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INDIANA DEPARTMENT OF TRANSPORTATION AND PURDUE UNIVERSITY

Developing a Business Ecosystem around Autonomous Vehicle Infrastructure in Indiana

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16. Abstract
INDOT will soon be embarking on infrastructure planning to accommodate autonomous vehicles. This new technology affords the ability to impact economic value creation across the supply chain in Indiana, as well as foster economic development in Indiana to support these emerging technologies. This proposal will be a first cut towards exploring the development of a strategy to realize this potential. Our proposal will consist of two phases.

Phase 1: A focus on industry choices and plans that can inform INDOT choices.
Phase 2: A focus on INDOT's internal decision making, risk tolerance, and choices regarding infrastructure projects.

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NOTICE

EXECUTIVE SUMMARY

Introduction

INDOT will soon be embarking on infrastructure planning to accommodate autonomous vehicles (AVs). This new technology affords the ability to impact economic creation across the supply chain in Indiana, as well as enable economic development in the state to support these emerging technologies. This proposal is a first cut toward exploring a strategy to realize this potential. Our proposal consists of two phases.

Phase 1: A focus on industry choices and plans that can inform INDOT choices.

Phase 2: A focus on INDOT's internal decision-making, risk tolerance and thus choices regarding infrastructure projects.

Findings

- After years of research and development, AVs have arrived. The developmental history of such vehicles can be traced to the early 1920s. Their development reached a critical mass in 2013, when autonomous driving was defined by the National Highway Traffic Safety Administration (NHTSA) (Fortuna, 2017).
- Significant research and development by major technology development companies have impacted the industry.
- Use of machine vision or computer vision coupled with neural networks enables data from multiple sensors to be combined with an offline map. The combination of this data with machine learning advancements has enabled sufficient fidelity to identify objects on the road.
- Ridesharing has been helpful in combating the argument of the high cost of AV utilization.
- Electrification is the best choice for fully automated vehicles. Thus, most AV implementations include a discussion of promoting air quality and greenhouse gas emission goals.

Positive and negative effects of fully AVs are as follows**.**

Positive effects

- Research by the NHTSA estimates that 94% of serious crashes are people-related (Lewis et al., 2017). Thus, the safety of AVs can be assumed as a key reason for their adoption.
- Currently, congestion causes increased commuting time. The benefit of reducing this time is increased productivity for individuals and businesses.
- AVs are a more sustainable (i.e., energy efficient) mode of transportation.

Negative effects

- Assigning responsibility for crashes (i.e., is it the autonomous system or the driver who set the controls?).
- Dealing with legacy costs (i.e., time and cost to replace current systems).
- Cybersecurity issues with connected transportation.
- Managing the economic shift for drivers who will be impacted and manufacturing shifts from current vehicle production.

Recommendation and Further Areas to Explore

INDOT's Action Item: Research and gain a better understanding of the VMT fee structure for AVs and potential revenue stream that might result in responsible use of AVs on public roadways.

INDOT's Action Plan: Initiate pilots of dedicated short-range communications (DSRC) and 5G wireless connected vehicle (CV) technologies.

INDOT's Action Item: Fund research at universities to understand the potential short-, medium-, and long-term effects of AVs on the transportation network, including the environment, social equity, and economic vitality.

The following are further questions to be explored.

- Developing a proper framework for the survey and further questions to be explored
- Identifying more primary and secondary players
- New opportunities for existing Indiana manufacturers
- Transportation equipment
- Specialty chemicals
- Advanced materials
- Overall, some key topics from the business case for Phase 1 have been covered in this report. Further expansion can be done by data gathering and one-on-one meetings with potential industries

Implementation

This study can be used by personnel at a number of divisions, offices, program areas, and units at INDOT to assess the benefits of future similar initiatives in Indiana. A core group of individuals at INDOT can further define specific implementation initiatives from the research product resulting from this study.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. OVERVIEW

Autonomous vehicles (AVs) are "self-driving" vehicles that can sense their surroundings and navigate without human intervention, offer the promise to transform transportation. These vehicles offer significant benefits which include improved safety, reduced congestion and more sustainable transport.

- After years of research and development, self-driving vehicles or autonomous vehicles have arrived. The history of development of such vehicles can be traced to the early 1920s. Their development reached a critical mass in 2013, when autonomous driving was defined by the National Highway Traffic Safety Administration (NHTSA) (Fortuna, 2017).
- Significant research and development by major technology development companies have impacted the industry as shown in Figure 1.1.
- Use of machine vision or computer vision coupled with neural networks enables data from multiple sensors to be combined with an offline map. The combination of this data with Machine Learning advancements has enabled sufficient fidelity to identify objects on the road (Fortuna, 2017).
- Ridesharing has been helpful in combating the argument of the high cost of autonomous vehicle utilization.
- Electrification is the best choice for fully Automated Vehicles. Thus, most autonomous vehicle implementations include a discussion of promoting air quality and greenhouse gas emission goals.

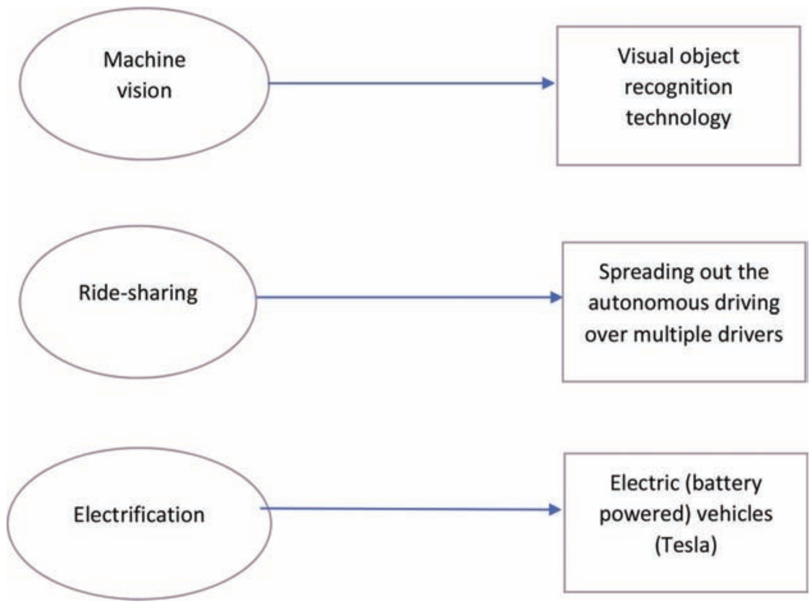

Figure 1.1 Research and developments in the autonomous vehicle industry.

2. THE SIX LEVELS OF AUTONOMOUS DRIVING (FORTUNA, 2017)

The description of the level of automation involves six possible levels, which are listed below and provided by the Society of Automotive Engineers.

- **Level 0:** No Automation–this involves human operation.
- **Level 1:** Driver Assistance–in this level, a driver will do the driving. However, assistive technologies such as adaptive cruise control provide support. These technologies may use lasers or radar to judge closeness to surrounding vehicles.
- **Level 2**: Partial Automation–offer steering control and speed simultaneously, without driver interaction for short periods. These cars offer lane navigation and automatic braking.
- **Level 3:** Conditional Automation–the driver is required to intervene only when the car is not automatically able to handle a situation and needs assistance. Tesla's Autopilot is a Level 3 automation.
- **Level 4:** High Automation–the vehicles performs all safety-critical driving functions including monitoring and adjusting to road conditions. However, there are some road types or geographic conditions that may demand the driver control.
- **Level 5:** Full Automation–the vehicle operates without driver intervention in any road or condition.

For INDOT's study, the levels being targeted are from 3 to 5, with increasing degrees of automation.

3. POTENTIAL COSTS AND BENEFITS OF AUTONOMOUS VEHICLES IN NUMBERS (LITMAN, 2020)

- With the reduction of the driver errors, that are estimated to contribute to over 90% of traffic accidents, self-driving cars are expected to reduce crashes by over 90% (Fagnant & Kockelman, 2013; Kok, et al., 2017; and McKinsey, 2016, as cited in Litman, 2020).
- Reports suggest that use of autonomous vehicles have the potential to reduce fuel consumption by 10% (see Figure 3.1). Similarly, the resulting improvement in safety is projected to decrease insurance costs by 30%. If 10% of AV are publicly shared, $250 in parking savings is assumed per new autonomous vehicle (Schmidt, 2018).

For autonomous vehicle planning, SAE suggests the timeline in Figure 3.2.

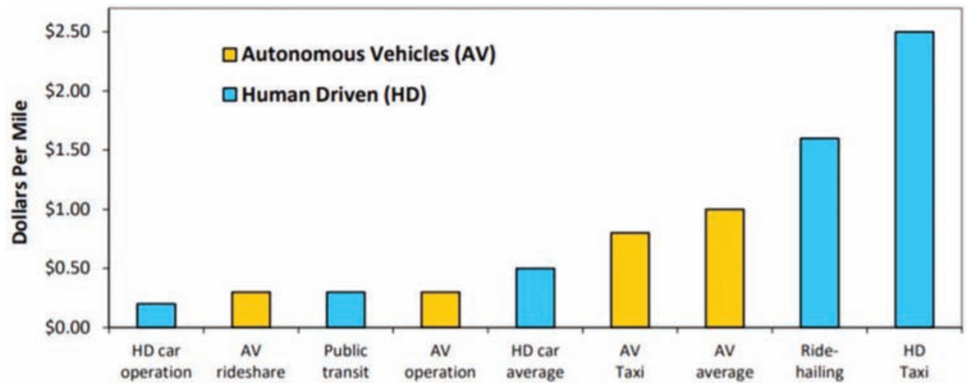

Figure 3.1 Cost comparison of AV vs. HD (Litman, 2020).

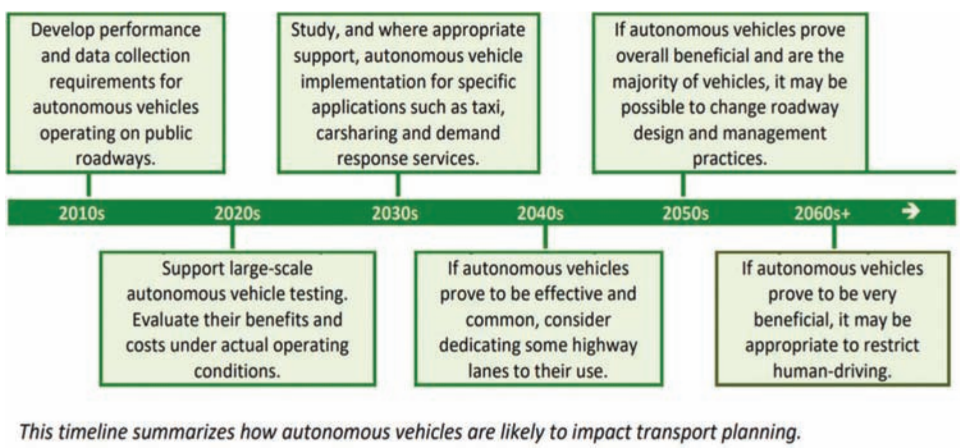

Figure 3.2 Autonomous Vehicle planning requirement timeline (Litman, 2020).

4. POTENTIAL ROLES OF PLATOONING AND OTHER TECHNIQUES

Another dimension to the use of automation is platooning. Platooning involves the linkage of two or more trucks in a convoy, through the use of connectivity technology and automated driving support systems (European Automobile Manufacturers Association, 2016b). Figure 4.1 shows a model of autonomous system architecture. Figure 4.2 shows the benefits of platooning.

The step-by-step introduction of platooning involves different types of platooning (European Automobile Manufacturers Association, 2017).

- **Type 1:** Mono-brand platooning—where trucks from the same brand can platoon. Such platoons are already being deployed.
- **Type 2:** Multi-brand platooning—where trucks of different brands can platoon with the driver available to intervene. Currently, this type is in the development stage.
- **Type 3:** Driver of a trailing truck—can afford to rest and there is semi-control.
- **Type 4:** Fully autonomous trucks—where operation is possible with or without a truck driver.

How can truck manufacturers contribute to or facilitate platooning?

- Continued development of platooning technology and its implementation, including communication standards for multi-brand truck platooning (European Automobile Manufacturers Association, 2016a, 2017).
- Involvement in the regulatory process to enable cross-border truck platooning (European Automobile Manufacturers Association, 2017).
- Investigating the operation of platoons in real traffic conditions and identifying the advantages and associated operational risks (European Automobile Manufacturers Association, 2017).

Impact on autonomous vehicle efficiency using platooning: Fernandes and Nunes (2012) describe a simple model of platooning to determine a "desired minimum gap" between vehicles, and an equation for calculating road throughput (Simko, 2016). If we use their equations, we can calculate a throughput rate for platooning different number of vehicles, as shown in Figure 4.3.

Figure 4.3 shows that autonomous platooning can significantly increase the number of cars that can be handled by a given road. If vehicles travel at 88 kilometers per hour (approximately 55 miles per hour), the graph above indicates that deployment of five-vehicle platoons would yield an approximate 350% increase in the road carrying capacity, while 10-vehicle platoons would increase capacity by almost 550% (Simko, 2016).

Figure 4.1 Autonomous system architecture (Bagloee et al., 2016).

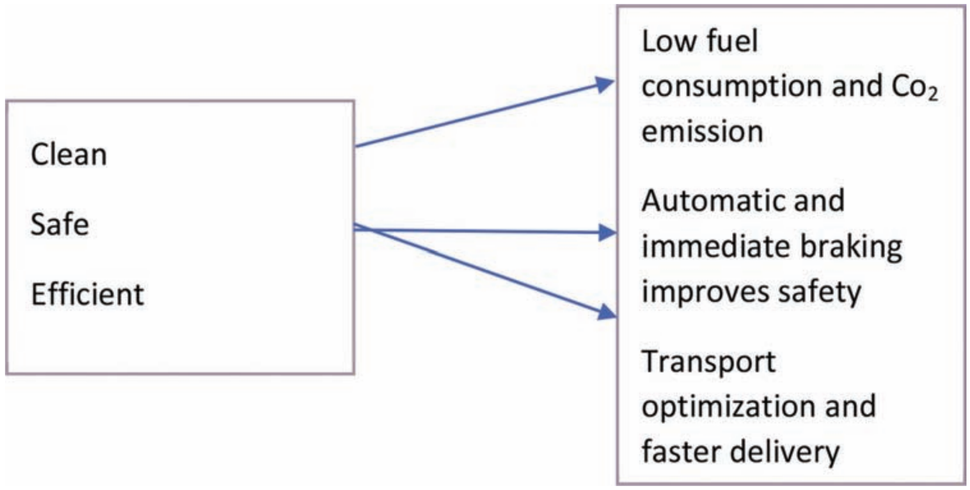

Figure 4.2 Benefits of platooning.

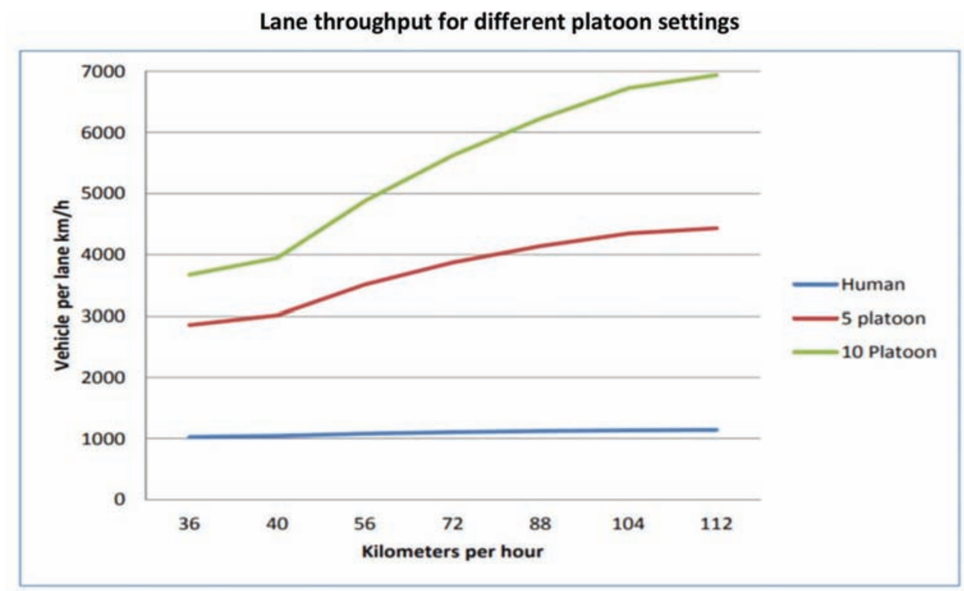

Figure 4.3 Autonomous vehicle implementation predictions (Litman, 2020).

5. EXPECTED COMPETITIVENESS BENEFITS FOR INDIANA MANUFACTURERS

As described earlier, AVs are forecasted to increase road throughput, decrease congestion, as well as reduce emissions and decrease energy consumption. Realizing these benefits will require exploration of choices such as Managed Lanes, operation of High Occupancy Toll (HOT) lanes, use of High Occupancy Vehicle (HOV) lanes, and use of express lanes (Talebpour et al., 2017).

Manufacturers with access to AVs can expect benefits along many possible dimensions, including the following.

- Just-in-time impact (Henderson & Spencer, 2016).
  - AVs can benefit just-in-time deliveries for a wide range of industries by reducing transport costs.
  - With automated trucks and warehousing, shipping and logistics companies can expect to see significantly lower labor costs. Thus, one should expect automated industrial and fleet vehicles to be early adopters of AVs.
- Automation of industrial, fleet and agricultural transport.
  - Some major companies such as Rio Tinto (mining) are already using fully autonomous truck fleets at two sites in Western Australia for the mining of iron ore (Henderson & Spencer, 2016).
  - In the agricultural market, John Deere has been selling auto-steering and self-guidance technology in their tractors in over 100 countries worldwide for many years (Henderson & Spencer, 2016).
  - Data from USDOT suggests that “interstate trucking transported 13.1 million tons of cargo valued at $11.1 billion” (Simko, 2016).

TABLE 5.1
Sample list of industries that can provide the infrastructure and technology needed to implement autonomous vehicles

Primary Industries	Secondary Industries
Schneider National	Peloton
UPS	Delphi
FedEx	
USPS	
Wabash National	
Cummins	
ZF	
Lozier	

Target 1st Tier and 2nd Tier Industries for Automation

The benefits of automation can impact both primary and secondary industries. Primary industries are major truck users and manufacturers who drive on Indiana roads. The benefits of switching to automation for such primary industries have been discussed in the previous section. Secondary industries are technology companies which can also be companies providing the necessary infrastructure and technology for autonomous vehicles technology implementation. Some examples of these industries are listed in Table 5.1

Supply Chain Analysis of Primary and Secondary Industries

The follow are some major questions to explore with user companies.

- What is the overall degree of automation in the company?
- What are the units within the company that utilize the greatest extent of automation?
- What is the level of ongoing R&D in the implementation of AVs?
- What are the budget constraints associated with AV implementation?
- What are the current major bottlenecks in production and how can AVs resolve these issues?
- What is the expected timeframe in which AVs are expected to be implemented (if the idea is prevalent)?
- What might be the impact of AV implementation on jobs, and what new opportunities are expected to rise to absorb the jobs eliminated by the introduction of AVs?

According to Morgan Stanley (2014), autonomous cars will generate huge economic benefits (U.S. market, non-exhaustive).

- Fuel savings: $158 billion
- Fuel savings from avoiding congestion: $11 billion
- Total savings from accident avoidance: $488 billion
- Increased productivity from autonomous cars: $507 billion
- Increased productivity from congestion avoidance: $138 billion
- Autonomous cars total savings: $1.3 trillion

6. POTENTIAL AIR FREIGHT IMPACT THROUGH AVs (FLÄMIG, 2016)

AVs can transform the air freight industries associated with companies like DHL and UPS by enabling JIT deliveries, thus providing delivery flexibility, increased responsiveness, and reliability. Through automation, freight can enter the system directly from the trucks onto a weighing unit. Initiating data such as the destination and flight details will be keyed in at time of receipt. The operator will be able to direct incoming cargo to the aircraft or to a breakdown/buildup area; thus, automation can impact several entities for air cargo handling (see Table 6.1).

Positive and Negative Effects of Fully Autonomous Vehicles

Positive effects

- Research by the NHTSA estimates that 94% of serious crashes are people related (Lewis et al., 2017). Thus, the safety of autonomous vehicles can be assumed as a key reason for its adoption as stated in Figure 6.1.
- Currently congestion causes increased road commuting time. The benefits of reducing this time, due to ease of deployment of central control of autonomous vehicles, are increased productivity for individuals and businesses.
- More sustainable (i.e., energy efficient) transportation.

Negative effects

- Assigning responsibility for crashes (i.e., is it the autonomous system or the driver who set the controls?).
- Dealing with legacy costs (i.e., time and cost to replace current systems).
- Cybersecurity issues with connected transportation.
- Managing the economic shift for drivers who will be impacted and manufacturing shifts from current vehicle production.

Figure 6.2 provides a summary of some of the major apprehensions associated with the adoption of autonomous vehicles.

TABLE 6.1
Changes automated vehicles would make to the air freight industry

Industry	Impact by AVs
Airlines	Would be able to stage delivery operations with greater efficiency through minimal and efficient manpower utilization.
Customs	Would have a more accurate and accountable framework.
Airports	Would have a greater utilization of facilities and future demands are met without extensive capital investment in construction.
Other Federal Agencies	Would have transparency of freight that is being transported through airport systems.

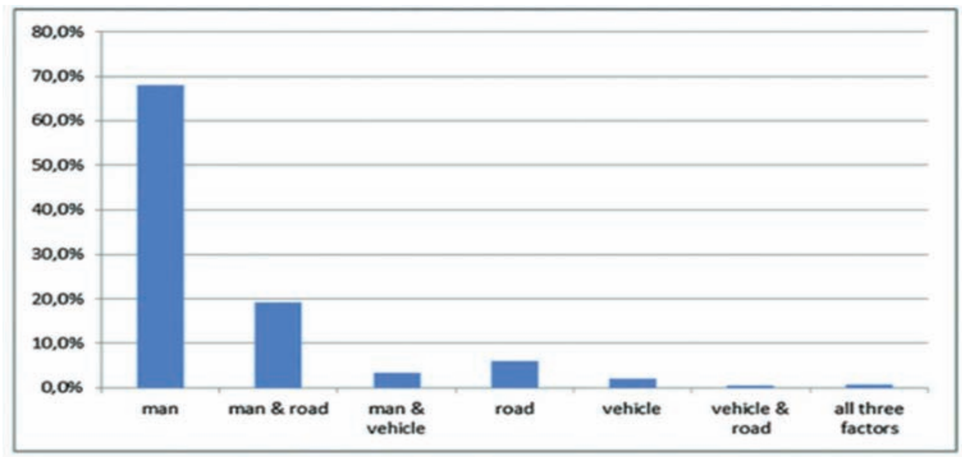

Figure 6.1 Human factors in traffic safety promotion (Ulleberg, 1997, as cited in Michałowska & Ogłoziński, 2017).

Figure 6.2 Autonomous vehicle implementation predictions (Litman, 2020).

7. PILOT CONNECTED VEHICLE PROJECTS

AVs refer to individual driverless transport while connected vehicles (CV), which can be driverless, communicate with other vehicles (Bagloee et al., 2016). Therefore, CVs and AVs are fundamentally different vehicles. One of the main features of CVs is the ability to communicate with other vehicles via vehicle-to-vehicle communication, or V2V. Other communication options include those with infrastructure, referred to as vehicle-to-infrastructure communication, or V2I. This data has the potential to improve traffic management and improve the ability to address episodic issues involving traffic in real-time (ICF International, 2016).

There are many such pilot projects underway on public roads. In 2016, the City of Sunnyvale, California entered into a partnership with Nissan, Savari, and U.C. Berkeley to install V2X-enabled roadside units across nearly 4.5 square miles and three public intersections. The goal of this project is reported to be "optimizing traffic light timing."

In Virginia, the Connected Corridors initiative is using more than 60 roadside equipment units to implement connected applications. The data used along the corridor includes traveler information, interventions to enhance transit operations, communicate lane closure alerts, and work zone and incident management (Lewis et al., 2017).

Currently, CVs rely on dedicated short-range communications (DSRC) as the means to transmit data. However, industry observers predict that 5G cellular technology will overtake DSRC. If that were to happen, investments in DSRC would become obsolete. In Virginia, Governor McAuliffe signed legislation that allows private companies to install 5G technology on existing structures on public roadways. The worry for state DOTs is that uncertainty in the final dominant technology makes them reluctant to fund the necessary infrastructure to enable CV deployment.

INDOT's Action Plan: Initiate pilots of DSRC and 5G wireless CV technologies (Lewis et al., 2017).

AVs are highly dependent on inputs from the surroundings. Better quality and accuracy of input would increase the efficiency of the vehicles. For AVs to function efficiently, smart infrastructure is a must.

Authorities may not only have to improve the infrastructure by improving and standardizing roads and signs, but they may also have to add additional equipment to create smart infrastructure for V2I communication.

8. DEVELOPING VEHICLE FEE IN CONCERT WITH THE FEDERAL GOVERNMENT (LEWIS ET AL., 2017).

Enabling efficient AV operation requires a substantial infrastructure investment. But the new vehicles may result in a loss of revenue (from gas taxes, particularly if they are electric vehicles), from parking fees (if they are self-park vehicles) and from lower traffic tickets (due to algorithms ensuring compliance with speed limits). The lower revenue and potential higher infrastructure needs presents a challenge.

Eno's 2017 Beyond Speculation report details why and how the federal government should develop a $0.01 per mile charge on automated driving (Lewis et al., 2017). Currently, companies are planning for potential ways to charge consumers by trip or by mile, thus enabling the possibility that such fees can be charged by local governments.

A Tennessee law plans to charge "a VMT for AVs at a rate of $0.01 per mile for two axle vehicles and $0.026 per mile for more than two axles." The state claims that it "will divide the revenue generated from the charge between the state general fund, state highway fund, counties, and localities according to a statutory formula" (Meyer & Beiker, 2019).

Reports suggest that AV developers are not necessarily against implementing a VMT fee on their vehicles. However, they suggest that policymakers may need to anticipate possible market distortions related to a VMT fee.

INDOT's Action Item: Research and gain a better understanding of the VMT fee structure for AVs and potential revenue stream that might result in the responsible use of AVs on public roadways (Lewis et al., 2017).

9. PARTNERING WITH INDUSTRIES

Enabling the success of AV and CV will require INDOT to develop partnerships with the state, connecting to communities and informing constituents about the collateral benefits. This is particularly important given the need to develop a prepared workforce to ensure success (Gettman et al., 2017).

Important unresolved issues surrounding CAV data include the following.

- How can such agreements be leveraged to enable operational efficiencies such as identifying potholes, etc.?
- How should data anonymity be preserved and what payments should be permitted between the collector and provider of data?
- Can INDOT devise ways to monetize the data to replenish depleted budgets and CAV infrastructure costs?
- What partnerships can INDOT establish with AV manufacturers to ensure appropriate cyber-infrastructure?

In order to possess and provide adequate data, INDOT will be required to develop partnerships with a wide group of industries where a working relationship doesn't exist. Given that efficient operation of AVs will necessitate data source redundancy.

As INDOT broadens its interactions within the state, and with non-traditional industry partners, INDOT may require acting more like mobility providers, over and above their current role as infrastructure providers.

10. DATA COLLECTION REQUIREMENTS

There is a great opportunity to use data to share parking, traffic congestion between vehicles and with road side units. This requires real time data to be collected and used in a meaningful way.

The following investments may be required to collect and provide real time data.

- Signal equipment and traffic management center upgrades
- Dedicated short-range communication (DSRC) investments
- End-to-end mapping systems
- Data management plans
- Ensuring security and privacy of data

While these investments are being planned, INDOT can experiment with small investments to procure already available data sets for traffic management, parking etc. This data could be used to meet short term deployments to enhance performance, as well as to estimate the benefits from large scale deployment.

11. TRANSMISSION OF REAL-TIME DATA TO VEHICLES

In the last decade, DOTs have invested in developing Intelligent Transportation systems (ITS). Typical impacts of efficient management are reported to be the following.

- Reduced crash rates
- Improved traffic flow
- Improved utilization of parking
- Reduced environment impacts
- Faster emergency response

According to the USDOT, "ITS encompass a broad range of wireless and wireline communication-based information and electronic technologies." The following three systems may need to be change significantly (Intelligent Transportation Systems Joint Program Office, n.d.).

- Integrating real time traffic data including speed limits, traffic signal state, etc.
- Provision for information regarding use of road side infrastructure and other locations like bicycle lanes, pedestrian, and other vehicles.
- Systems to manage the merging and platooning across vehicles

12. WORKFORCE TRAINING REQUIREMENTS

In 2015, there were 15.5 million jobs related to the driving occupation. This suggests the need for appropriate workforce training to overcome that skill gap. There is the potential to create testing areas and partnerships with major research universities like Purdue, Indiana University to upskill drivers to use AV technology.

13. IMPACT ON DRIVERS' EMPLOYMENT

A key question is the impact of the introduction of AVs on drivers of commercial vehicles. To understand the transfer of skills of drivers, we categorized driving operations into Motor Vehicle operations and Other On-the-Job drivers as shown in Figure 13.1.

Knowledge and Skills in Driving-Related Occupations

Consider the knowledge and skills involved in driving professions. These cross functional skills can be deployed across other task execution that requires these specific skills (see Figure 13.2). Thus, a planned transition to use of AVs will require plans to enable existing drivers to transition to other professions that leverage these skills.

ONET—ongoing educational and training; SOC—standard occupational classification.

Figure 13.1 Driving operations for motor vehicle operations and on-the-job drivers.

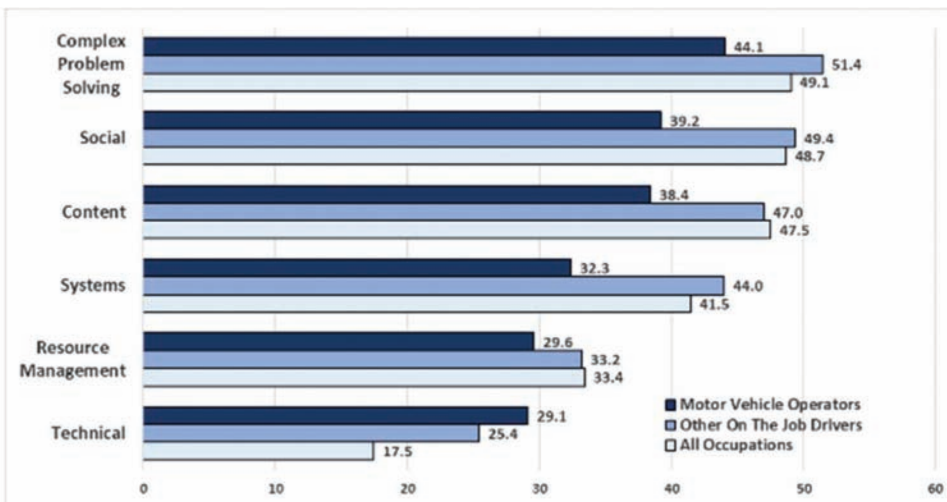

Figure 13.2 Comparison of cross-functional skills for motor vehicle operations and on-the-job drivers (Beede et al., 2017).

14. FOSTER THE CREATION OF TESTING GROUNDS

The development of AV technologies has largely been led by the private sector and university research, with a combination of public and private funding.

At Santa Clara University, for example, local startup Auro Robotics is conducting a first-of-its kind deployment of low-speed automated shuttles on the university campus. The pilot program, which began in November 2016, is not subject to California's motor vehicle laws since it is operated on university grounds. The pilot is authorized to operate for segments of a few months at a time, after which the university decides on extensions—as well as whether Auro Robotics can remove its human backup drivers to make the shuttles fully automated (Meyer & Beiker, 2019).

One of the most publicized centers for AV research is MTC's Mcity, which is designed to simulate an urban environment for testing in all four seasons. Tests conducted at Mcity provide auto manufacturers and academics with a laboratory to experiment with different safety and design approaches for dynamic driving conditions. This includes preparing for interactions with pedestrians and cyclists, city intersections where views may be obstructed by buildings, and adverse weather conditions. Michigan also amended state laws to authorize the creation of the American Center for Mobility at Willow Run, an old factory site, to conduct AV research and education (Simko, 2016). This includes how AVs will interact with built environments, pedestrians, bicyclists, public transit, motorcycles, and every other roadway user.

15. PROGRAMS TO DEVELOP WORKFORCE

By their nature, AVs pose a threat to thousands of driver jobs across the country. But when, if, and how automated driving systems will affect industry workers or replace humans behind the wheel is widely debated. Lower level automation (Level 3), for example, could significantly reduce crashes, affecting the 915,000 workers employed in auto maintenance jobs in the U.S. (Blanco et al., 2015).

The threat of substantial job losses or economic disruption, however, is a long way off. In the short and medium term, automation can help address some of the serious problems associated with professional driving. For example, the trucking industry is grappling with a shortage of drivers. Automated trucks could create much safer and enjoyable jobs for the workforce, first by avoiding collisions and eventually by allowing truckers to avoid sitting for extended periods of time. More flexible work hours and technology-based driving might also attract younger workers. Similar workforce improvements apply to public transit and taxi workers.

INDOT's Action Item: Fund research at universities to understand the potential short-, medium-, and long-term effects of AVs on the transportation network, including the environment, social equity, and economic vitality (Lewis et al., 2017)

16. AVs IMPACT ON INDOT TRAFFIC SAFETY PLANNING

Current state and local laws can conflict directly with the nature of AVs. "No person shall operate a motor vehicle upon the streets of the city without giving full time and attention to the operation of the vehicle." This well-intended traffic code, which is common in cities, is in direct conflict with the goal of AV developments: to reduce the need for humans to drive (Vanderbilt, 2012).

Eventually all states and localities will need to consider how their current traffic laws work with driverless vehicle capabilities and update them accordingly. For example, driver licenses are issued at the state level. How should those laws change when there is a driverless fleet of vehicles? More importantly, how should laws for AVs co-exist with current laws for human drivers?

17. INDIANA'S LEGISLATURE

Currently Indiana has no laws for self-driving vehicles. At the federal level, the NHTSA approved guidelines for the industry, but did little to actually regulate autonomous technology (Lange, 2018).

The first Indiana bill focused on autonomous vehicles House Bill 1341 was authored by Representative Ed Soliday. Representative Soliday's House Bill 1341 was heard in January 2019, passed the Indiana House, and moved to the Indiana Senate. During a Senate Homeland Security and Transportation Committee meeting on February 13, manufacturers opposed the bill. Currently, vehicles are currently classified by level of autonomy that varies from 0 to 5.

Under Representative Soliday's initial bill (Lange, 2018):

- Level 0 to 3 operators would need a valid driver's license.
- Anyone operating a Level 4 or 5 vehicle would be required to have a licensed driver to ride along with them (unless the requirement was waived).
- An autonomous driving task group would approve the operation of self-driving cars that did not require a driver in any capacity.
- The task force would also have the capability to revoke an autonomous vehicle's ability to operate in Indiana if safety issues were identified.
- Operators would have a minimum of $5 million financial responsibility.

The bill was opposed by many leading automakers. Representative Soliday's House Bill 1341, which would have set regulations for autonomous vehicle (AV) development in Indiana, ran into changes in the Senate and did not pass the Indiana legislature by a March 14 deadline.

Two weeks later, Committee Chairman Mike Crider, R-Greenfield, introduced an amendment as a compromise with auto manufacturers. The amendment removed some regulatory provisions, including a requirement that AVs meet federal and state laws and that operators have a minimum of $5 million financial responsibility. By then though, Representative Soliday added platooning requirements, with no mention of the word "autonomous," to his House Bill 1290, written primarily as a clean-up of motor fuel tax distribution legislation from the previous year. The bill was signed into law by Governor Holcomb on March 21.

House Bill 1290 (National Conference of State Legislatures, 2020):

- Defines "vehicle platoon" to mean a group of motor vehicles that are traveling in a unified manner under electronic coordination at speeds and following distances that are faster and closer than would be reasonable and prudent without electronic coordination.
- The bill clarifies that vehicle platooning is exempt from the following too close provisions of three hundred feet.
- The bill also lays out an approval system for vehicle platooning in the state, including requiring the person or organization to file a plan for general vehicle platoon operations with the transportation commissioner.

18. SURVEY SUMMARY

We had a list of 50 companies we wanted to survey, but we could get only 4 companies to take the survey and so the sample set of the survey is very small. For the survey, we used the Likert scale, where questions 1 through 4 are rated on a scale of 0 to 7, question 5 from

-5 to +5, and questions 6 through 10 multiple answer. The results for the Likert scale are calculated by:

$$\% = \frac{sum\ of\ responses}{range * number\ of\ participants}$$

According to the survey, 89.28% of the companies that took the survey reported that autonomous vehicles would have the most economic impact on their firm among the new transportation technologies. Also, 85.71% companies reported electric vehicles would have most impact on their firm followed by platooning (71.42%). While drones (42.85%) reportedly had the least economic impact on their firms.

It was noticed that the Supply Chain (78.57%) department would be impacted the most, followed by Marketing (57.14%) with the new transportation technologies being introduced in the market. Human Resources (39.282%) department would be impacted the least. The other departments that would see an impact besides these would be Operations (50%) and Research & Development (46.42%) in the respective order.

According to the survey conducted, Indiana Department of Transportation (82.14%) would be the most impacted entity in Indiana due to the emerging transportation technologies. It is followed by Indiana Legislature (67.85%) and Technology companies (67.85%) that would be most impacted. It was reported that Investment community (60.71%) and Indiana workforce (60.71%) would be impacted the least according to the survey carried out.

The survey reported that the companies expected high impact on initiatives such as increased INDOT investments in road technology (75%) and expected least impact on enthusiasm from local communities on the emerging transportation technologies (53.57%). While the companies also felt that availability of real time information regarding road condition and average speeds (60.71%), and new training programs for future truck operators (64.28%) will be impacted mildly.

The survey indicates that there will be a high impact on roles such as road traffic management (85%) and data analysis (85%) due to the new transportation technologies. Roles such as driving (80%), material handling (80%), and information management (82.5%) will have less impact than those mentioned above. Automotive repairs & maintenance (47.5%) and software development (50%) will have the least impact according to the companies.

Almost 50% of the companies surveyed reported to be the adopter of the new transportation technology and a few reported to be the driver and influencer of the transportation technology.

The survey suggests that due to the emergence of the new transportation technologies, more than 50% companies see predictable deliveries as one of the key benefits and see themselves engaging as a component provider for the industry rather than engage as a technology provider or service provider for the industry.

Based on the survey results in Figure 18.1, some of the potential key challenges the organizations will face in the development and implementation of the transportation technology are regulations and legal risks (75%) and road & infrastructure's ability to support the new technologies (75%) among others. Cost and time commitment to develop software and/or hardware and consumer reluctance to pay for new technologies are some of the challenges that are less problematic.

Some of the legal issues that concern the companies while developing the potential transportation transforming technologies are personal injury/property liability (75%) and compliance with state and federal regulations (50%) while consumer data privacy being the least of the concerns.

	Organisation Name	Company A	Company B	Company C	Company D
Questions					
1	What is your estimate of the economic impact of the following new transportation technologies for your firm? Rate from 0 (no impact) to 7 (high impact)				
a)	autonomous vehicles	7	7	5	6
b)	platooning	5	6	4	5
c)	electric vehicles	5	7	6	6
d)	drones	2	2	2	6
2	What level of impact with the new transportation transforming technologies have on each of the following areas of your				
a)	Marketing	6	5	4	1
b)	Supply chain	7	6	5	4
c)	Operations	6	4	3	1
d)	R&D	3	7	2	1
e)	Human Resources	6	3	1	1
3	What impact do you expect on each of the following Indiana entities due to the emerging transportation transforming technologies? 0-Small Impact, 7 Large Impact				
a)	INDOT (Indiana Dept of Transportation)	6	5	6	6
b)	Indiana Legislature	6	4	4	5
c)	Investment Community	5	3	3	6
d)	Technology Companies	6	3	4	6
e)	Indiana Workforce	6	4	2	5
4	What level of impact do you expect from each of the following initiatives to adopt new commercial transport vehicles in your industry? 0-Small Impact, 7 Large Impact				
a)	Increased INDOT investments in road technology	4	6	6	5
b)	Greater availability of real time information regarding road conditions and average speeds	3	7	5	2
c)	New training programs for future truck operators	7	5	3	3
d)	Local communities enthusiasm for future vehicles	6	5	1	3
5	Rate the impact of implementing potential transportation transforming technologies on the following roles on a scale of -5 to 5 (where -5 represents 'this role will no longer exist' and 5 represents 'this role will have the highest demand'.)				
a)	Driving	5	-1	4	4
b)	Material Handling	4	0	5	3
c)	Software Development	0	1	-3	2
d)	Cyber security	3	3	-3	1
e)	Information management	3	4	4	2
f)	Data Analysis	4	4	4	2
g)	Automotive Repairs and Maintenance	0	0	-4	3
h)	Road Traffic management	1	4	5	4
i)	Electronic Repairs and Maintenance	0	4	-2	4
6	the development and/or adoption of potential transportation transforming technologies? (includes autonomous vehicles, platooning,electric-vehicles and drones) (You may choose multiple items)				
1	Driver of technology and application	3	1	3	2
2	Influencer of the technology				
3	Adopter of the technology				
4	Not impacted by the technology				
7	What opportunity does your company see in the emergence of potential transportation transforming technologies? (feel free to select multiple choices if appropriate)				
1	Deliver items at a lower cost	2,4	1,4,5	2	5
2	Provide more predictable deliveries				
3	Engage as a technology provider for industry				
4	Engage as a Service provider for this industry				
5	Engage as a Components provider for this industry				
8	organization in the development and implementation of potential transportation transforming technologies? (includes autonomous vehicles, platooning, electric-vehicles and drones)?				
1	Cost and time commitment to develop software and/or	3,4	1,2,3,4,5	5	3, 4
2	Consumer reluctance to pay for new technologies				
3	Regulations and legal risks				
4	Roads and infrastructure's ability to support new technologies				
5	VehicLack of standardization in technologies across provider fi				
9	Which of the following legal issues are of concern to your organization when developing technology for autonomous vehicles, platooning, electric-vehicles and drones?				
1	Consumer data privacy	3	4	3, 6	3, 5, 6
2	Cybersecurity attacks				
3	Personal injury/property liability				
4	Intellectual property protection				
5	Warranties				
6	Compliance with state and federal regulations				

Figure 18.1 Survey results of five companies.

19. RECOMMENDATIONS AND FURTHER AREAS TO EXPLORE

INDOT's Action Item: Research and gain a better understanding of the VMT fee structure for AVs and potential revenue stream that might result in the responsible use of AVs on public roadways.

INDOT's Action Plan: Initiate pilots of DSRC and 5G wireless CV technologies (Lewis et al., 2017).

INDOT's Action Item: Fund research at universities to understand the potential short-, medium-, and long-term effects of AVs on the transportation network, including the environment, social equity, and economic vitality (Lewis et al., 2017).

Further Questions to Explore

- Developing a proper framework for the survey and further questions to be explored.
- Identifying more primary and secondary players.
- Exploring in more depth for new opportunities for existing Indiana Manufacturers.
- Exploring details of transportation equipment.
- Exploring the impact on transport of specialty chemicals and use of advanced materials.
- Overall, some key topics from the business case for Phase 1 have been covered in this report. Further expansion can be done by data gathering and one-to-one meetings with potential industries.
- Literature review can be further expanded based on more research on the current industry automation impact (for air freight industries, logistics, supply chain network and Manufacturing).
- More data on the average budget allocated for semi to complete automation of processes and the interested industries.
- Predicting analytics can be performed for analyzing the current state revenue and resource utilization and a future state can be mapped with the associated benefits.
- A data mining approach can be utilized to support a data-driven scheduling system for air cargo terminals (Boxnick et al., 2014).

20. CONCLUSION

This report provided an overview of the opportunities offered by autonomous and connected vehicle technology. The deployment of recently approved platooning solutions promises cost and throughput advantages. The use of autonomous vehicles generates primary economic benefits for manufacturers due to improvements in safety and reduced fuel costs. The supply chain benefits include lower cost just-in-time deliveries and reduced labor costs across the supply chain. Additionally, economic benefits will also accrue to secondary industries that generate software or technologies to assist in this transformation. This report suggests several possible initiatives where INDOT can lead in this transformation.

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About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,600 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at http://docs.lib.purdue.edu/jtrp.

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