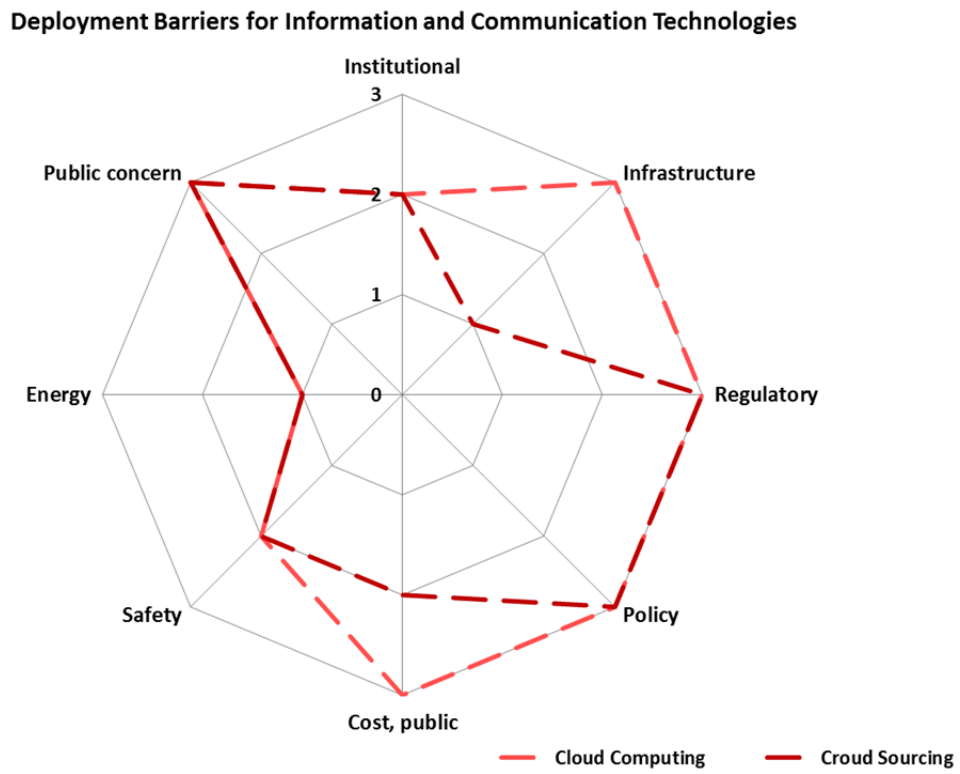
Figure 3 (a-e): Trade-Off Results for Goals Alignment by Technology Group


Depployment Barriers for Autonomous Vehicle Technologies
Institutional
Infrastructure
Regulatory
Policy
Cost, public
Safety
Energy
Public concern
Time (develop and deploy)
Technology
4
3
2
1
0
A1/A2
A3/A4

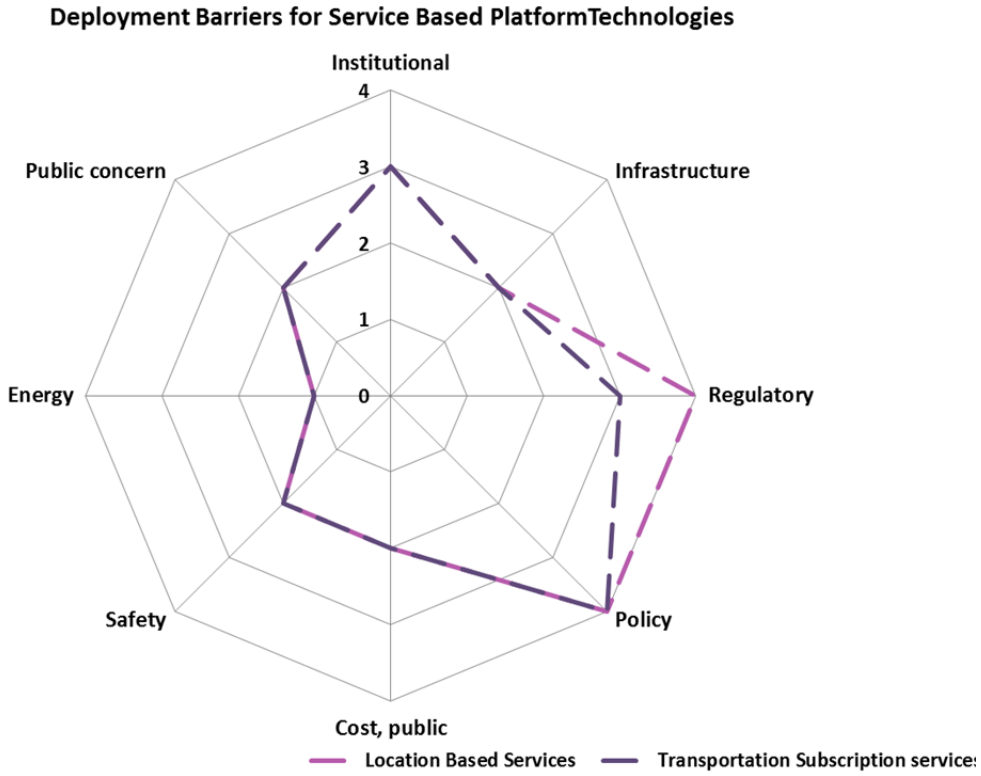
4(a)


Deployment Barriers for Connected Vehicle Technologies
Institutional
Infrastructure
Regulatory
Policy
Cost, public
Safety
Energy
Public concern
4
3
2
1
0
V2I
V2V

4(b)


Deployment Barriers for Information and Communication Technologies
Institutional
3
Infrastructure
Regulatory
Policy
Cost, public
Safety
Energy
Public concern
2
1
0
Cloud Computing
Croud Sourcing

4(c)


Deployment Barriers for Service Based PlatformTechnologies
Institutional
4
Infrastructure
Regulatory
Policy
Cost, public
Safety
Energy
Public concern
3
2
1
0
Location Based Services
Transportation Subscription services

4(d)

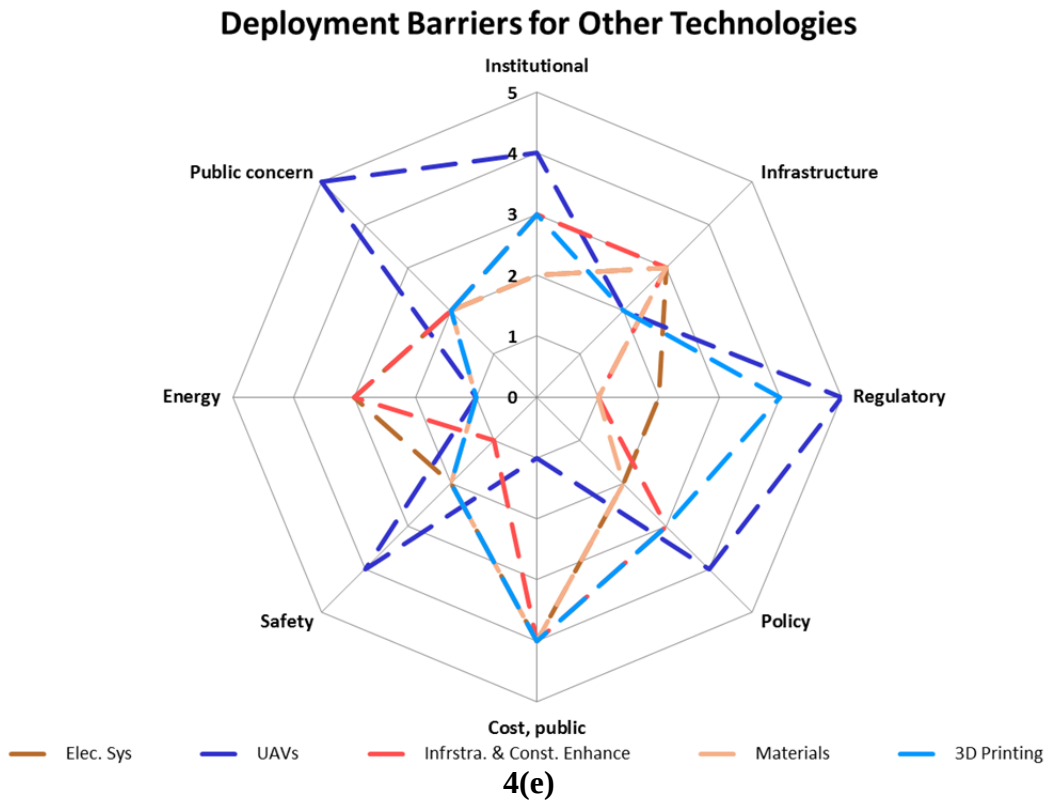
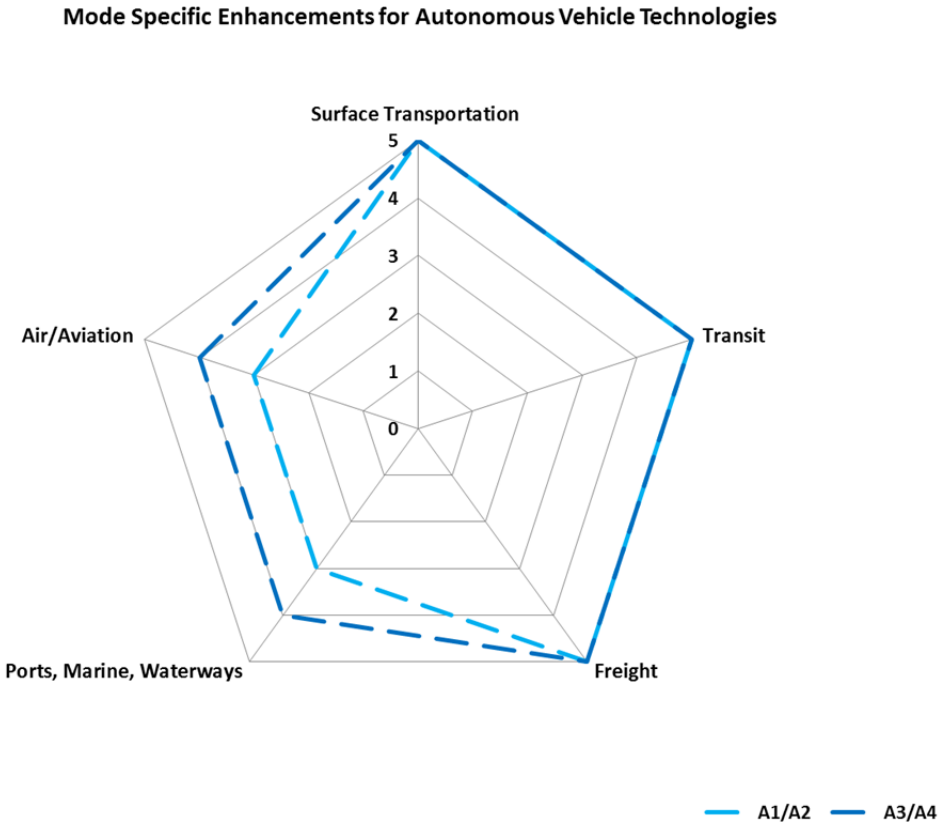
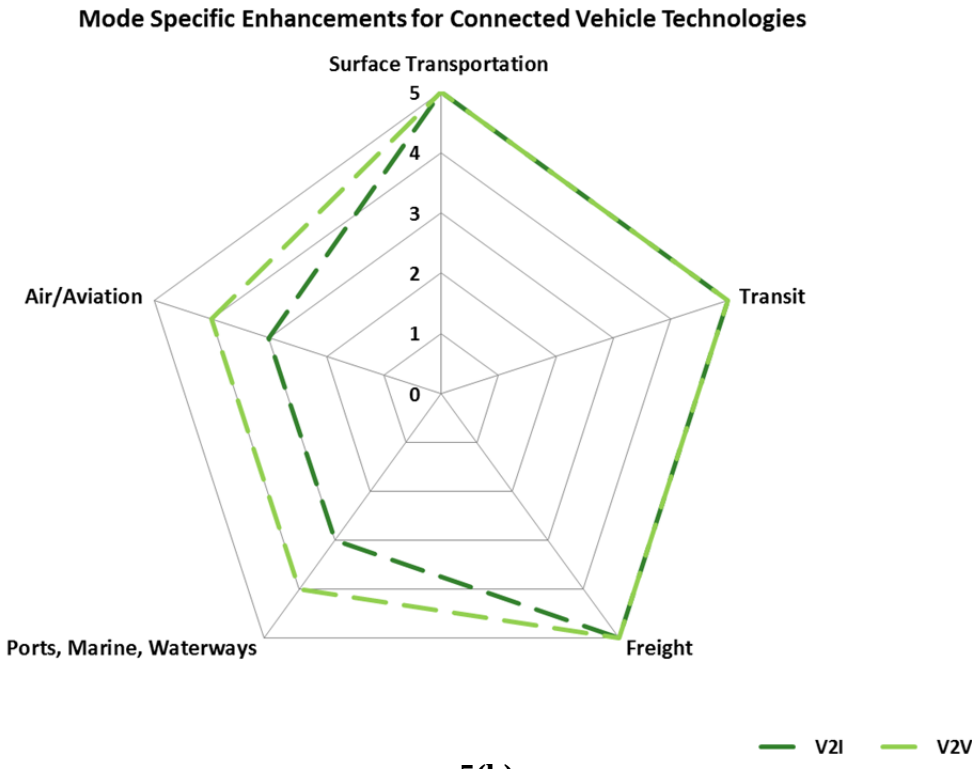


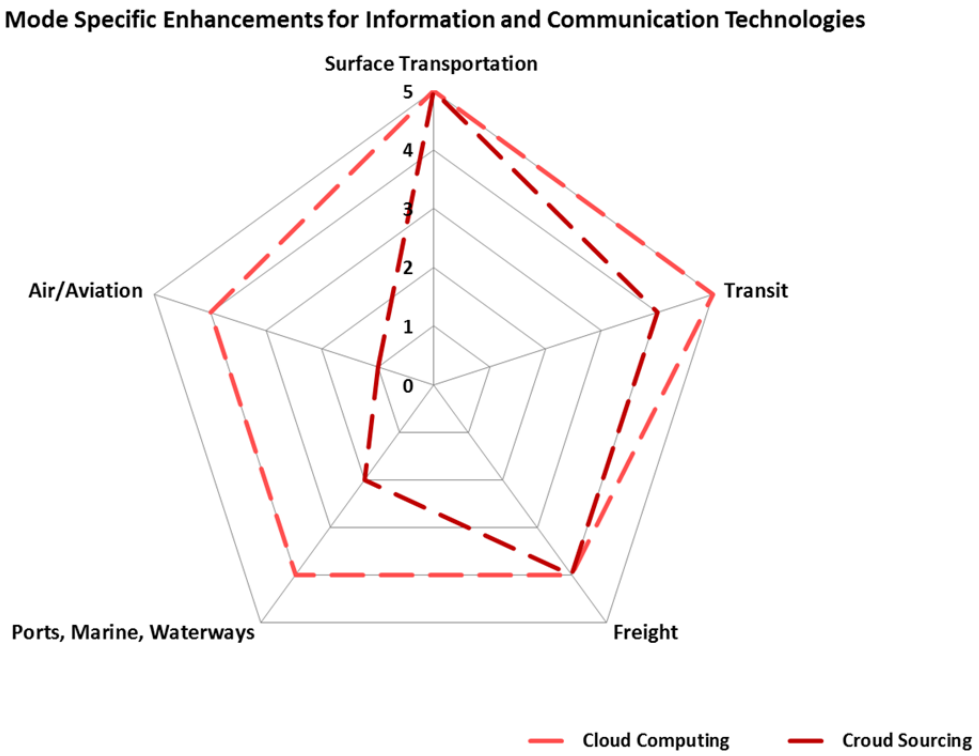
Figure 4 (a-e): Trade-Off Results for Deployment Barriers by Technology Group


Mode Specific Enhancements for Autonomous Vehicle Technologies
Surface Transportation
5
4
3
2
1
0
Transit
Freight
Ports, Marine, Waterways
Air/Aviation
A1/A2
A3/A4

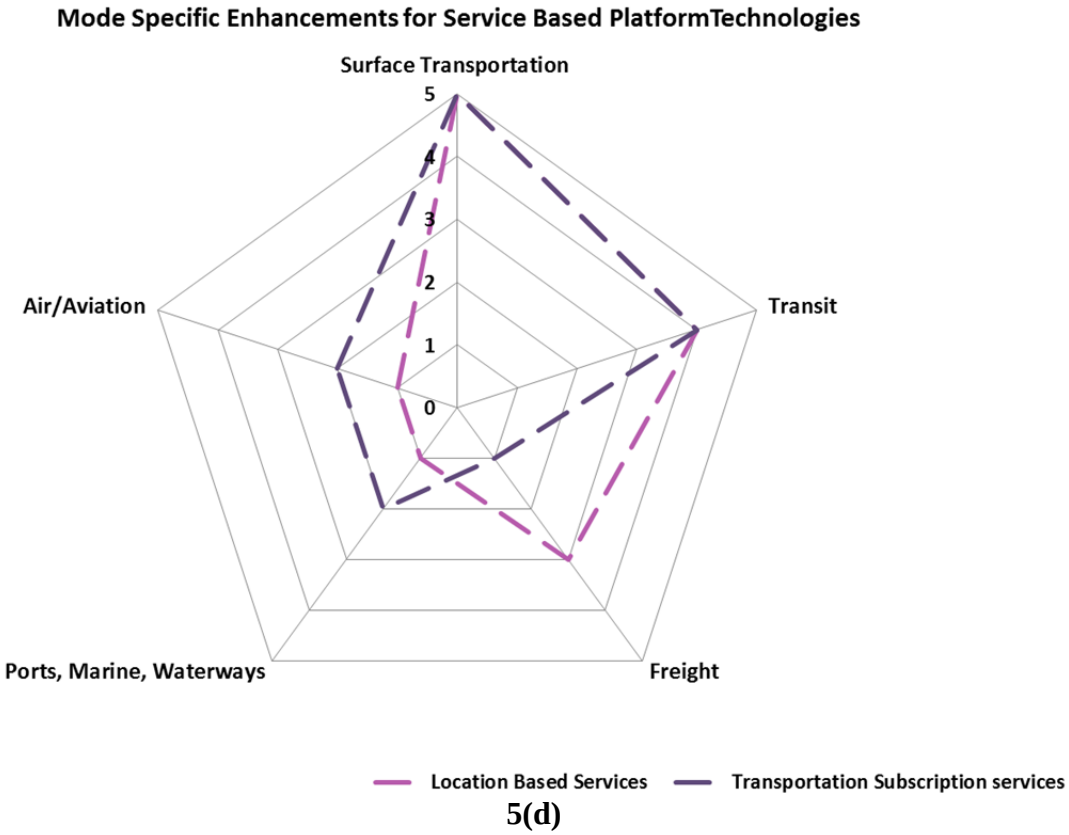
5(a)


Mode Specific Enhancements for Connected Vehicle Technologies
Surface Transportation
5
4
3
2
1
0
Transit
Freight
Ports, Marine, Waterways
Air/Aviation
V2I
V2V

5(b)


Mode Specific Enhancements for Information and Communication Technologies
Surface Transportation
5
4
3
2
1
0
Transit
Freight
Ports, Marine, Waterways
Air/Aviation
Cloud Computing
Croud Sourcing

5(c)


Mode Specific Enhancements for Service Based PlatformTechnologies
Surface Transportation
5
4
3
2
1
0
Transit
Freight
Ports, Marine, Waterways
Air/Aviation
Location Based Services
Transportation Subscription services

5(d)

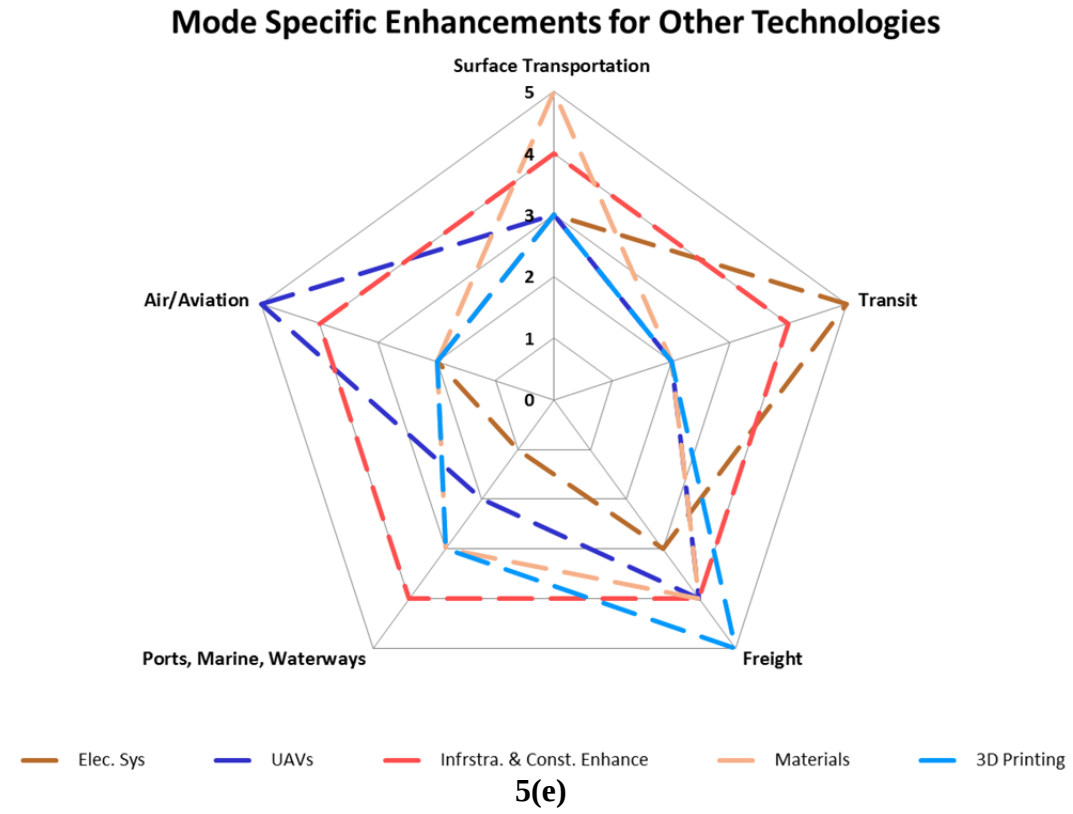
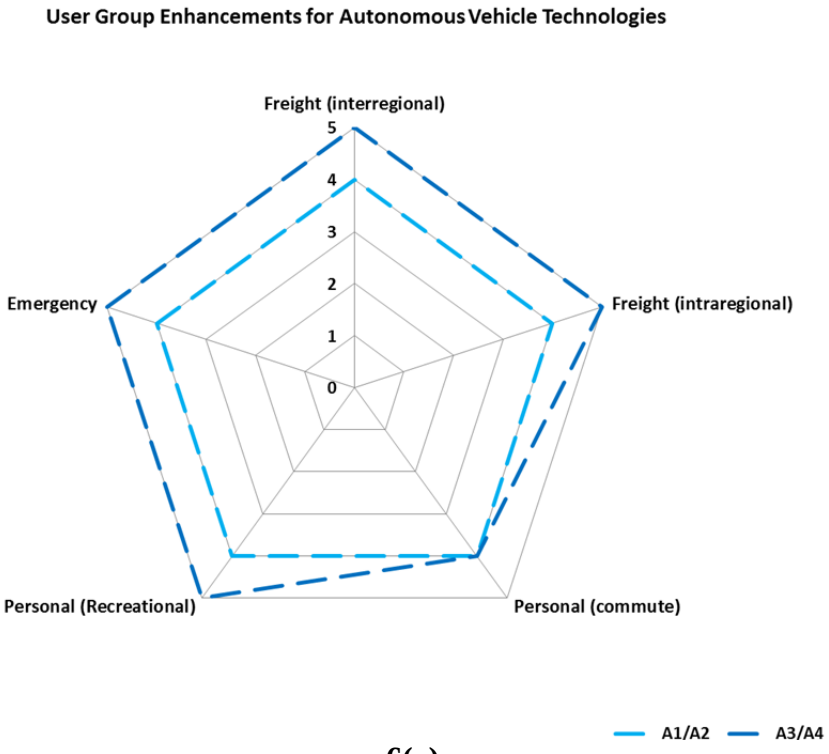
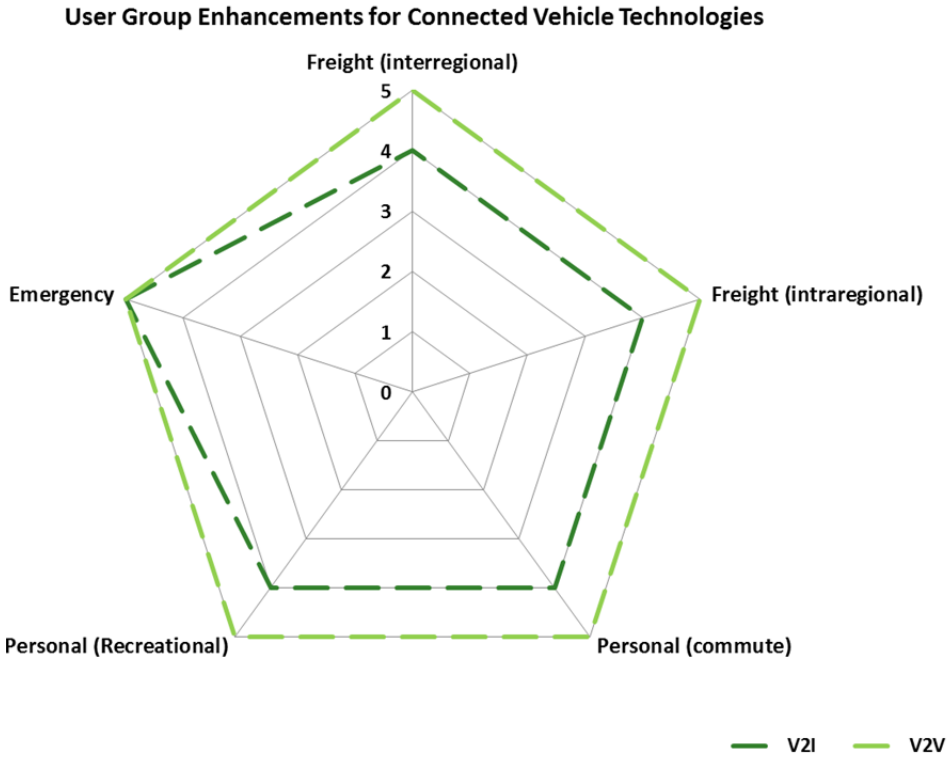


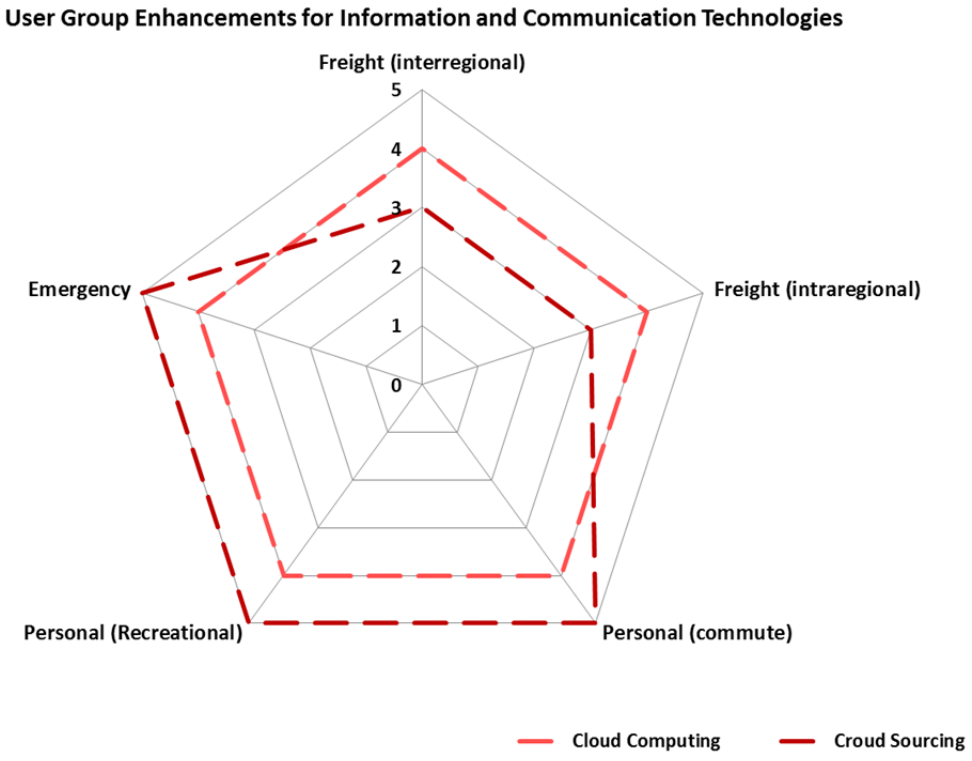
Figure 5 (a-e): Trade-Off Results for Mode Specific Enhancements by Technology Group


User Group Enhancements for Autonomous Vehicle Technologies
Freight (interregional)
5
4
3
2
1
0
Freight (intraregional)
Personal (commute)
Personal (Recreational)
Emergency
A1/A2
A3/A4

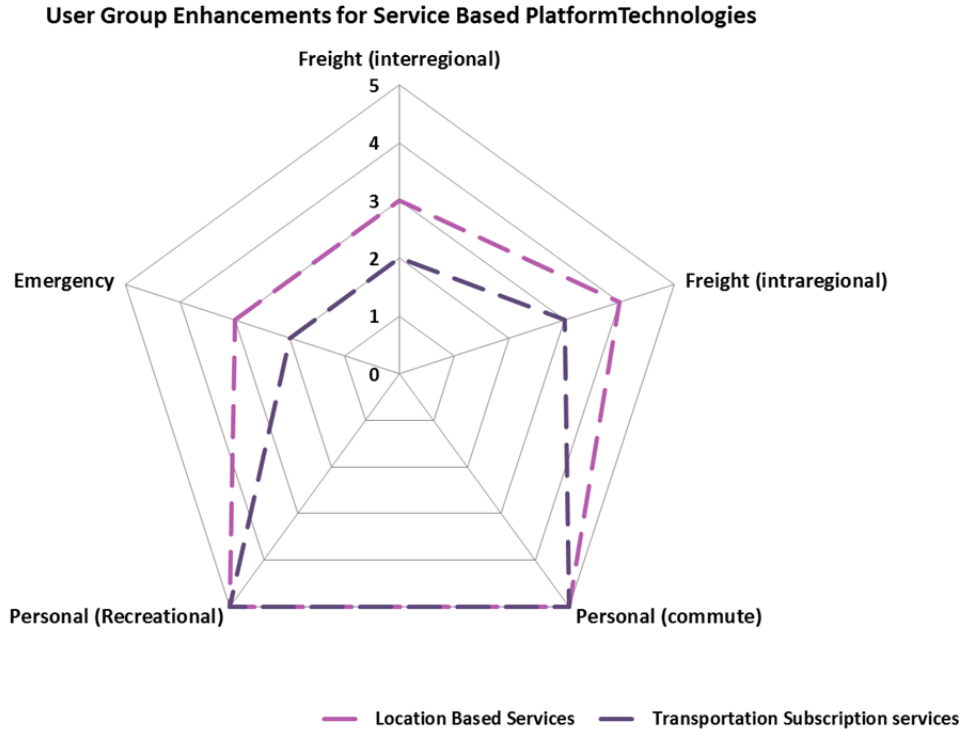
6(a)


User Group Enhancements for Connected Vehicle Technologies
Freight (interregional)
5
4
3
2
1
0
Freight (intraregional)
Personal (commute)
Personal (Recreational)
Emergency
V2I
V2V

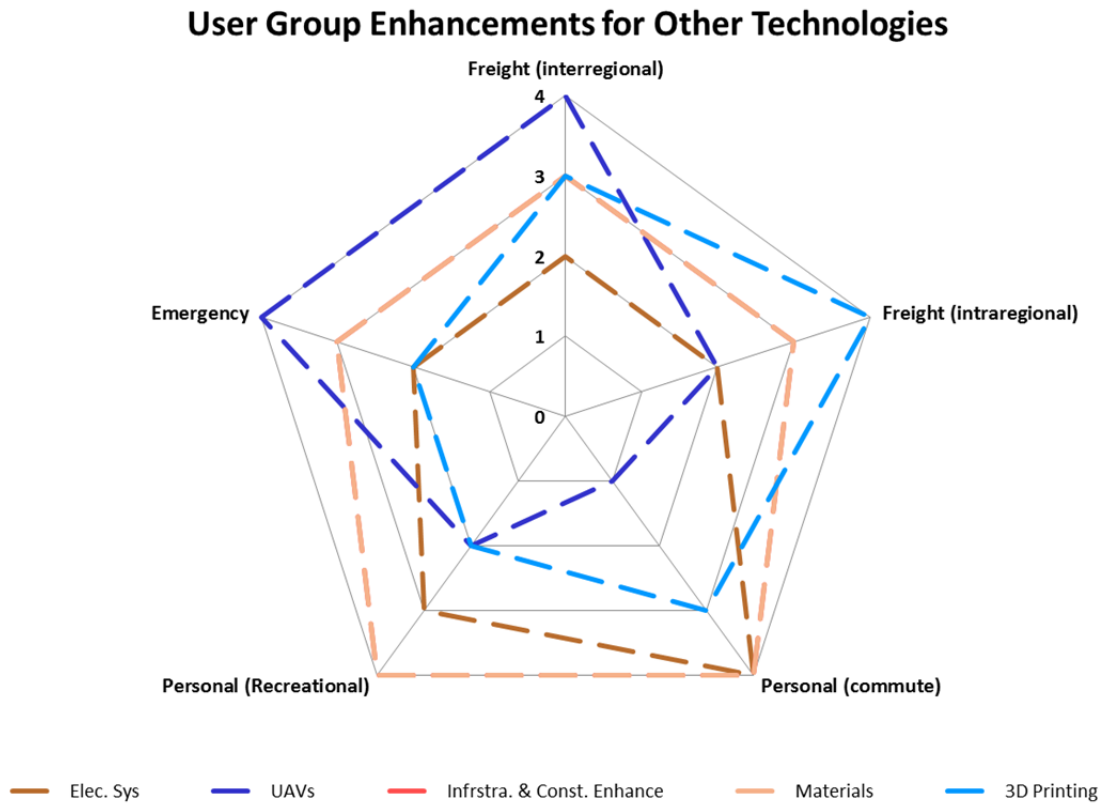
6(b)


User Group Enhancements for Information and Communication Technologies
Freight (interregional)
5
4
3
2
1
0
Freight (intraregional)
Personal (commute)
Personal (Recreational)
Emergency
Cloud Computing
Croud Sourcing

6(c)


User Group Enhancements for Service Based PlatformTechnologies
Freight (interregional)
5
4
3
2
1
0
Freight (intraregional)
Personal (commute)
Personal (Recreational)
Emergency
Location Based Services
Transportation Subscription services

6(d)



6(e)

Figure 6 (a-e): Trade-Off Results for Mode Specific Enhancements by Technology Group

Environmental Scan

An environmental scan serves as an inventory of resources with TxDOT, within the state of Texas, and nationwide that can be leveraged for support in future work and partnerships in transportation technology. As an extension to the SWOT analysis, a detailed scan of the available internal and external resources can lead to a comprehensive understanding of the opportunities and challenges for technology development in Texas. The environmental scan is divided into the in-state internal resource scan and the out-of-state external resource identification.

Resources within TxDOT

The following is an overview of resources within TxDOT that can be used for furthering the TTTF's goals.

- **TxDOT's State Legislative Affairs (SLA)** ***(26)***
  This department within TxDOT is responsible for the department's interaction with state legislative offices and officials, which includes the Texas Legislature, the Governor's office, and other statewide elected officials. SLA responsibilities include responding to legislative requests with timely and accurate information, researching and analyzing legislative and policy issues, attending legislative hearings and preparing the department's testimony for those hearings, providing educational briefings to members and staff, preparing transportation materials for legislative visits, tracking legislation, monitoring legislative actions, and communicating with experts throughout the department. In addition, the SLA facilitates TxDOT's strategic planning process and develops and distributes the department's strategic plan. The office also directs the development and reporting of TxDOT performance measures and results.

- **TxDOT's Federal Affairs (FED)** ***(27)***
  This department within TxDOT is responsible for TxDOT's interaction with legislative offices and officials on the national level, such as Congress, the USDOT, and other national and federal agencies and organizations. The office's responsibilities include responding to Congressional requests, attending Congressional hearings, preparing materials for legislative visits, and providing educational briefings to Congressional members and staff. The office also researches, analyzes, and tracks legislation in addition to communicating with experts throughout TxDOT.

- **TxDOT's Research and Technology Implementation Office (RTI)** ***(28)***
  RTI draws upon the knowledge found in numerous state-supported universities across Texas and combines it with TxDOT's own expertise to benefit Texas drivers. Emphasis areas for research include safety, construction, planning, geometric design, environmental considerations, and hydraulics, among others.

Resources within Texas

Resources within Texas that can be leveraged for support include government research centers and programs, universities and academic research centers, innovative technology companies, and start-up-support organizations. The following provides a preliminary list of such resources and a description of relevant research, project areas, and agency offices.

- **Johnson Space Center (JSC)** ***(29)***
  NASA's Johnson Space Center, located outside of Houston, runs a variety of programs and operations. These include educational, research, and partnership programs that further NASA's goals and innovative technological research. Within the JSC is the Technology Transfer and Commercialization Office (TTO). This office provides support for licensing and partnering for the development and commercialization of numerous technology categories, including clean/green environmental technologies and power, communications, sensors and robotics, software, etc. The TTO encourages partnerships between industry, academia, and other government agencies and researchers at JSC while leveraging the expertise and facilities the JSC has to offer. Each candidate partnership project may fall into one of two categories: a reimbursable where the external party reimburses JSC for JSC's equipment, labor, and facilities, or non-reimbursable, where each party contributes to the project at its own expense.

- **Southwest Research Institute (SwRI)** ***(30)***
  SwRI is an independent, nonprofit applied research and development organization with headquarters in San Antonio. The staff of nearly 3,000 specializes in the creation and transfer of technology in engineering and the physical sciences. Eleven technical divisions offer a wide range of technical expertise and services in such areas as engine design and development, emissions certification testing, fuels and lubricants evaluation, chemistry, space science, nondestructive evaluation, automation, mechanical engineering, electronics, and more. SwRI conducts research in the following areas.

  - Aerospace electronics, systems engineering, and training
  - Applied physics
  - Applied power
  - Automation and data systems
  - Chemistry and chemical engineering
  - Engine, emissions, and vehicle research
  - Fuels and lubricants research
  - Geosciences and engineering
  - Mechanical engineering
  - Signal exploitation and geolocation
  - Space science and engineering

  SwRI is also a founding member and participant in the joint research and educational programs of the nine-member Southwest Research Consortium. In addition the SwRI has established a variety of automotive consortia.

- **Texas A&M Transportation Institute (TTI)/Texas A&M University (TAMU)** ***(31)***
  TTI is a research organization with headquarters in and laboratories on the Texas A&M University campus in College Station and additional offices in cities around the state. TTI employs over 650 professionals, students, and support staff with research focus areas that include transportation economics and policy, environmental issues, freight movement, human and behavioral studies, infrastructure, mobility, safety, security, and workforce development.

- **Center for Transportation Research (CTR)/The University of Texas at Austin (UT)** ***(32)***
  Located at The University of Texas in Austin, CTR is a research institution focusing on transportation research, education, and public service. Its current and ongoing projects address all aspects of transportation, including economics, multimodal systems, traffic congestion relief, transportation policy, materials, structures, transit, environmental impacts, driver behavior, land use, geometric design, accessibility, and pavements.

- **The Center for Innovation (CFI)** ***(33)***
  CFI is a nonprofit organization in Arlington that serves as a catalyst for technology-based economic development. CFI supports a strategic approach to the formation of collaborative partnerships that facilitate and enable the integration of industry, academic, and government research and discovery through venture capital, talent, and expertise. CFI focuses on the commercialization of technology-based research outcomes from universities, industries, and U.S. federal labs that lead to the development of integrated industry clusters. CFI facilitates cooperative or joint activities between federal labs, educational institutions, and industry. Services include patent license agreements, cooperative research and development agreements, material transfer agreements, and educational partnership agreements.

- **Austin Technology Incubator (ATI)** ***(34)***
  ATI harnesses business, government, and academic resources to provide strategic counsel, operational guidance, and infrastructure support to its member companies to help them transition into successful, high-growth technology businesses. Since its founding, ATI has worked with over 200 companies, helping them raise over $1 billion in investor capital. As a program of the IC² Institute of The University of Texas at Austin, ATI fulfills two objectives: promote economic development in Central Texas through entrepreneurial wealth and job creation, and provide a "teaching laboratory" in applied entrepreneurship for UT-Austin students. ATI has over 20 years of experience adding value to technology start-ups. And, based on that experience, the incubation model has evolved as Austin's tech economy has grown and developed. Today, the belief is that the early stage community is best served by offering a broad business building platform, but complementing that with industry-specific capabilities. To that end, ATI has invested in developing domain expertise and market- and technology-specific networks of advisors and investors in four areas:
    - Information technology (broadly defined to cover both software and silicon)
    - Wireless telecommunications (again, covering both hardware infrastructure and software tools)
    - Bioscience (with a human health focus, from device to therapeutics)
    - Clean energy/clean technology (with a strong sub-focus on electric power, although ATI welcomes applications from alternative fuels companies)

- **The Circuit of The Americas (COTA)** ***(35)***
  COTA is a multi-purpose facility that hosts prestigious racing events, including the Formula 1 US Grand Prix. It is the first and only purpose-built Grand Prix facility in the

U.S. The grounds have a state-of-the-art 3.4-mile circuit track and capacity for 120,000. The facility is designed for any and all classes of racing. COTA offers training areas, educational programs, a center with research facilities, services, and amenities to support a broad range of business, technology, and education partners.

National Resources

The following is a list of national organizations and associations made up of transportation professionals that support advanced transportation research and practices. TxDOT has an affiliation, relationship, or connection with each entity listed.

- **The American Road & Transportation Builders Association (ARTBA)** ***(36)***
  ARTBA is an organization of transportation construction-related professionals whose primary goal is to grow and protect transportation infrastructure investment so that public and business demand for safe and efficient travel will be met. In support of this mission, ARTBA provides programs and services designed to give its public and private sector members a global competitive edge. For example, its Transportation Development Innovation Showcase program is committed to helping bring innovative products and services into the transportation design and construction marketplace and to informing the public and their elected representatives how these innovations can provide returns on investment and can be used as a marketing tool. ARTBA also has research staff to complete organization-related research.

- **American Association of State Highway and Transportation Officials (AASHTO)** ***(37)***
  AASHTO is a nonprofit, nonpartisan association that represents highway and transportation departments in the United States, the District of Columbia, and Puerto Rico. The primary goal of AASHTO is to foster the development, operation, and maintenance of an integrated national transportation system, and represents and promotes all transportation modes. AASHTO seeks to educate the public and decision-makers about transportation and the role it plays in securing a good quality of life and sound economy for the U.S. It does so by serving as a liaison between state departments of transportation and the federal government. AASHTO is also an international leader determining technical standards for all phases of highway system development.

- **The Transportation Research Board (TRB)** ***(38)***
  TRB, as part of the National Research Council, is the largest transportation research organization in the world. TRB is organized into committees with specific interest areas. Under the TRB umbrella are several significant research programs that have funded many noteworthy projects and studies on innovative transportation technologies. Such research programs include NCHRP (National Cooperative Highway Research Program), NCHFP (National Cooperative Freight Research Program), and SHRP 2 (the second Strategic Highway Research Program).
    - **NCHRP** ***(39)*****:** NCHRP conducts research in problem areas that affect highway planning, design, construction, operation, and maintenance nationwide. The NCHRP-IDEA program has funded hundreds of innovative ideas with commercialization potentials.

- **NCFRP *(40)*:** NCFRP is another research program focusing on funding the projects related to freight transportation.
- **SHRP 2 *(41)*:** Authorized by Congress, SHRP 2 addresses the significant safety, infrastructure, and congestion issues of the nation's highway system. Its main funded areas include safety countermeasures, renewable energy, facility reliability, and highway capacity.

National Academic and Industry Research Forums

The following section is a list of academic and industry research forums, professional organizations, and other outlets where the Task Force or TxDOT could participate to promote the TTTF project and other emerging technology initiatives.

- **Institute of Transportation Engineers (ITE)**
  The Institute of Transportation Engineers is an international educational and scientific association of transportation professionals who are responsible for meeting mobility and safety needs. ITE facilitates the application of technology and scientific principles to research, planning, functional design, implementation, operation, policy development, and management for any mode of ground transportation. Through its products and services, ITE promotes professional development of its members, supports and encourages education, stimulates research, develops public awareness programs and serves as a conduit for the exchange of professional information.

  Upcoming Meetings: August 14-17, 2016 | Anaheim, California

- **Intelligent Transportation Society of America (ITSA)**
  The Intelligent Transportation Society of America (ITS America) is the nation's largest organization dedicated to advancing the research, development, and deployment of Intelligent Transportation Systems (ITS) to improve the nation's surface transportation system. Founded in 1991, ITS America's membership includes more than 450 public agencies, private sector companies, and academic and research institutions. ITS America's 27 State Chapters are represented across 40 states and includes more than 1200 member organizations.

  Upcoming Meetings: October 10-14, 2016 | Melbourne, Australia

- **International Bridge, Tunnel, and Turnpike Association (IBTTA)**
  The International Bridge, Tunnel and Turnpike Association (IBTTA) is the worldwide association representing toll facility owners and operators and the businesses that serve them. Founded in 1932, IBTTA has members in 20 countries on six continents. Through advocacy, thought leadership and education, members are implementing state-of-the-art, innovative user-based transportation financing solutions to address the critical infrastructure challenges of the 21st Century.

  Upcoming Meetings: August 30-September 2, 2015 | Dublin, Ireland

- **American Association of State Highway and Transportation Officials (AASHTO)**

AASHTO is a nonprofit, nonpartisan association representing highway and transportation departments in the 50 states, the District of Columbia, and Puerto Rico. It represents all five transportation modes: air, highways, public transportation, rail, and water. Its primary goal is to foster the development, operation, and maintenance of an integrated national transportation system.

Upcoming Meetings: September 24-28, 2015 | Chicago, Illinois

- **Eno Center for Transportation**
  The Eno Center for Transportation (Eno) was founded in 1921 by William Phelps Eno (1859-1945), who pioneered the field of traffic management in the United States and Europe. Mr. Eno sought to promote safe mobility by ensuring that traffic control became an accepted role of government and traffic engineering a recognized professional discipline. Eno focuses on all modes of transportation, with the mission of cultivating creative and visionary leadership for the sector. We pursue this mission by supporting activities in three areas: professional development programs, policy forums, and publications.

- **Transportation for America**
  Transportation for America is an alliance of elected, business and civic leaders from communities across the country, united to ensure that states and the federal government step up to invest in smart, homegrown, locally-driven transportation solutions. These are the investments that hold the key to our future economic prosperity.

- **Congress for New Urbanism**
  The Congress for the New Urbanism (CNU) helps create vibrant and walkable cities, towns, and neighborhoods where people have diverse choices for how they live, work, shop, and get around. People want to live in well-designed places that are unique and authentic. CNU's mission is to help build those places.

- **Information Technology and Innovation Foundation (ITIF)**
  Founded in 2006, ITIF is a 501(c)(3) nonprofit, nonpartisan research and educational institute—a think tank—focusing on a host of critical issues at the intersection of technological innovation and public policy. Its mission is to formulate and promote policy solutions that accelerate innovation and boost productivity to spur growth, opportunity, and progress.

- **Mobility Lab**
  Mobility Lab is a leading U.S. voice of "transportation demand management – moving people instead of just cars" – and works to create a shared national voice with clear calls to action from TDM agencies across the country.

  Upcoming Meetings: September 28-30, 2015 | Chicago, Illinois

- **American Public Transportation Association (APTA)**
  APTA is the leading force in advancing public transportation. APTA's mission is to strengthen and improve public transportation. APTA serves and leads its diverse membership through advocacy, innovation and information sharing. APTA and its

members and staff work to ensure that public transportation is available and accessible for all Americans in communities across the country.

Upcoming Meetings: October 4-7, 2015 | San Francisco, California & November 15-17, 2015 | Minneapolis, Minnesota

- **American Society of Civil Engineers (ASCE)**
  The American Society of Civil Engineers represents more than 146,000 members of the civil engineering profession in 174 countries. Founded in 1852, ASCE is the nation's oldest engineering society. Through the expertise of its active membership, ASCE is a leading provider of technical and professional conferences and continuing education, the world's largest publisher of civil engineering content, and an authoritative source for codes and standards that protect the public.

  Upcoming Meetings: October 11-14, 2015 | New York, New York

- **Aircraft Owners and Pilots Association (AOPA)**
  With hundreds of thousands of members, AOPA is the largest, most influential general aviation association in the world. AOPA has achieved its prominent position through effective advocacy, safety education and training, enlightened leadership, technical competence, and hard work. Providing member services that range from representation at the federal, state, and local levels to legal services, advice, and other assistance, AOPA has built a service organization that far exceeds any other in the aviation community.

- **Coalition for America's Gateways and Trade Corridors (CAGTC)**
  The Coalition for America's Gateways and Trade Corridors (CAGTC) was established to bring national attention to the need to significantly expand U.S. freight transportation capabilities and to work toward solutions for this growing national challenge. Their sole purpose is to raise public recognition and Congressional awareness of this need and to promote sufficient funding in federal legislation for trade corridors, gateways, intermodal connectors, and freight facilities.

- **United Transportation Union (UTU)**
  The United Transportation Union (UTU) is headquartered in the Cleveland suburb of North Olmsted, Ohio. It is a broad-based, transportation labor union representing about 125,000 active and retired railroad, bus, and mass transit workers in the United States and Canada.

- **American Association of Port Authorities (AAPA)**
  Founded in 1912, the American Association of Port Authorities is a trade association which represents more than 130 public port authorities in the United States, Canada, the Caribbean, and Latin America. In addition, Association members include more than 300 sustaining and associate members—firms and individuals with an interest in the seaports of the Western Hemisphere. AAPA is dedicated to serving deep draft public ports by enhancing port management professionalism, and advocating issues critical to public seaports.

Upcoming Meetings: November 2-4, 2015 in Miami, Florida; October 23-27, 2016 in New Orleans, Louisiana; October 1-4, 2017 in Long Beach, California

- **Transportation Research Board**
  The mission of the Transportation Research Board (TRB) is to promote innovation and progress in transportation through research. In an objective and interdisciplinary setting, TRB facilitates the sharing of information on transportation practice and policy by researchers and practitioners; stimulates research and offers research management services that promote technical excellence; provides expert advice on transportation policy and programs; and disseminates research results broadly and encouraged their implementation.

  Upcoming Meetings: January 10-14, 2016 | Washington, DC

- **Young Professionals in Transportation**
  YPT provides professional development, fellowship, and networking opportunities for young professionals in the transportation field across the country and around the world.

- **American Public Works Association (APWA)**
  The American Public Works Association exists to develop and support the people, agencies, and organizations that plan, build, maintain, and improve our communities. Working together, APWA and its membership contribute to a higher and sustainable quality of life.

  Upcoming Meetings: August 30-September 2, 2015 | Phoenix, Arizona

VISIONS AND STRATEGIES DEVELOPMENT

This section summarizes the preliminary research conducted on vision and strategy development conducted by the task force. Several basic technology development elements are discussed, including the definition of success, funding and investment, organization structure, service offering, client selection, and facility requirements.

Missions, Goals, and the Definition of Success Criteria

The task force was established to identify and plan technological solutions to address TxDOT's key missions, that is, to provide a safe and reliable transportation system for Texas, while addressing congestion, connecting Texas communities, and becoming a best-in-class state agency. Combing TxDOT's goals with the national goals described in MAP-21, the following set of goals were established for evaluating the success of technology development:

- Economic Development
- Safety
- Congestion
- Connecting Texas communities

- Best-in-class Agency
- Infrastructure Conditions
- System Reliability
- Energy Security
- Environmental Sustainability
- Efficient Project Delivery

Based on these goals, the task force further proposes a series of success criteria to guide technology development. The task force considered the success of the transportation technology development program from several different perspectives, such as economic gain, advances in the state of the knowledge and practice, stakeholder engagement, and cooperation and collaborations, prioritized as the following.

- **Economic gain**: The first priority is to promote economic development in Texas; economic gain is considered a crucial indicator. Economic gain can be quantified by return on investment, commoditization, and completion and exiting rates (for incubators).
- **Stakeholder engagement**: Another key factor of defining the success of technology development in Texas is the stakeholder engagement. New transportation technology cannot be successfully implemented without full engagement of all related parties, such as state and local transportation agencies; metropolitan planning organizations; other related non-transportation funding, legislation, policy, and economic development agencies; the private sector; and academia.
- **Advance the state of knowledge and practice**: The newly developed technologies should significantly advance the current planning, operations, management, and maintenance of the transportation systems. The significance of technology advancement should not only be evaluated based on the number of academic papers, patents, and copyrights produced but also the innovative ideas generated and the long-term impact on the development of next-generation safe, efficient, and sustainable transportation systems.
- **Cooperation and collaboration**: There will be multiple parallel efforts by other state DOTs, national or international research and development entities, and private company R&D departments in emerging technology development. The success of the developed transportation technologies should also be evaluated based on their compatibility with similar systems and national standards. The technology development should create opportunities to promote regional, national, and international collaboration and cooperation.
- **User satisfaction**: User response and satisfaction will be more and more important as new technologies move toward field testing and implementation. Feedback from transportation system users, including the car commuters, truck drivers, transportation planners, operators, maintenance crew, and decision-makers, will provide important indicators to determine the success of transportation technologies in the field.

Funding and Investment Criteria

The task force designed funding and investment criteria based on the different development stages of a technology. For unproven ideas, research funding entities such as the DOE (Department of Energy) *(42)*, NSF (National Science Foundation) *(43)*, and NCHRP may be approached about conducting proof-of-concept and field test research. For proven ideas, the task force is establishing PPPs in the form of incubators to help accelerate and commercialize the ideas. For fully developed technologies or methodologies, TxDOT can apply research funds for implementation. Pairing different funding sources with technologies at different development stages can help maximize the benefits and economic returns while minimizing the risks and barriers. Figure 2 illustrates the proposed funding and investment strategies. The technology task force and TxDOT will organize a governing structure responsible for the selection, evaluation, and management of technology development projects. Note: when implementing the commercialized products from the PPP, the proposed funding process requires them to go through the standard TxDOT funding competition procedures in a research program instead of directly entering the research program to obtain funds for implementation. TxDOT and TTTF will be responsible for developing problem statement and performance measures for the process. This additional process will allow TxDOT to maintain the integrity of the research program. Meanwhile, the funding and proposal competition allows competing technologies and products to be considered.

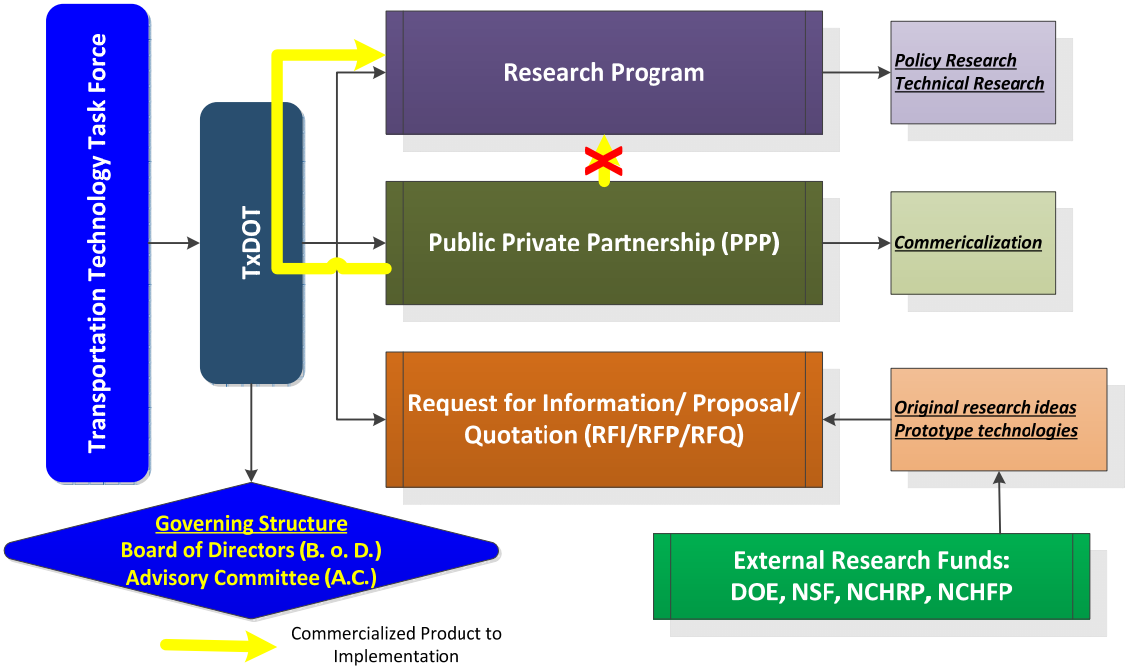


Figure 1. Schematics of the Funding and Investment Strategies

Organizational Structure, Service Offering, and Client Selection

The organization structure of the proposed technology development program consists of two major entities: the board of directors (BOD) and the advisory committee (AC). Figure 3 illustrates the organizational structure and the work flow. The BOD consists of major stakeholders who provide funds for the program such as TxDOT, cities (e.g., City of Austin),

trade groups such as COTA and ARTBA, and private industry and original equipment manufacturers (OEM). The AC is then formed and organized by individuals within the BOD groups and outside experts and specialists. The BOD will organize funding competitions to call from proposals from Principle Investigators (PI) of interested research and development groups. The AC is responsible for selecting among the proposed projects for funding. After being selected, the PIs are then managed by BOD throughout the project period.

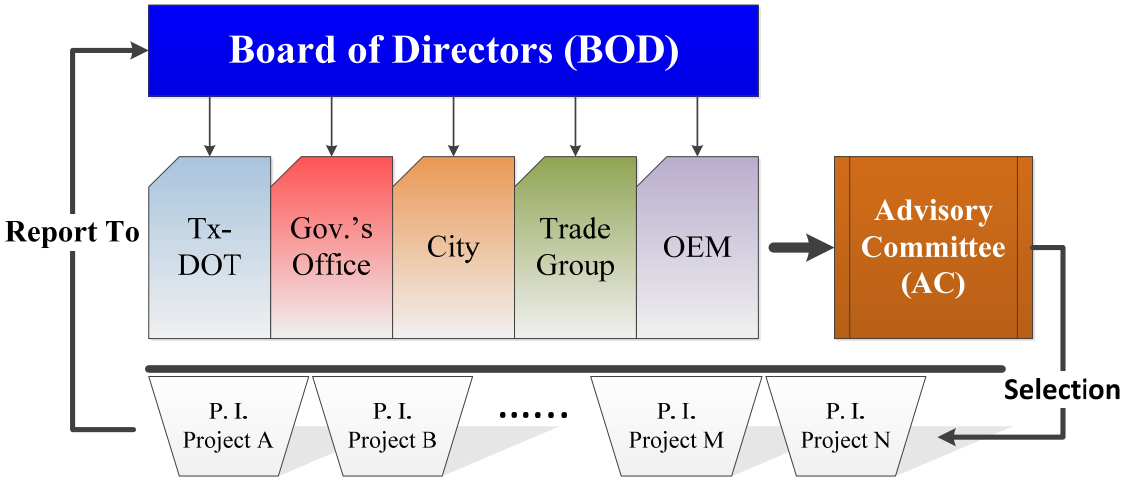


Figure 2. Organizational Structure and Work Flow

The proposed structure is different from a regular funding organization since the selected project may also be incorporated into an incubator program for commercialization in which the BOD and AC have continued advisory and management roles in assisting selected projects. The BOD and AC provide a wide range of service to the selected R&D groups such as direct business development assistance, professional network support, educational programs, facility and infrastructure support, and public relation support. The structure differs from that of a regular accelerator or incubator in its heavy involvement with and impact from the public sector. The hybrid structure allows the technology development program to take advantage of both financial and business support from the trade groups and private industry and the funding, policy, and infrastructure support from the public sectors. The client selection criteria will focus on matching R&D groups with investors while involving the technology development mission and goals set by the public sector members.

FACILITY AND INFRASTRUCTURE REQUIREMENTS

Another important aspect is the facility and infrastructure support for the technology development. Based on the types and ownership, the needed facilities and infrastructures can be classified into the categories provided in Table 3.

Table 3 demonstrates that early-stage technologies such as CV and AV technologies have more significant facility and infrastructure needs than EVS and Crowdsourcing and Cloud Computing technologies. Since the technologies are developed to serve the transportation systems, more public infrastructures needs are identified than the private infrastructure needs. Efficient and

sustainable procedures and business models for providing those public and private infrastructures to the interested R&D groups can play significant role in the success of the technology development program.

Table 3. Facility and Infrastructure Needs for Different Emerging Technologies

Facilities/Infrastructures	AV	CV-DSRC	CV-Cellular	EVS	CS/CC
Public					
Research labs	X	X	X	X	X
Materials labs				X	
Computing centers		X	X		X
Open-road testing sites	X	X	X	X	
Testing corridor or network	X	X	X	X	
Data centers		X	X	X	X
Traffic sensors	X	X	X		X
Access to electrical system				X	
Traffic operations center		X	X		
Driving simulator environment		X	X		
Private					
Closed testing facilities	X	X	X	X	
Testing vehicles	X	X	X	X	
Cellular communication system	X		X		
Private lots and charging stations				X	

X = Facility/infrastructure needed

Acronym Guide:
AV: autonomous vehicles, CV: connected vehicles, EVS: electric vehicle system, CS/CC: crowdsourcing and cloud computing

Summary and Future Work

This appendix presents preliminary background research for the development strategic business plan. During Phase II of the project, the task force mainly focused on the background research with respect to the SWOT analysis, environmental scan, and the vision and strategy development. To complete a workable business plan, a great deal of research and strategic planning remains to be completed, especially in the areas of economic impact and industrial impact assessment, technology-specific policy, and business development strategies. The work plan provides the guidelines for completion of the strategic business plan.

APPENDIX II. Accelerator Texas: Creating Autonomous Vehicle Economic Development

1. Concept

Accelerate Texas (*Accelerate*) will be a public-private partnership established with the intent of developing, commercializing, and implementing new transportation-related technologies with a specific focus on organizations collectively working towards the autonomous vehicle. *Accelerate* ultimately will be an independently operated organization with input and participation of several state agencies, private sector firms, other governmental entities (such as metropolitan planning organizations, cities, etc.) and research institutions (such as Texas universities). The increased use of private-public consortia is attractive as a means for industry to participate in leading-edge research, development, and testing, while maintaining a reasonable cost structure. Texas recognizes the importance that these consortia play in developing next generation transportation technologies and services that are led by industry and supported by government and academia.

2. Context

At least four major external trends align to support the increased integration of technology into the transportation system of Texas.

1. **Texas' role in the global marketplace will only grow over time, as the economy continues to move toward higher value-added production and services.** The transformation of Texas from a center of commodity production to a place that emphasizes adding value through the application of knowledge and technology is virtually complete, notwithstanding the recent surge in energy production. Until recently, the structure of the Texas economy was similar in many ways to that of a developing nation: the state sold basic products such as food and energy, and tended to purchase more sophisticated manufactured goods. That trend has been turned upside down in recent years, as Texas has become a center of research, advanced technology, and high value-added services.
2. **Rapid population growth relative to the rest of the nation will characterize Texas over the next 30 years.** Three main factors influencing Texas' demographics landscape over the coming decades are relatively high birthrates, in-migration, and an aging population; each creates new challenges for the public sector. Strong overall population growth will place greater strain on an already overstressed road and highway network, as well as prompting continued interest alternative forms of transportation.
3. **The physical character of Texas communities continues to evolve**. The traditional model of community development is changing. Urban areas in Texas have long been characterized by relatively low density, as abundant land fostered spread-out cities that relied almost exclusively on the automobile. In recent years, the rate of population and traffic growth has outstripped the road system in many areas, leading to increased congestion. Partially as a result, many communities are now focusing on traditional neighborhood design. The defining characteristics of this development approach are walkability or pedestrian-oriented design; transportation options; a mix of land uses that

integrate housing, shops, civic facilities, and work places; and maintenance or creation of green space.

4. **Public sector funding of basic infrastructure, including the transportation network, has been declining for some time, as the State of Texas spends proportionately less today on highways than it did 20 years ago**. As a result, the focus has shifted toward alternatives to traditional general obligation debt financing of basic infrastructure, with a greater emphasis on tolls, tax-increment financing, development fees, and other alternative financing structures.

Collectively, these factors will require Texas to leverage its existing transportation infrastructure as efficiently as possible, as continued growth runs head-on into evolving development patterns and constrained resources. Meanwhile, the nature and scope of the state's infrastructure is changing. Much of the modern economy's development can be traced to the implementation of networks—highways, rail, telecommunications, and energy. The ability to efficiently move goods, people, capital, energy, and ideas continues to transform the way humans live, work, and play.

Throughout history, transportation was the first network system to be comprehensively deployed, with improvements in the movement of goods and people preceding every stage of industrial development. As outlined by Dr. John Kasarda of University of North Carolina, transportation was a critical ingredient in the four major waves of industrialization that have occurred to date *(44)*:

- The first great cities developed around seaports and along trade routes.
- The second wave of development—and the beginning of the Industrial Revolution—occurred when factories used canals and rivers for power and shipping.
- The third wave of industrial development started with the railroad system, which opened up landlocked resources.
- The fourth wave of development began with massive investments in highway infrastructure that increased traffic, expanded personal mobility, and accelerated metropolitan growth.

According to the FHWA, the current (fifth) wave of industrialization is based on innovations in logistics and manufacturing. Increasingly, components are manufactured offshore, and then they are assembled into finished products near the point of their final consumption or use. This business model depends strongly on a fast and reliable transportation network that minimizes the cost of production. Just as highway infrastructure made the fourth wave possible in the United States, the country's current performance depends heavily on a seamless, intermodal transportation system.

While the future is somewhat uncertain, the sixth wave might well entail the integration of different types of networks into a seamless and invisible underpinning to the movement of goods and people. In particular, the nascent efforts on connected and autonomous vehicles, smart grids, and a general orientation toward minimizing and ultimately removing human beings from a direct operational role in transportation promises a range of social and economic benefits. It is

the promise of these benefits, along with the economic gains associated with first-mover advantage and the pressures outlined above, that make the exploration of better integrating technology and transportation such a timely issue for Texas.

3. Outline for Establishing Accelerate Texas

The work plan for establishing *Accelerate* includes two major phases: 1) near-term preparation, organizational refinement, and announcement; and 2) transition to permanent organization.

Phase I: Near-Term Preparation, Refinement, and Announcement

The objectives of Phase I include 1) seeking and securing initial public and private "founding members" of *Accelerate*, 2) refining the organization's mission, structure, and program of work, and 3) announcing *Accelerate*'s formation. At this point, it appears that TxDOT, the Governor's Office of Economic Development, Texas A&M University, the University of Texas, and Circuit of the Americas (COTA) will be the initial participants, with COTA prepared to offer substantial in-kind resources to the effort. The initial governing board should reflect the founding organizations, though some may choose to participate on an *ex officio* basis. Enabling organizational documents (bylaws, operating procedures, etc.) should be as flexible as possible at this early stage, as they likely will be modified subsequent to Phase II.

Key Short-Term Tasks:

- Secure agreements from initial founding member organizations
- Draft initial enabling organizational documents/structure
- Prepare for organizational announcement
    - Secure facilities at COTA
    - Develop materials to educate and promote *Accelerate* to race attendees, etc.
    - Identify/target key attendees and events
- Continue to brief key officials
- Prepare and implement event-based and soft launch communications plan

To properly create the ongoing structure of *Accelerate*, the following key issues and concerns will be identified: missions and goals, organizational structure, program of work, business plan/funding model, interaction with research partners, and qualifications, regulations, and rights/responsibilities of initial and future participants.
The plan is to have answers to all of the following fully developed over the period from January to November 2014, creating the strategic and operating plan for *Accelerate* in the process.

This will be accomplished via primary research and interaction with analogous organizations, potential participants, and stakeholders that are both informed by and integrated with an external research/outreach program that follows. This strategic communications plan will be built and executed to fit the goals and mission as defined is Phase II.

Timeframe: January 2014 through Summer 2014.

Phase II: Transition to Permanent Operations

The outcome of Phase II should be a plan that prepares *Accelerate* to transition to permanent operations, with policies, plans, and procedures that address the five areas outlined in Phase I in place.

Timeframe: Summer 2014 through the Formula One event in November 2014.

4. Initial Participants/Resources

The proposed initial participants are TxDOT, the Governor's Office of Economic Development, Texas A&M University, the University of Texas, and Circuit of the Americas (COTA). COTA is prepared to offer substantial in-kind resources, including access to portions of the facility for testing and permanent office, meeting, and conference space. These in-kind resources are easily worth more than $1 million (COTA, for example, charges $50,000 to rent the track per day**).** Equally important, both the existing track and the presence of global private-sector transportation stakeholders give Texas a considerable head start on competing states pursuing similar strategies but lacking existing test and office facilities**.**

5. Stakeholder Interaction

We recommend starting Phase II with a review of work-to-date in the wake of the *Accelerate* launch at Formula One 2014. This will be followed by a research process, ensuring that we work with the best data possible to define the strategy and tactics that meet project objectives. Most importantly, it helps us develop the most effective communications strategy because it is based on a clear understanding of our objectives and resources, extensive research, and gaining buy-in from key decision makers at critical steps in the process**.**

Review

We will convene a meeting of the project's key decision-makers to define short-term and long-term success of the project. As a group, we will define the following tasks:

- Review information/contacts gleaned from the *Accelerate* launch;
- Establish key initial metrics—goals and objectives, communications/marketing goals, key dates, and milestones;
- Identify and understand critical issues and the organization's position relative to them;
- Refine target audiences and key stakeholders; and,
- Further structure *Accelerate*'s product offering and marketing efforts.

Analytics

After the initial discovery, we will perform research to identify how specific transportation issues and projects are being framed and who is driving those conversations. The research step is critical as it informs organizations we target, messages and product offerings we create, the routes and strategy we recommend, where the pitfalls may be, where to find the most success, and how to take advantage of it all. This research approach will likely include these aspects:

- We will conduct an assessment of the digital landscape (A Digital Advance™) that looks at key names and organizations that are talking about our issue, a media review of notable earned media coverage, and how the issue is being framed online.
- This step will also dive deeper into the stakeholder and potential partner analysis that was started in Phase I. This includes identification of any emerging voices, organizations, companies, or inventors of transportation technology who would be target partners or collaborators.
- The research will also allow us to identify how (and how often) Texas and Texas-based organizations show up in the national conversation about transportation technology and pinpoint opportunities to own parts of that conversation on a much broader scale.

This initial research phase will also provide a baseline of qualitative and quantitative data that can be used as a reference point after the project launch to compare change in opinion and/or awareness.

Communications Plan for Permanent Operations Launch

We will use the research to develop project messaging (and pair it with key target audience groups) and the initial project launch's communications plan that includes detailed tactics and tools to best meet the goals.

The support team is also available to conceptualize, plan, organize, and execute any external meetings needed in this phase. This may include, but is not limited to, key stakeholder meetings, a speaker's bureau, a rolling road show, and press conferences.

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Appendix F: *Transition Plan* (0-6803-01-P6)

CENTER FOR TRANSPORTATION RESEARCH

0-6803-01-P6

TRANSITION PLAN

Kristie Chin
Andrea Hall
C. M. Walton

TxDOT Project 0-6803-01: The Technology Task Force

AUGUST 2015; PUBLISHED NOVEMBER 2015

Performing Organization:	**Sponsoring Organization:**
Center for Transportation Research The University of Texas at Austin 1616 Guadalupe, Suite 4.202 Austin, Texas 78701	Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080
Performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.	

1. Introduction

With the conclusion of Phase III in August 2015, the Texas Technology Task Force (TTTF) is preparing to transition to its next phase. The Performing Organization has submitted a three-year work plan proposal to the Sponsoring Organization that is currently under review. This three-year work program shall enhance previously completed work by the TTTF and provide necessary supporting research on emerging technologies and their trial programs to form the basis of recommendations to TxDOT regarding the development of programs and initiatives for technology adoption and integration in Texas.

2. Transition Plan

The transition plan outlines four phases that are designed to guide the TTTF in its future efforts of supporting TxDOT: Discover, Define, Demonstrate, and Deliver. The following sections describe each of these phases in greater detail. The full list of proposed deliverables and timeline may be found in Appendix A. A graphic outlining the three-year work plan may be found in Appendix B.

2.1 Discover

During the "Discover" Phase, the Performing Organization will continue to invite subject matter experts to participate in Task Force meetings. These experts will be selected under the guidance of the Task Force and have the opportunity to share detailed information on technology development and applications to transportation. The discussions and presentations will be facilitated in order to encourage open dialogue.

The Performing Organization will also visit U.S. technology pilot programs, attend industry and research conferences, and invite key personnel to participate in Task Force meetings to share their expertise. Lessons learned will be compiled in order to provide TxDOT with valuable insights.

2.2 Define

During the "Define" Phase, the Task Force will work together in order to narrow down and select the most critical technologies from those in the transportation portfolio. The Performing Organization will conduct a competitive analysis, reviewing pilot programs and initiatives of other entities and identifying areas in which TxDOT can differentiate itself as a leader in its class.

In collaboration with the Sponsoring Organization, a short list of viable pilot projects will be developed in order to focus the Task Force's energies. Using the recommended list of pilot projects as a guide, the Task Force will invite state, regional, and local leadership to participate in Task Force meetings. By engaging with community partners and key stakeholders, the Task Force will gather input and feedback required to assist in the prioritization of the pilot programs.

At the conclusion of the "Define" phase, the Performing Organization will recommend a vision and opportunities for strategic programs and initiatives in order to promote the advancement and integration of transportation technologies in Texas. Leveraging Task Force member expertise, the Performing Organization will enhance the Strategic Technology Business Plan (STBP) by

contextualizing technologies within the Texas transportation system. As a supplement to the vision and STBP, the Performing Organization will provide information to form the basis of a communication strategy that may be used to convey TxDOT's vision to key audiences.

2.3 Demonstrate

The Performing Organization will identify areas where TxDOT has a unique and leading advantage for establishing programs or initiatives for emerging technologies. The Task Force will establish a framework to measure the performance of small pilots or trials that are deployed by the Sponsoring Organization. Building upon lessons learned, the Task Force will propose recommendations for the Sponsoring Organization's review regarding the scaling of the small pilots or trials into statewide services.

2.4 Deliver

The Performing Organization will continue to provide guidance to TxDOT regarding the evaluation of emerging technology programs or initiatives. The Task Force will create a framework and assist in the identification of the necessary steps to realize the vision for strategic opportunities in Texas. The Performing Organization will develop another Transition Plan to provide a detailed description of next steps for further research work, Task Force meetings, and recommendations.

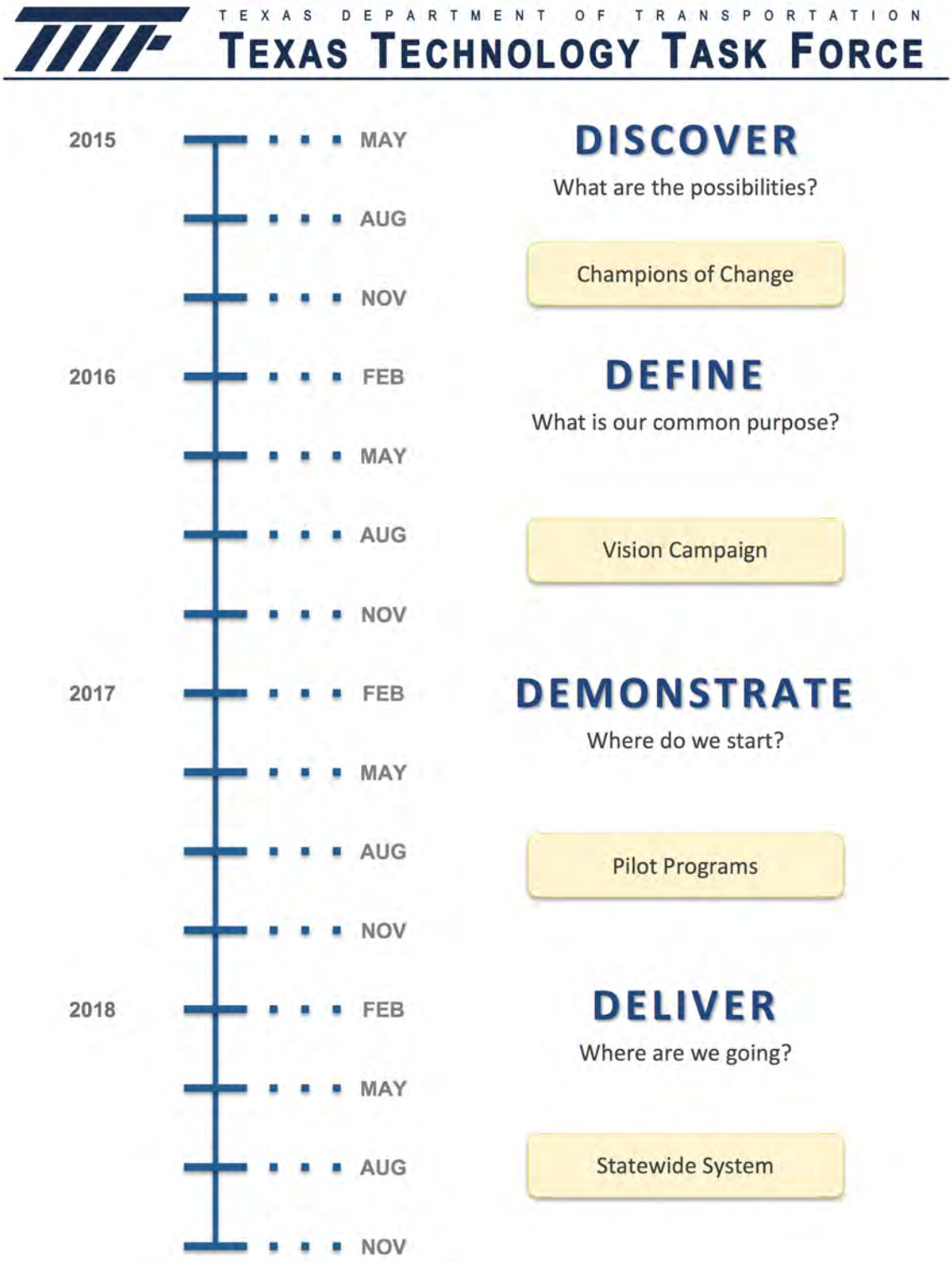
3. Further Research Work and Next Steps

In order to remain current in the wake of rapid technological advancements, the Performing Organization will conduct further research by building on lessons learned from research in transportation and non-transportation fields. Sources will include private, academic, and nonprofit sectors and draw on the nation's capacity in academia, industry, and elsewhere as needed. Research will continue to expand on modes (e.g., rail, airports, pedestrian, bicycling), technologies (e.g., virtual reality, materials, etc.), pilot programs (successes and failures), policies (federal, state, and local), as well as other social and economic factors influencing consumer behavior.

APPENDIX A: Proposed Deliverable Timeline

Deliverable Description	Due Date	Comments
Technical Memorandum	11/31/2015	Agendas, detailed panel descriptions, and minutes will be attached in appendix
Technical Memorandum	11/31/201	Revisions or additions to the SWOT analysis of identified technologies for Texas adoption will be attached in appendix
Technical Memorandum	7/31/2016	Results from the pilot program competitive analysis
Technical Memorandum	7/31/2016	A list of new Task Force members along with title and contact information will be provided in appendices
Technical Memorandum	7/31/2016	Presentations will be attached in appendix
Technical Memorandum	7/31/2016	Presentations will be attached in appendix
Technical Memorandum	7/31/2016	Will include a summary of activities that lead to Receiving agency press releases or other media content
Technical Memorandum	3/31/2016	Agendas, detailed panel descriptions, and minutes will be attached in appendix
Technical Memorandum	3/31/2017	Agendas, detailed panel descriptions, and minutes will be attached in appendix
Technical Memorandum	3/31/2018	Agendas, detailed panel descriptions, and minutes will be attached in appendix
Research Report	7/31/2016	A full research on activities for FY 2016 will be submitted.
Research report- Enhancements to the Strategic Technology Business Plan	7/31/2017	A full research report on activities for FY 2017 will be submitted and will include a final short list of recommended areas for pilot projects, trials, and/or initiatives to consider in greater detail.
Research report – Transition Plan	7/31/2018	A full research on activities for FY 2018 will be submitted.
Summary of work performed, findings and recommendations	7/31/2017	
Monthly Progress Reports	3 days following the end of each month	

APPENDIX B: Proposed Three-Year Work Plan Outline



Appendix G: TTTF Meeting Materials

Phase III

Texas Technology Task Force

The Future of Transportation

TEXAS TECHNOLOGY TASK FORCE

VISION

The TTTF is committed to advancing the development of a state of the art transportation system to position Texas as the leading nexus of economic activity and technological innovation.

MISSION

Support the Texas Department of Transportation by outlining clear, actionable strategies and enhancing the delivery of quality transportation services.

BACKGROUND

Authorized by Texas's 83rd Legislature General Appropriations Bill, S.B. No. 1, Item 44, VII-31, the Texas Department of Transportation (TxDOT) established the Texas Technology Task Force (TTTF) in 2013 to develop a vision for the future of Texas's transportation systems.

PHASE I (February to August, 2013) began with a core knowledge group that sought experts in various transportation technologies. The initial Emerging Technology Portfolio was presented and a public-private consortium was established to further develop key emerging technologies.

PHASE II (September to December 2013) focused on the background research pertaining to the Strategic Technology Business Plan (STBP) and outlined steps for completion in the next phases.

PHASE III (September 2014 to August 2015) is dedicated to updating the Emerging Technology Portfolio, completing the STBP, and establishing a transition plan for implementation.

TASK FORCE GOALS

The overall goals of the Task Force are to

- Identify emerging technologies;
- Analyze economic, engineering, and policy impacts; and
- Develop strategies to integrate and advance emerging technologies.

PHASE III DELIVERABLES

- Emerging Technology Portfolio
- White Papers on Critical Technologies
- Strategic Technology Business Plan (STBP)

TEXAS TECHNOLOGY TASK FORCE

PHASE III TASK FORCE PARTICIPANTS (TENTATIVE)

Public Agencies

Darran Anderson

Chief Strategy & Innovation Officer
Texas Department of Transportation

Mike Heiligenstein

Executive Director
Central Texas Regional Mobility Authority

Michael Morris

Director of Tranportation
North Central Texas Council of Governments

Thomas Bamonte

Assistant Executive Director of Strategy and Innovation
North Texas Tollway Authority

Industry

Shelley Row

President & CEO
Shelley Row Associates, LLC

Harry Voccola

Senior Vice President
Nokia Location & Commerce

David Ferdman

Founder & Director
CyrusOne, Inc.

JD Stanley

Executive Director
Central Texas Regional Mobility Authority

Research

Steve Dellenback

Executive Director, Intelligent Systems
Southwest Research Institute

Srimat Chakradhar

Department Head
NEC Laboratories

Michael Manser

Program Manager
Texas A&M Transportation Institute

C. Michael Walton

Executive Director
Central Texas Regional Mobility Authority

TEXAS TECHNOLOGY TASK FORCE

EMERGING TECHNOLOGY PORTFOLIO

DETAILED EMERGING TECHNOLOGY PORTFOLIO

Next Generation Vehicles
Autonomous Vehicles
Connected Vehicles
Electric Vehicles
Unmanned Aerial Vehicles

Infrastructure & Construction
Infrastructure Enhancements
Construction Techniques
Equipment

Information & Communications
Cloud Computing
Crowdsourcing

Service-Based Platforms
Location-Based Services
Transportation Subscription Services

Materials & Additive Manufacturing
Self-Healing Pavements
Nanotechnologies
3D Printing

Other Technologies
Google Glass
Virtual Reality

MAINTAIN A SAFE SYSTEM. CONNECT TEXAS COMMUNITIES. BECOME BEST-IN-CLASS STATE AGENCY. ADDRESS CONGESTION.

TEXAS TECHNOLOGY TASK FORCE

CRITICAL TECHNOLOGIES

Unmanned Aerial Vehicles (UAVs)

Unmanned Aerial Vehicles (UAVs) have potential applications in law enforcement, border control, agriculture, traffic control, and freight. Rapid delivery of lightweight commercial products using UAVs has been proposed by Amazon and Google X's program known as "Project Wing." Policymaking is underway concerning the civil applications of UAVs and the FAA has selected six states to host test sites.

Automated Freight

The use of autonomous long-haul trucks (ALHTs) could add up to a multibillion-dollar opportunity for companies throughout the trucking value chain, and in turn, lower prices for consumers. Combined with 3D printing and last-mile solutions, Texas has the opportunity to overcome urban freight challenges, reduce the impacts on its infrastructure, and grow the state's economy.

Big Data

Cloud computing and crowdsourcing technologies are revolutionizing transportation. Companies from IT service providers and OEMs are making advancements in the collection, storage, management, and integration of data. Application programming interfaces (APIs), smartphone platforms, and open data portals are enabling consumers to share information with one another and public agencies.

Connected Vehicles

Connected vehicles will directly impact areas of safety and mobility. Using cellular or DSRC technology, vehicles may connect with one another (V2V) and/or with the infrastructure (V2I). When applications such as collision warning, automatic incident reporting, and emergency vehicle signal priority are combined, connected vehicles have the potential to move Texas towards a goal of zero traffic fatalities.

3D Printing

3D printing allows for mass customization, express manufacturing, and rapid prototyping. Major OEMs are incorporating 3D printed components, while Local Motors and others are fully 3D printing the car chassis and body. When 3D printing combines with cloud computing, decentralized production and distribution may be achieved, alleviating congestion and lowering the impact of freight vehicles on the roadways.

TEXAS TECHNOLOGY TASK FORCE

TRANSFORMATIVE TOPICS

Revolutionizing the Global Logistics Industry

Moderator**:** Shelley Row, *President & CEO – Shelley Row Associates, LLC*

By integrating 3D printing and truck platooning technologies, Texas can modernize its freight transportation system and position itself for future economic competition. As traditional logistic models continue to evolve, it is important to discuss the potential to cut lead time, customize production, and improve reliability in timely delivery.

Skip Yeakel, *Principal Engineer – Volvo Group North America*
Jack Levis, *Senior Director of Process Management – UPS*
Antonio Williams, *Ph.D. - PARC*

Understanding the Opportunities & Challenges of Drones

Moderator: Michael Morris, *Director of Transportation, NCTCOG*

The versatility of UAV technology has implications for transportation, agriculture, and business. Key applications include bridge inspection, crop yield evaluation, and package delivery. It is also critical to examine the role public agencies will play in developing standards and regulations for R&D and operations.

Brian Wynne, *President & CEO – AUVSI*
Ronald George, *Senior Research Development Officer – FAA UAS Test Site*
Alvin Brunner, *FAA Flight Standards Division – FAA*

Using Big Data as a Tool for Managing Customer Relationships

Moderator: JD Stanley, *Executive Director – Cisco Systems, Inc.*

Translating data into meaningful information empowers public agencies, government officials, and consumers to make better informed decisions. Analysis improves asset management, understanding of community needs, and public awareness. Issues of privacy, data collection, and system maintenance are all integral to this conversation.

Joseph Kopser, *President & CEO – RideScout*
Mansour Raad, *Data Scientist – Esri*
A. Stewart Fatheringham, *Professor – Arizona State University*
Josh Johnson, *Assistant Director – Southwest Research Institute*

TEXAS TECHNOLOGY TASK FORCE

Meeting: **Texas Technology Task Force, Phase III, Meeting I**

Date: Monday, May 11, 2015 | 9:00am – 5:00pm

Location: TxDOT 125 E 11th Street, Ric Williams Room

In Attendance: Darran Anderson, TxDOT; Kent Marquardt, TxDOT; Stacey Strittmatter, TxDOT; Thomas Bamonte, NTTA; Mike Heiligenstein, CTRMA; Michael Morris, NCTCOG; Shelley Row, Shelley Row Associates LLC; JD Stanley, Cisco; Srimat Chakradhar, NEC Labs; Skip Yeakel, Volvo; Brad McDonald, Stratasys Direct Manufacturing; Eric Jackson, Stratasys Direct Manufacturing; Alvin Brunner, FAA; Karen Ulferts, AUVSI; Josh Johnson, SwRI; Jospeh Kopser, RiseScout; Eric Hoel, ESRI; C. Michael Walton, UT-Austin, Andrea Gold, UT-Austin; Kristie Chin, UT-Austin

Project Overview – *Andrea Gold & Kristie Chin, UT-Austin*

- The Texas Technology Task Force (TTTF) started Phase I in 2013. The group is currently moving into Phase III.
- Accelerate Texas was a product of Phase I of TTTF which included the Strategic Planning Initiative. The group paused for the Texas Department of Transportation (TxDOT) Sunset Review. It started again in September 2014.
- The UT research team plans to schedule the next meeting for August 2015 with a follow up meeting in the fall of 2015.
- During Phase I, the TTTF focused on four main groups:
  - Connected Vehicles
    - Several different kinds of Connected Vehicle programs were studied.
  - Automated Vehicles
    - Automated Vehicles from Level 0 – Level 4 were reviewed.
  - Electric Vehicles and Systems
    - This includes projects like one studying whether electric cars can be charged as they are being driven down certain kinds of roads. They also studied alternative methods of powering vehicles.
  - Cloud Computing
    - This area covers big data, cloud computing, crowd sourcing.
- The research group also studied combining these new technologies to see which produced the synergistic benefits. The top level would be fully automated and connected vehicles, which they dubbed, the "Automated Highway System."
- During Phase II, TTTF developed the vision, mission, and goals for the task force. They also prepared an outline for the business plan.
- During Phase III, they will be updating the Emerging Technology Portfolio to encompass multimodal applications. This includes next generation vehicles, infrastructure and construction, materials and additive manufacturing, information and communications, service-based platforms, and other technologies.
- The critical technologies to be studied during the first meeting include:
  - Automated Freight
  - Connected Vehicles
  - 3-D Printing
  - Unmanned Aviation Vehicles (UAVs) and
  - Big Data
- The goals for the meeting included determining priorities and providing new topics for white papers.

Updates on Strategic Initiatives – *Kent Marquardt*

- The mission for the newly formed Office of Strategic Planning (OSP) includes finding more cost effective, efficient, and sustainable transportation opportunities. These could potentially include initiatives like fuel-efficient vehicles and ways to reduce the number of vehicle miles traveled.
- OSP will be working with the Commission to develop the future focus of the office this summer.
- After Kent's discussion, it was asked if these technology solutions are serving the customer. The response was that the market would decide.

Transformative Topic: Revolutionizing the Global Logistics Industry – *Skip Yeakel, Volvo*

- Mr. Yeakel represents Volvo. He pointed out that Volvo is an American made trucking company. They are very focused on customer needs.
- The latest technology they are pursuing is a connected vehicle strategy. This strategy breaks down into three parts:
    - Connected to Support: Remote diagnostics allows the trucks with maintenance issues to be repaired as quickly as possible. This has reduced the average uptime by one day per event.
    - Connected Vehicles to the Road: The vehicle remembers frequent routes to use fuel in the most efficient way possible. The vehicles can also use kinetic energy from the trip to help power the vehicle. These innovations save 5% of fuel costs.
    - Connected to Each Other: This includes Volvo's Vision 2020 plan to have semi-automated trucks on the road by 2020.
- The improved service professional will fix Volvo trucks much faster than in the past.
- The trucking industry uses the same technical language that was decided in the 1980s. This allows new innovations like current safety features to be adopted across many companies very quickly.
- A question from the group asked, "What is the likelihood of transferring platooning tech to personal motor vehicles?" The response was that it could become a reality because of the work being done at Trusted Truck Technology (TRB) in Knoxville, TN.
- It was pointed out that Federal regulations may be behind technologies. The distance required between trucks and vehicles is no longer necessary. Mirrors on trucks are really no longer needed due to the cameras on trucks.

Transformative Topic: Revolutionizing the Global Logistics Industry – *Brad McDonald & Eric Jackson, Stratasys Direct Manufacturing*

- Chuck Hall of 3-D Systems started making 3-D printers in the mid-1980s.
- All of the technologies used at Stratasys are available to see at the Belton, TX facility.
- The company mainly focuses on additive manufacturing. This includes adding one material at a time to make the product. They use this process to make production grade materials and supplemental materials.
- They focus on prototype pieces that are early in the development cycle.
- They have between 55-100 FOM machines. These machines can lay materials to 10,000th of an inch. The amount of time it takes to create an object depends on the complexity and size.
- They can also make items with support materials that are water-soluble. This means that once the piece is complete the support materials can be removed by placing the piece in water.
- 3-D printing will be a $20 Billion industry by 2020.
- The objects are mostly used in product development. The aerospace industry buys a lot of 3-D printed items.
- 3-D printing also allows you to specialize any item.

Transformative Topic: Understanding the Opportunities & Challenges of Drones – *Karen Ulferts, AUVSI*

- This session began with a TED Talk on drones as a weapon. The TED Talk called for an international treaty for robotics weapon control and a ban on killer robots. There is a U.S. directive that every kill decision must be made by a human, but it is not a permanent directive. The speaker still wanted the U.S. to use drones and automated vehicles but he would like them to be unarmed and all contain serial numbers that can be tracked by all American citizens.
- Ronald George wants a safety warning for the UAVs in our airspace but he would also like to push the technology.
- He believes they can be used in the following areas:
    - Natural Disaster Assessment
    - Construction Monitoring
    - Accident Reconstruction and
    - Design & Asset Management
- The consensus was that TxDOT should support UAV research as long as transparency is the main priority.

Transformative Topic: Understanding the Opportunities & Challenges of Drones – *Alvin Brunner, FAA*

- He pointed out that this is another area where the regulations cannot keep up with the technology. He also explained that economics has pushed these technologies to the forefront. Safety has not always been the top concern.
- A UAV must meet the following criteria:
  - Unmanned
  - Aircraft Control System and
  - Command & Control Links
- The operations of UAVs are good for dangerous and dull tasks. Humans are not at risk. UAV operations cost less than manned aircrafts.
- U.S. air space is public space. UAVs are subject to regulations.
- He explained that the FAA knows a lot about airplanes but does not currently track information on drones. The FAA wants them to all be registered.
- FAA does not regulate model aircrafts.
- The following website was recommended for further information www.knowbeforeyoufly.org
- The FAA is currently in a rulemaking process that would require all drones to be registered and would not all drones to fly over people.

Transformative Topic: Using Big Data as a Tool for Managing Customer Relationships – *Josh Johnson, SwRI*

- With connected cars we could collect 1TB of data in 10 seconds. One month's worth of data could be stored in the world's largest database. Even if we do not save the data, we should be analyzing the data.
- As systems advance, we will be able to take the weather, events, and things like school closings into consideration to better predict traffic.
- Josh suggested an article on A.I. in the Economist.

Transformative Topic: Using Big Data as a Tool for Managing Customer Relationships – *Joseph Kopser, RideScout*

- Ridescout was launched in 2013 in Washington, DC. The app compares all available modes of transportation, takes traffic and the cost of the transportation into account, and then provides the best mode of travel at that specific time and place.
- His objective includes three parts:
  - Seamless Experience – Make it as easy as possible to see all available modes at once.
  - Lifestyle Integration – Use all available data about a person.
  - Single Sign-on – Make the app easy to use.
- He is very concerned about information security. The app is PCI compliant through Braintree. The user data is anonymized to the public and the data is hosted on google cloud.

Transformative Topic: Using Big Data as a Tool for Managing Customer Relationships – *Eric Hoel, ESRI*

- Disk space is cheap, Hadoop is free, and extra commodity hardware is abundant. Though lots of data is being collected, there is not a lot of analysis.
- Most companies are waiting on finding undetected patterns in the data.
- Automated vehicles are driven by video data.
- A question was asked about RideScout using public and private data. Joseph explained that start-ups are processing public data faster than the State Government can regulate. He was surprised to find that Government camera footage is not stored because they do not want the footage to be used in a court case. They also do not want to provide this information to private companies because of the privacy loss.

Forum: Building a Strong Foundation – *Mike Heiligenstein, CTRMA*

- Mobility Authority – We will never have enough infrastructure capacity to serve the growing population in Texas.
- They are focused on
  - Cashless Tolling
  - Dynamic Tolling
  - Smart Roads and
  - Developing user-based applications to maximize capacity and change behavior.
- Metropia is a traffic management and navigation app. It reduces congestion, saves time, reduces CO_2 and GHG emissions, rewards behavior change, and provides safety feedback.
- Carma is similar to the slugging practice in DC. It will reduce or eliminate tolls for those who carpool.
- Mike H. is interested in how human behavior plays into these transportation choices. How can we influence people to make certain travel choices?

- It was suggested that instead of toll lanes we could have technology lanes to motivate people to be early adapters of connected or automated vehicles.
- It was pointed out that car turnover is between 5-7% each year so it would be a long time before there were a lot of automated vehicles on the road. It was also suggested that this new technology might influence more people to change faster similar to how quickly smart phones took over the cell phone market.
- When is the Texas state legislature going to allow automated vehicles on the road? They would like to test them on State and National holidays when there are fewer people on the road. So far the test of the cars in parking lots and test sites has gone well.
- It was asked if there are opportunities to work with other state DOTs so we are not all running the same tests.
- It was asked how we can predict what kinds of cars will be on the road in 5 years or 10 years.
- Someone suggested that connected vehicles are being pushed by regulation but that the market is pushing for automated vehicles.

Forum: Developing a Common Vision – *Darran Anderson, TxDOT*

- Darran explained that we have formed the TTTF so we do not wander blindly into the future. They are hoping to have a finalized KPM document by the end of the summer.
- Darran provided a list of 10 things he would like to see come out of this meeting:
  - The TTTF members to identify the leading technologies for the future.
  - He called for a research agenda and a long range strategy.
  - TxDOT has to work with the DDOs, MPOs, and local authorities to get buy in into these new initiatives.
  - He asked the industry partners to help us identify industry forums.
  - He also asked them for ideas for our communication plan. What will shape hearts and minds?
  - He asked them to identify policy areas that TxDOT can implement.
  - Establish standards for business operations / regulatory suggestions.
  - He asked if there are any environmental sustainability initiatives we should explore. Are there any infrastructure issues?
  - What kinds of training / certifications should we explore?
  - He asked for a list of potential projects. For example, one project could be what kinds of communication elements (like Google Fiber) should we incorporate in infrastructure maintenance?
  - He would like all future projects to have technology gates tied to the project gates.

Closing Remarks – *C. Michael Walton*

- He asked all of the team members for their thoughts and thanked everyone for participating in the meeting.

Phase III

Texas Technology Task Force

The Future of Transportation

TEXAS TECHNOLOGY TASK FORCE

VISION

The TTTF is committed to advancing the development of a high-performance transportation system to position Texas as the leading nexus of economic activity and technological innovation.

MISSION

Support the Texas Department of Transportation by outlining clear, actionable strategies and enhancing the delivery of quality transportation services.

BACKGROUND

Authorized by Texas's 83rd Legislature General Appropriations Bill, S.B. No. 1, Item 44, VII-31, the Texas Department of Transportation (TxDOT) established the Texas Technology Task Force (TTTF) in 2013 to develop a vision for the future of Texas's transportation systems.

PHASE I (February to August, 2013) began with a core knowledge group that sought experts in various transportation technologies. The initial Emerging Technology Portfolio was presented and a public-private consortium was established to further develop key emerging technologies.

PHASE II (September to December 2013) focused on the background research pertaining to the Strategic Technology Business Plan (STBP) and outlined steps for completion in the next phases.

PHASE III (September 2014 to August 2015) is dedicated to updating the Emerging Technology Portfolio, publishing white papers on critical technologies, and drafting the STBP.

TASK FORCE SERVICES & OBJECTIVES

The Task Force offers services in the following areas:

- *People* – Form a core knowledge group and network of subject matter experts
- *Portfolio* – Identify emerging technologies and analyze potential impacts
- *Plan* – Develop key strategies to integrate and advance critical technologies

VALUE TO TXDOT

Community of Expertise

Relevance

Knowledge Transfer

Actionable Recommendations

Positive Visibility

VALUE TO THE CUSTOMER

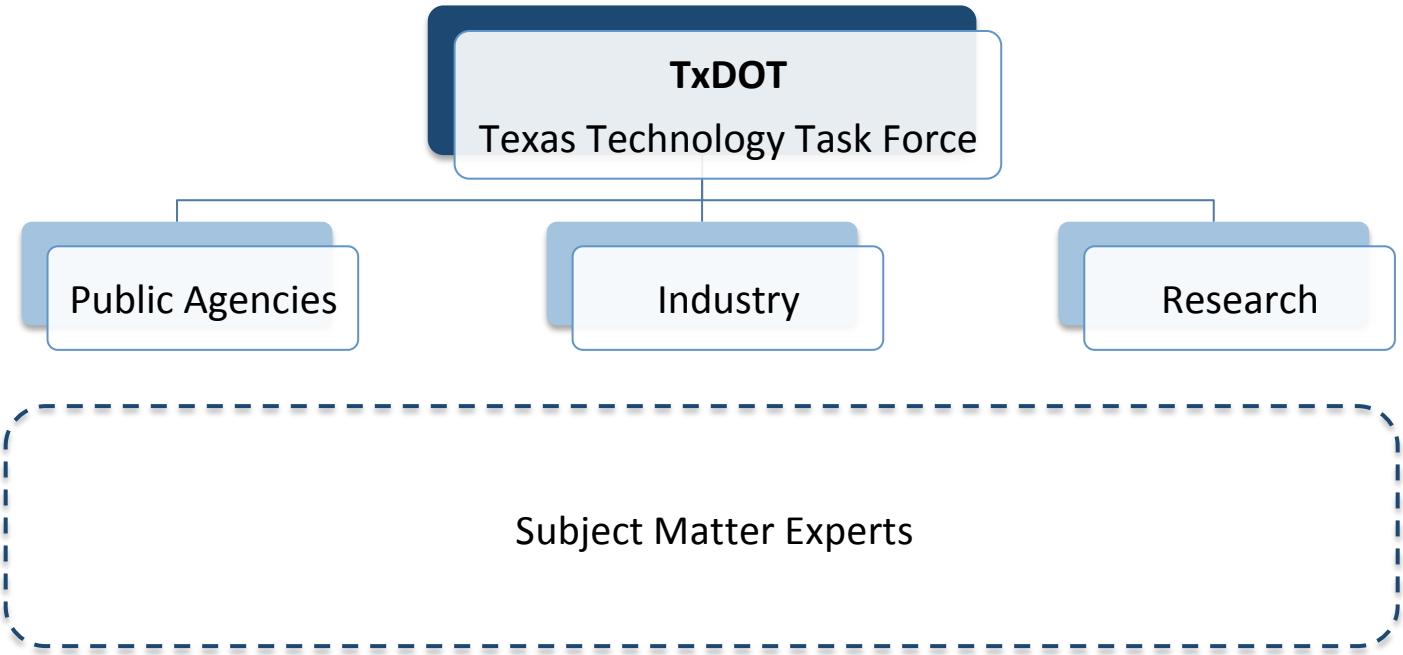
Customer Trends

Transparency & Accountability

Technology Transfer

TEXAS TECHNOLOGY TASK FORCE

COMPOSITION



Public Agencies

Thomas Bamonte
General Counsel
North Texas Tollway Authority

Mike Heiligenstein
Executive Director
Central Texas Regional Mobility Authority

Michael Morris
Director of Transportation
North Central Texas Council of Governments

Industry

David Ferdman
Chief Strategy Officer
CyrusOne, Inc.

Shelley Row
President and CEO
Shelley Row Associates LLC

JD Stanley III
Global Director of Strategy & Integrated Solutions | Data & Analytics Business Unit
Cisco

Harry Voccola
Executive Advisor
Nokia/HERE

Research

Srimat Chakradhar
Department Head | Integrated Systems
NEC Laboratories America, Inc.

Steve Dellenback
Executive Director of R&D
Southwest Research Institute

C. Michael Walton
Cockrell Centennial Chair in Engineering | Department of Civil, Architectural & Environmental Engineering
University of Texas at Austin

TEXAS TECHNOLOGY TASK FORCE

EMERGING TECHNOLOGY PORTFOLIO

DETAILED EMERGING TECHNOLOGY PORTFOLIO

Next Generation Vehicles & Energy
Autonomous Vehicles
Connected Vehicles
Electric Vehicles
Unmanned Aerial Vehicles

Information & Communications
Cloud Computing
Crowdsourcing

Materials & Additive Manufacturing
Self-Healing Pavements
Nanotechnologies
3D Printing

Infrastructure & Construction
Infrastructure Enhancements
Construction Techniques
Equipment

Service-Based Platforms
Location-Based Services
Transportation Subscription Services

Other Technologies
Google Glass
Virtual Reality

MAINTAIN A SAFE SYSTEM. CONNECT TEXAS COMMUNITIES. BECOME BEST-IN-CLASS STATE AGENCY. ADDRESS CONGESTION.

TEXAS TECHNOLOGY TASK FORCE

CRITICAL TECHNOLOGIES

Open Data Portals

Creating a centralized repository of information enhances the efficacy of multiple stakeholder operations. By integrating and standardizing data, port community systems and traffic management centers can break down silos and encourage the development of a multimodal interface. Open data may also enable third parties to leverage the data through the creation of applications and services that address public and private demands.

Robotics

Advanced robotics has the potential to affect $6.3 trillion in labor costs globally. From collaborative welding in automotive manufacturing to automated loading and unloading operations at port terminals, increasingly sophisticated robots are improving productivity. As the labor market continues to evolve, robotics skills will play a crucial role in modernizing the Texas economy to take advantage of industry growth opportunities.

RFID

Radio frequency identification (RFID) may be used for radical improvements in intelligent transportation systems. To address the issues of congestion, security, and air quality, ports can utilize RFID transponders to expedite the identification and authentication process. RFID may also be used as part of a major multimodal smart card system that incorporates local, regional, and state infrastructure to provide Texas travelers with seamless connectivity.

Cybersecurity

By the year 2020 it is projected that more than a billion connected M2M (machine-to-machine) devices will be in highway transportation, of which more than half will be road vehicles. With the new insights promised by big data, there are also concerns about the privacy and security of these devices. Public agencies will need to protect their citizens and infrastructure by minimizing risks to safety and mobility systems.

Smart Cities

Transportation is the key to developing a network of smart cities. As urban populations continue to grow and consumer behavior shifts towards e-commerce, municipalities will need to work closely with the freight industry to address logistical challenges. By using transportation investment as a catalyst, Texas can fuel sustainable development for citizens' energy, water, communications, health, and public safety.

TEXAS TECHNOLOGY TASK FORCE

(DRAFT) TRANSFORMATIVE TOPICS

Port Investment as a Gateway to Innovation

Moderator**:** Shelley Row, *President & CEO – Shelley Row Associates, LLC*

Maritime, air, and inland ports are tightly interwoven components of the state economy. By advancing technologies such as Green Lanes, NextGen air traffic control, and multimodal distribution systems, Texas can improve operational efficiency and expand network connectivity. Understanding the implications of energy development as well as the Panama Canal expansion are also critical to seizing opportunities for future growth.

SME #1, *Seaport Technology*
SME #2, *Airport Operations*
SME #3, *Inland Port Logistics*

Protecting the Privacy & Cybersecurity of Civic Data

Moderator: Steve Dellenback, *Executive Director of R&D – Southwest Research Institute*

Privacy and security issues are magnified by velocity, volume, and variety of big data. To fully realize the benefits of real-time traffic management information or origin-destination patterns, it is imperative that Texas manage the risks and take the necessary steps to protect its citizens. Essential to the success of these efforts are solutions that are secure, reliable, and privacy-enhancing.

SME #4, *Data Ownership*
SME #5, *Data Security*
SME #6, *Data Privacy*

Intelligent Commerce Fuels Smart Cities

Moderator: Harry Voccola, *Executive Advisor – Nokia/HERE*

With 66 percent of the world's population expected to live in urban areas by 2050, the Texas freight industry must adapt to remain competitive. City planners will need to address the increase in e-commerce, location of distribution centers, and introduction of new delivery service business models. By responding to trends in consumer behavior, Texas can develop an intelligent infrastructure to support smart cities.

SME #7, *Urban Freight & Logistics*
SME #8, *Customers & Urbanization*
SME #9, *OEM Solutions*

TEXAS TECHNOLOGY TASK FORCE

(TENTATIVE) AGENDA

DATE August 11, 2015
TIME 9:00am – 5:00pm
LOCATION TxDOT, Ric Williamson Room

9:00 AM **Welcome** – General Weber*, TxDOT & Dr. C. Michael Walton, UT Austin*

9:15 AM **Project Overview** – *Andrea Gold & Kristie Chin, UT Austin*
Introduce the project, outline its development through Phase III, and present the highlights of the Strategic Technology Business Plan.

9:45 AM **Updates from the Office of Strategic Planning** – *Stacey Strittmatter, TxDOT*
Provide an update on strategic initiatives that are pertinent to the objectives of the TTTF.

10:00 AM **Discussion**

10:20 AM **Break**

10:30 AM **TRANSFORMATIVE TOPIC: Port Investment as a Gateway to Innovation**
Moderator: Shelley Row, *President & CEO – Shelley Row Associates, LLC*
SME #1 – Seaport Technology
SME #2 – Airport Operations
SME #3 – Inland Port Logistics

11:30 PM **LUNCH PRESENTATION: UAVs in Action, an Update from the Corpus Christi Test Site**
Introduction: Srimat Chakradhar, *Department Head – NEC Laboratories America, Inc.*
Ronald George, Senior Research Development Officer – Corpus Christi UAS Test Site

12:00 PM **TRANSFORMATIVE TOPIC: Protecting the Privacy & Cybersecurity of Civic Data**
Moderator: Steve Dellenback, *Executive Director of R&D – Southwest Research Institute*
SME #4 – Data Ownership
SME #5 – Data Security
SME #6 – Data Privacy

1:00 PM **Break**

1:15 PM **TRANSFORMATIVE TOPIC: Intelligent Commerce Fuels Smart Cities**
Moderator: Harry Voccola, *Executive Advisor – Nokia/HERE*
SME #7 – Urban Freight & Logistics
SME #8 – Customers & Urbanization
SME #9 – OEM Solutions

2:15 PM **Break**

2:30 PM **FORUM: Strategic Technology Business Plan –** *Dr. C. Michael Walton, UT Austin*
Discuss the proposed outline, identify areas of greatest potential, and develop a roadmap for completion.

3:30 PM **FORUM: Developing a Common Vision** – *Darran Anderson, TxDOT*
Synthesize the information presented throughout the day in order to identify key strategies, critical barriers, and priority areas that support TxDOT's mission.

4:30 PM **Closing Remarks** – *Dr. C. Michael Walton, UT Austin*
Participants recommend emerging technologies, additional subject matter experts, and supplementary research to enhance the Task Force's efforts.

5:00 PM **Adjourn**

TEXAS TECHNOLOGY TASK FORCE

Meeting: **Texas Technology Task Force, Phase III, Meeting II**

Date: Tuesday, August 11, 2015 | 9:00am – 5:00pm

Location: TxDOT 125 E 11th Street, Ric Williams Room

In Attendance: Darran Anderson, TxDOT; Stacey Strittmatter, TxDOT; Thomas Bamonte, NTTA; Mike Heiligenstein, CTRMA; Michael Morris, NCTCOG; Shelley Row, Shelley Row Associates LLC; JD Stanley, Cisco; Harry Voccola, Nokia/HERE; Srimat Chakradhar, NEC Labs; Steve Dellenback, Southwest Research Institute (SRI); Louis Noriega, Automated Port Solutions; Hugo Hernandez, Automated Port Solutions; Ryan Mariacher, Port of Houston; Joe Henry, Lone Star UAS; Mike Brown, Southwest Research Institute (SRI); Barry Einsig, Cisco Systems; Shantanu Rane, Palo Alto Research Center (PARC), Xerox; Jules Moise, UPS; Kevin Dyer, Walmart; C. Michael Walton, UT-Austin, Andrea Gold, UT-Austin; Kristie Chin, UT-Austin

Project Overview – *Andrea Gold & Kristie Chin, UT-Austin*

- They began the day by listing the transportation innovative projects being done in other states around the country including:
  - MI – M City Urban AV Test Bed
  - OR – VMT Pilot Program OReGO
  - CA – High Speed Rail
  - NJ – Port Automation; Readying the State for Automated Vehicles (AV)
  - VA – Automated Vehicle Corridors
  - FL – AV Summit
  - MO – Smart Highway System
- What is Texas Doing?
  - The Texas Technology Task Force (TTTF) was established by the legislature to plan 5-15 years out.
  - TTTF is bringing value to TxDOT and the customer. They started with four technologies. They then moved on to the research background stage.
  - On May 11, 2015 they held a meeting with industry experts to build a plan to move forward. The focus for TTTF will remain on the People, Portfolio, and Plan.
- May 11th Meeting - This meeting covered Automated Freight, Connected Vehicles, 3-D Printing, Unmanned Automated Vehicles (UAVs), and Big Data.
- They are developing 5 white papers based on the following topics:
  - Customer of the Future
  - Logistics
  - Opportunities & Challenges of UAVs
  - Using Data to Manage Relationships
  - Develop a Communications Plan
- August 11th Meeting – This meeting will focus on Open Data Portals, Robotics, RFID, Cybersecurity, and Smart Cities.
- TTTF Objectives are to engage the panelists, provide direction for the work plan, and identify new opportunities.

Updates from the Office of Strategic Planning (OSP) – *Stacey Strittmatter*

- OSP was created in the middle of 2014 by Darran Anderson and General Weber. OSP is now the sponsor for TTTF.
- OSP provides analysis and perspective to enable TxDOT leadership to anticipate, plan for, and guide the Department.

- OSP is currently working on a project to reevaluate the Vision, Mission, Values, and Goals (VMVG) for the Department. OSP began this initiative by working with Darran Anderson to prepare a Dashboard to measure and track performance measures. After discussions with the Commission it was decided that the VMVG should be reviewed. A Core Strategy Team (CST) was formed. They held focus groups across the state.
- Recommendations for revised Vision and Mission Statements have been provided to Administration. The new Goals and Objectives will be provided soon followed by the performance measures.
- The majority of the CST was chosen by Commissioner Vandergriff. He chose a team with a fresh, forward thinking perspective.
- There was some discussion on why Texas has not produced any innovative transportation technologies like the other states mentioned earlier. It was stated that TxDOT has been working to modernize the organization over the last several years which may have taken away some of the focus on innovative R&D. OSP is helping to make sure that we stay within our strategic priorities while also serving the Governor's office, the State Legislature, and the people of Texas. There has been some mention from the State Legislature that new technologies should be left to industry to figure out.
- While the word clouds from the focus groups were being shared it was pointed out that "Innovation" was not included as a value for the Department. This is one small indicator that it might be hard to push for innovation as a priority. Stacey pointed out that when we asked employees about their idea of "success" for the Department, innovative technologies were almost always mentioned.
- It was also acknowledged that states that have been doing this innovative research have received Federal grants for these programs. TxDOT has applied for similar grants but they have not made it through all of the gates. The other states also have a strong University focus.
- The Governor's office has an economic development team that could possibly become a more focused area now that session is over.

Transformative Topic: Developing Ports as Gateways to Innovation – *Louis Noriega, Automated Port Systems*

- Texas has a lot of ports. They are a major player in the Oil and Gas Industry. Houston is the 8th largest port in the country.
- The Panama Canal expansion is going to be a game changer. It is supposed to open in early 2016. They have had some construction strikes that have caused some delays.
- New York and New Jersey have invested money to increase terminals and raise bridges.
- The Port of Miami paid $1.2 billion to open a terminal at 54ft. This included rebuilding the wharf.
- Texas has been a leader in creating land ports to reduce congestion.
- At the Port of Miami each inbound and outbound interaction takes an average of 6 minutes. With the number of interactions they handle in a day, it can cause bottlenecks.
- The Port Identification and the TWIC cards are supposed to speed up the pre-security area. The containers then go through the Gate Mechanic Inspection Area. This reduces the number of overweight trucks on the road which will reduce accidents.
- Appointment systems are not approved by the truckers. They want to be able to dispatch the trucks based on their client's needs.
- The Green Lanes allow certain companies to go through security without stopping. It encourages companies to share data, preannounce their arrival, and arrive during a certain time period. If they comply with these rules then they can use the Green Lane. The trucks will then be able to be processed faster and make more money. This achieves a balance between technology and streamlining processes. This initiative can dramatically reduce turnaround times. This creates efficiencies and reduces labor costs.
- HD cameras will be able to detect damage to the truck. Gamma rays will determine when a truck is full.

Transformative Topic: Developing Ports as Gateways to Innovation – *Hugo Hernandez, Automated Port Systems*

- The trucker, the trip, and the cargo must be processed. It is usually a slow process.
- Sensors in the road can provide a lot of data without making the truck stop. Most of the things needed to implement this technology already exist.
- Implementing a Ground Transportation Management System like in an airport can prove to be very effective. They have started this in Miami to manage the number of cars around the ports.

Transformative Topic: Developing Ports as Gateways to Innovation – *Ryan Mariacher, Port of Houston*

- The Port of Houston has a 52 mile channel that runs from Galveston to Downtown Houston. They operate 7 facilities. People generally associate the port with the Oil and Gas Industry.
- Over the next couple of years they would like to break into the top 5 ports in the country. They moved 2 million twenty-foot equivalent unit (TEU) containers in 2014. They believe they will exceed that amount in 2015.

- They are planning on spending $5 million updating the terminal to double the capacity. They have added 4 cranes that they hope to have operational by October 2015. They are also densifying the yard.
- The Bayport terminal is also being expanded. They want to be a step ahead of the business surplus they expect to hit Texas. They have been able to handle the 20% increase in activity so far due to the dedication of their employees.
- The Port of Houston has minimized truck turnaround times and they are a leader in the number of moves per hour. The average truck time is 36 minutes. Cutting seconds off of this time can provide better logistics for the industry. They have partnered with outside agencies to make sure they are as connected as possible. Through partnerships with TxDOT and others they have provided infrastructure improvements on corridors around the port to create a non-stop atmosphere. There are 6,000 truck movements per day.
- They have a state of the art terminal operating system so they know who is where at all times. Through their Gate Operating Systems they can interface remotely with all trucks. They communicate through closed circuit TVs. They use imaging with the transactions to have visual proof.
- They are currently working on customer transparency. There is a redesigned website and an app so the public can track containers and see where / when they moved. A new effort has been started to upgrade the app to gather more information. Pulling information from the dispatchers avoids a duplication of effort.
- RFID technology will allow them to reduce stops and identify bottlenecks before they occur.
- A question was raised saying they were surprised that more advanced technologies are not being explored by the ports. He was surprised no one mentioned automation. It was mentioned that the Port of Houston does not have the same challenges as Rotterdam. They have a good relationship with their labor unions. They do not think choke points start where the labor unions are involved so they are not currently lobbying for automation just for the sake of automation.
- The cranes at the Port of Houston have auto-steering and laser capabilities. They are studying new operating techniques and looking for ways to update their infrastructure to meet these needs. From what they have seen of automation, it is not the fastest, but it is very consistent.
- Louis mentioned that the Port Community System enables the sharing of data between terminals. Within the cargo yards they are doing a great job but they are not communicating with each other frequently. Sharing this data can give you a more global view of the entire port, which will increase the capacities of all of the facilities. TxDOT might be a good partner in coordinating this communication between terminals.
- It was asked what kinds of upgrades to the transportation system they would like to see.
- Any upgrades would be appreciated but rail upgrades would be the most helpful. Road improvements across the state will help everyone and helps sustain growth.
- It was asked what their thoughts were on Big Data with how it pertains to Ports.
- The Port of Corpus Christi uses RFID technology. If Texas could look at New Jersey's model and require RFID sensors on all trucks then we would know where all of the trucks were in the state at all times. This can increase output. Sharing data is good for competition. It allows for more movement which increases revenue.
- Truckers do not like appointments but they do like being linked to the overall system so they know wait times to make the best decision for their business. Companies are still wary of sharing this data. TxDOT could help establish a system that would put those fears aside.

Lunch Presentation: UAVs in Action, an Update from the Corpus Christi Test Site – *Joe Henry, Lone Star UAS*

- Lone Star UAS has one of the 6 nationally approved test sites for UAVs by the FAA. With the Aerospace history in Texas, we should be a leader when it comes to UAVs. There have been some concerns that there are too many competing technological industries in Texas.
- Since they have been approved by the FAA, they have not been included in a lot of their discussions. Lone Star UAS has been trying to build this relationship by providing a lot of data to help the FAA while they are establishing new regulations for UAVs.
- Currently, the FAA has the following rules for UAVs:
  - You can only fly during the day.
  - You have to fly within eyesight.
  - You cannot fly within 500 ft of an airplane.
- The FAA also published a draft rule that said you must be 17 years of age to operate a drone. You must certify that you will operate it safely online and you must show that you have insurance. To get more specific rules, we will have to rely on the State Legislature.

- Lone Star UAS provides services to the Oil and Gas Industry to help make sure the drones they use are the best for what they are trying to accomplish. They have done work in the Gulf looking for oil spills and signs of potential oil spills. They have also done some search and rescue operations.
- As an approved test site, they have been given a broad waiver to fly over most of the US. They are also qualified to do night operations.
- There are a lot of complex issues surrounding the use of UAVs because people are not using them properly.
- A question was asked if the UAVs would focus on flying above highways.
- Joe does not think they will be above the highways anytime soon because you are supposed to avoid flying UAVs above people.
- There were some participants from Valero who mentioned that they believe the major use of commercial drones immediately will be photography.
- They also mentioned that the main customers for the FAA are the airlines so they are not sure how much attention is going to be given to UAVs. He thinks it might be better to focus on NASA.
- Battery life, miniaturization, and reduction in weight are the major areas for R&D with UAVs.
- The insurance companies are not that concerned about commercial drones that fly below 500 ft. They are not sure that they would grant policies to those who fly above 500 ft.
- Texas is a great place to test UAVs because we have lots of different kinds of infrastructure and there is a lot of available airspace.
- UAVs can be very useful to TxDOT, but the line of sight rule does prove to be sort of an issue. If we send UAVs out to do inspections, we have to follow the UAV with a car to make sure it stays within our line of sight. But they could definitely be very helpful with bridge inspections.

Transformative Topic: Protecting the Privacy & Cybersecurity of Civic Data – *Mike Brown, SRI*

- Connected vehicles (CVs) require a system or systems. The vehicles communicate with other vehicles, infrastructure, pedestrians, and bicyclists.
- Two technologies currently trying to be launched are emergency electronic brake lights and height & weight warnings. Emergency electronic brake lights would warn cars behind them when someone slams on the brakes and apply the brakes in the cars behind them before the drivers of those cars even see the brake lights. The height and weight warnings would warn trucks when they were approaching a bridge they cannot fit through.
- CVs use wifi, cellular signals, Bluetooth, and dedicated short range communications (DSRC). Most regulations are focused on DSRC. They are concerned with hackers. The Jeep hack involved wifi. The GM OnStar hack also used wifi. The Tesla hack was the result of a physical Trojan being put on the car. These incidents erode the public's trust in this technology.
- Most security analysts think DSRC is a much more secure system that will be harder to hack. NHTSA mandates that vehicles publish a basic safety message over DSRC every 10 seconds. If the signal is interrupted then they know someone is trying to hack they system.
- TxDOT can provide small pilot deployments to analyze the security and privacy impacts of CVs.

Transformative Topic: Protecting the Privacy & Cybersecurity of Civic Data – *Barry Einsig, Cisco Systems*

- Consumers want more and more connectivity. ATT connected 3 million GM vehicles to OnStar in one year.
- 100 years ago the US Government did not tell Ford how to make cars but the US Government got involved in producing safety standards and developing the roadways. We are at this stage for AV/CV.
- The US is not the top producer of cars anymore. These means we will not be deciding the future of these cars. We are going to have to understand global data standards since we produce cars that are shipped globally.
- Cisco is working on developing a Connected Intelligent Transport System using expert opinions, current and potential regulations, and global standards. They are working with the Federal Government to develop this system.

Transformative Topic: Protecting the Privacy & Cybersecurity of Civic Data – *Shantanu Rane, PARC, Xerox*

- Data collection is widespread and data breaches are common. Companies and the Government are not always good stewards of civilian data.
- The development of technological systems has been focused on utility and efficiency and not as focused on cybersecurity. Privacy for individuals must have different solutions than those for privacy for enterprise.
- There are broad research areas within data privacy:
    - Private Set Intersection
    - Multiparty Computation
    - Secret Sharing
    - Homomorphic Encryption

        - Signal Embedding
        - Differential Privacy
        - Anonymization
    - It was asked how many participants Cisco needs to roll out their transportation system.
    - They have seen some hesitation to participate but they know all new technologies go through this kind of hurdles. They want to make sure they put together the greatest system possible to get a wide variety of participants. Cisco will share design and implementation documentation to try to assuage any fears.
    - They want the Federal Government to have a fully formed roadmap moving forward.
    - It was asked if there are any new business solutions with regards to State agencies running transportation infrastructure.
    - They think this role may be diminished in the future. There was an example shown using roadmaps. State Departments of Transportation used to sell roadmaps. Then MapQuest & Google Maps became popular and people stopped buying state roadmaps.
    - How is the system integrity of connected vehicles being maintained?
    - This is a major issue now since all of the new technologies included in cars do not talk to each other. They need to work to integrate these systems and prevent interference.
    - Is DSRC more secure?
    - It is licensed. The wireless spectrum has a problem that they are only secure when they are obscure. As soon as everyone uses it someone figures out how to hack it. DSRC is secure because all you have to do is secure the umbrella, then all of the cars under that umbrella are secure.
    - If the car is a computer who is going to be in charge of the software controls?
    - We are going to have to utilize the best encryption technologies available to protect these cars. There should be standards in place to make sure bad encryption technologies are not being used.
    - Are there any concerns with the information TxDOT is collecting?
    - There are concerns about maintaining security while keeping costs low. Increasing transportation costs can kill business so they would not like to see any increases there.
    - Privacy concerns are always the last thought. They are usually added after the product is developed. It should be considered in the design process.
    - We should also study how to use the data we collect to help emergency responders and community planning. We must also maintain anonymity.
    - The risk of doing nothing is the worst option. TxDOT should start some pilot deployments and include more strategic planning. TxDOT should run as many scenarios as possible then develop mitigation plans to stop any future hacks.

Transformative Topic: Fueling Smart Cities through Intelligent Commerce – *Kevin Dyer, Walmart*

- Freight movement trucks are going to increase by 20%.
- Walmart has 7,600 professional drivers, 10,500 tractors, 600,000 trailers, and they log 800,000,000 miles per year.
- In 2010, they started an effort for fleet efficiency. They have made reductions with process efficiencies. They have only added one new distribution center in that time.
- With a movement toward urban development, they are producing smaller format neighborhood markets. These stores are mostly serviced by trucks even in bigger cities. They have a new focus on last mile services. They provide home delivery through direct to customer, remote pickup location, and fixed pickup location. They are working with third parties to deliver directly to the customer. They are doing this by using the following technologies:
    - Advanced Driver Assist Systems (ADAS)
    - Cameras
    - Radar
    - Electrification and
    - Automated Vehicle Communication
- All of their vehicles purchased after 2010 have accident avoidance capabilities. They have a concept freight vehicle that is powered by turbines. It has a composite trailer so it has a significantly reduced weight.

Transformative Topic: Fueling Smart Cities through Intelligent Commerce – *Jules Moise, UPS*

- UPS is a connected company. They have 90,000 drivers in the US. They are collecting data on braking, accelerating, seat belt usage, etc. They have driver mapping so they know where all of the drivers are located at all times.

- They can playback the driver's entire day to view performance. They can also use this to directly research customer complaints. They are currently rolling out the driver's fuel efficiency scorecard. They use a lot of optimization tools.
- They have a proprietary application called Orion that handles the logistics. This app provides a direct route for each driver to reduce the number of miles driven. They are working on improvements to Orion to re-optimize the route based on changes throughout the day. This upgrade should be live within a year or two.
- They utilize collision mitigation systems that can actually stop the vehicle at speeds up to 50 mph. They have a great safety record.
- There is a longer term strategy for "Smart Cab." This involves a driver assist system. It includes electronic logging devices. It measures idle time and enables machine to machine communication. This allows them to be ready as soon as the shipment arrives.
- The UPS manifest is maintained in the cloud. They can share data from the manifest with emergency responders pretty quickly. They also use mobile technology for their equipment inventory.
- They use smart trailers that have GPS and automated lock/unlock systems.
- They invest $1 billion in R&D each year.
- It was asked if platooning was still a viable technology.
- They are interested. UPS is investing in a company that is researching platooning. So far this company has found it produces a better safety record and fuel savings. They think this technology is still in the early stages. Walmart has not pursued this technology.
- What research have you done on the customer of the future?
- Walmart – Most of their new stores in urban areas are replacing stores that went out of business. So far, the neighborhood markets are successful in seeing customers return several times a week for smaller, mostly food, purchases.
- Are you looking at an Uber-like approach to delivering goods?
- Walmart – They are researching these kinds of solutions but since they are a low cost leader they have to make sure that these kinds of approaches do not raise the overall cost too much.
- Are you looking into UAVs?
- UPS – Yes, they have a team to develop this kind of technology.
- Walmart – Yes, but right now they are more concerned with selling drones then using them.
- What can TxDOT do to help?
- Walmart – Anything that can provide real time traffic updates and road projects would be useful. Most of their deliveries are between midnight and 6am. They want to have the shortest route possible.
- UPS – They work with the Federal and State Governments to build a good relationship. Any infrastructure improvements are always appreciated.
- Are there any improvements that can make travel more reliable?
- Both representatives from Walmart and UPS said their drivers are allowed to use toll roads. They support anything that improves schedules.
- Did you have a plan in place when you started collecting data or was it a happy discovery?
- Walmart – There was a strategic focus when they began collecting the data. They have found more uses for the data since they started collecting it.

Forum: Defining a Vision – *Dr. C. Michael Walton, UT Austin & Kristie Chin, UT-Austin*

- The plan for TTTF is to focus on discovery in 2015 to see who and what can be champions of change. They want to pull these people from the HQ at TxDOT to go to the Districts to highlight the technologies that TTTF is researching. Kristie and Andy would like to be Ambassadors for Change.
- In 2016, they would like to prepare a vision campaign to make sure equal focus is being placed on each technology so nothing important is overlooked.
- In 2017, they want to reach out to stakeholders and local communities so they can work with industry and universities to create pilot programs.
- In 2018, they will roll out the pilot programs.
- In 2019, they will evaluate these programs and tout their successes.
- In 2020, they will scale up the successful programs to address any barriers and put their best foot forward.
- An early success could be communicating the work we are doing so people can see the progress and see TxDOT's dedication to innovation.
- Don't Mess with Texas is a good example because it is a successful campaign.

- It is going to be hard to get the legislature and the public excited about new ideas unless we have a solid communication plan to back it up.
- In Florida, most of their projects have PR people on the team. Florida gets tons of national awards because they have people dedicated to seeking public recognition for their work.
- It was mentioned that the Texas IT system, Lone Star, is extremely successful but almost no one knows about it.
- We have to sell these projects with the transportation industry and the State Legislature.
- We should seek out areas ready for disruption where Texas can be a new leader.
- We should take advantage of the participation by companies like Walmart and UPS to strengthen our public private partnerships.
- There were some concerns that the timeline for the project is too long. They thought these pilot programs could be kicked off faster. But it was also mentioned that some of the pilot programs that are ready to go, like the Freight Corridors, are near term and TTTF is supposed to be more forward thinking.
- If we can add a personal story to the communication plan it will hit home with more people. The example of asking someone what the price of milk is was mentioned. They also think public events would be helpful.
- They think there should be a solid brand created for the project so all communications can be standardized to really drive home the message.
- There was some support for a pilot program making TxDOT a data center where we should focus on making as much data public as possible. There may be privacy issues and we are not sure if we know where all of the data is located.
- They are not sure we need to add any new topics at the next meeting but we should work on selecting pilot programs from the topics that have already been discussed. TTTF should begin an assessment to narrow the field and see where TxDOT can make the biggest splash.
- TxDOT would like to use the success of this program to request more funding for R&D in the future. The last ask was not successful because it was not specific. If we prepare a well-researched, synchronized approach we would probably be more successful.

Forum: Developing a Path Forward – *Darran Anderson, TxDOT*

- Darran shared his takeaways from the meeting:
  - There should be some focus on what TxDOT is doing compared to other states.
  - We should stop talking and start doing. TxDOT is a bit behind but we are working to catch up. We have found big savings in the efficiencies and innovations that have been implemented. They put together a two page list of small innovations that have been successful and had a positive return on investment. We need to get better about sharing this message. He thinks we are going to get one of the Federal grants.
  - The Innovation Council will hopefully be picking up steam. The Economic Council is being renamed as an R&D endeavor to pull PhDs and SMEs together to make Texas an R&D leader. Grants for this initiative are going to be up for grabs in September.
  - How to make ports more effective? – TxDOT would like to be more multi-modal. Maritime is working closely with the ports.
  - UAVs – TxDOT has prepared a white paper on this subject but we need to do more. Aviation is going to be a big voice in the regulations for UAVs.
  - Cybersecurity – UT has approached us about data sharing. We have been told to commoditize it and it to make it free. With google maps and other data available, he is not sure how much the TxDOT data will add. TxDOT is working on reviewing Information Management so we are sure where all of the data is located. We may need to seek outside expertise in this area.
  - Smart Cities – He heard them say they listen to their customers. It made him ask if TxDOT is really listening to our customers.
  - Work Plan – He hopes we can get Accelerate Texas moving. The change in leadership caused a hiccup. It needs to be reinvigorated. We will provide an update on Accelerate Texas at the next meeting. He would like to include Communications and SLA in the communication plan for this project.
  - He ended by saying the TTTF started with the State Legislature but it definitely has a strong backing within TxDOT.

Closing Remarks – *C. Michael Walton*

- He asked all of the team members for their final thoughts and thanked everyone for participating in the meeting.