Testimony of Darcy Bullock
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Purdue University
to the
U.S. House of Representatives
Committee on Science, Space, and Technology
Subcommittee on Research and Technology

"Bumper to Bumper: The Need for a National Surface Transportation Agenda"
July 11, 2019

Chairwoman Stevens, Ranking Member Baird, and Members of the Committee, my name is Darcy Bullock. I am a professor of civil engineering at Purdue University and serve as the director of the Joint Transportation Research Program (JTRP). I appreciate the opportunity to share with you some recent transportation research and implementation initiatives, as well as perspectives on future opportunities and challenges we face in developing a national surface transportation agenda.

Joint Transportation Research Program (JTRP)

JTRP is a partnership between Purdue University and Indiana Department of Transportation (INDOT) that dates to 1937. JTRP resides in Purdue University's Discovery Park, a collaborative research environment with a multi-disciplinary focus. JTRP's mission is to facilitate collaboration between public agencies, academia, and industry to implement innovations resulting in continuous improvement in planning, design, construction, operation, management and economic efficiency of our transportation infrastructure. The program generates innovative research and new knowledge to help solve current and future transportation challenges while improving efficiency and quality. To accomplish our mission, JTRP uses the collaboration model depicted in Figure 1. We currently have 60 faculty members, 170 grad students and 270 professionals involved in 84 active projects. Over our 82-year history, we have produced over 1,600 technical reports with over 4,200 co-authors.

Figure 1: JTRP collaboration impact model for transportation research and innovation

When our research projects are initiated, stakeholders with subject area expertise participate as active members of the study committee to provide background knowledge and domain expertise that are critical to innovation. Of particular significance to Purdue, INDOT promotes careful and responsible use of their infrastructure (such as bridges, pavements, and signals) as "living laboratories" for research activities that cannot be duplicated in a university setting. INDOT staff are empowered by agency leadership to implement research leading to continuous improvement that allows them to do things cheaper, better, faster, safer. Private sector participation and input early in the research process leads to industry buy-in and is critical to implementation success. This integrated approach provides several benefits: 1) It involves government and industry stakeholders early in the research so that the team remains focused on implementable results; 2) The opportunity for students to directly engage with decision makers is a powerful motivating force with students; and 3) This sustained early engagement between stakeholders provides opportunities for field prototype implementations early in the research and informal professional development on emerging technologies within the partnering transportation agencies and private sector entities.

After projects are completed, INDOT identifies key performance measures and documents the impact of the JTRP research program. Finding out what does not work can be just as important as finding the solution to a problem. However, more often than not, the impact model produces deliverables that INDOT can implement. I would like to share two JTRP projects that have resulted in long-term, sustained impact due the collaboration of public agencies, academia, and industry. I will conclude with some thoughts on emerging opportunities for you to consider in shaping the next national surface transportation agenda.

DamageWise

Roadway infrastructure elements, such as guardrails, signs, and bridges, routinely sustain damage from motor vehicle crashes. In 2009, INDOT initiated a JTRP project to examine business processes related to repair of state property damaged by crashes. The research project involved extensive collaboration between relevant parties, including law enforcement agencies, INDOT maintenance departments, collection departments, and the insurance industry. The Purdue-INDOT research team recommendations resulted in initiation in 2011 of a statewide program called DamageWise and introduced a tagging system to be used by law enforcement when state property is damaged. This system allows INDOT maintenance teams to efficiently associate repair costs with a crash report so insurance companies can subsequently be invoiced for repair costs. (1)

INDOT's deployment and implementation of DamageWise required cross-cutting team participation from district maintenance crews and supervisors, central office finance personnel, information technology departments, as well as interagency partnerships with public safety and law enforcement colleagues. The direct involvement and establishment of performance measures by INDOT's Chief Financial Officer was critical to the success of this project. Figure 2 shows the annual collections realized from the DamageWise program, which went from $1.6 million prior to the program to $7.3 million in FY 2018 after full implementation. The on-going costs for DamageWise in FY 2018 were estimated to be $889,300. Adjusting the FY 2018 collections by the FY 2010 pre-DamageWise collections ($7.3 million versus $1.6 million) and applying the overhead costs ($889,300) resulted in a benefit-cost ratio of 6.4 for the DamageWise program in FY 2018. This program provides a recurring benefit to INDOT and the success of DamageWise was recently documented in the May-June 2019 publication of TR News, a publication of the Transportation Research Board (TRB). (2)

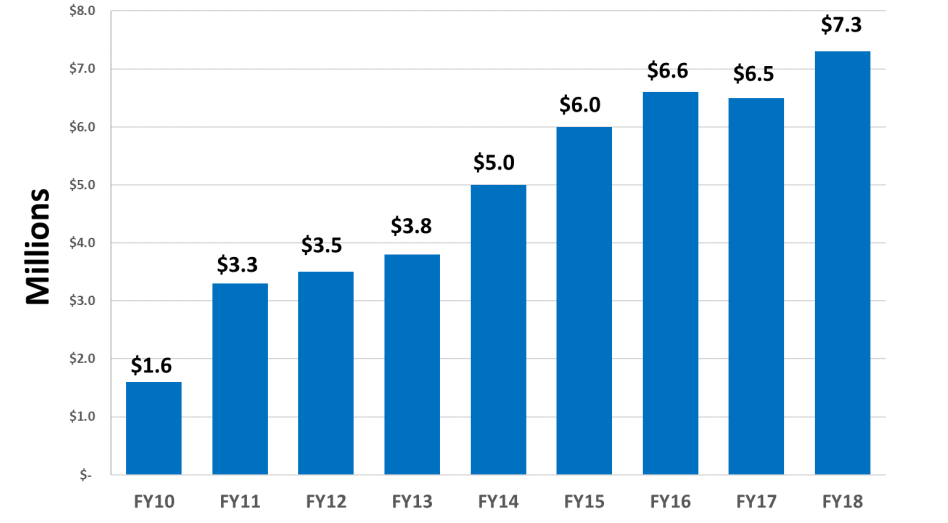

Figure 2: Annual collections from pre-DamageWise program (FY 2010) through full implementation

The key takeaways from this project are: 1) The implementation of DamageWise was relatively low tech, but success was dependent upon understanding the interface between public sector agencies and private sector insurance companies; 2) It required teamwork among a variety of diverse stakeholders ranging from public safety colleagues to INDOT maintenance staff; 3) The sustained multi-year tracking of DamageWise performance measures and recognition of stakeholder contributions is extremely valuable in the sustained growth and impact shown in Figure 2; and 4) It is important to share

these research successes on a national level, through venues such as TRB, so other agencies can learn about peer agency innovation and perhaps adopt as well.

Traffic Signal Performance Measures

As I indicated, INDOT is a strong advocate of partnering with universities and using their infrastructure as "living laboratories." INDOT's initiative to work with JTRP to develop instrumented intersections in 2005 provided the foundation for development of several public and private sector partnerships that led to the nationwide deployment of traffic signal performance measures. Purdue and INDOT started this effort by working with the traffic signal industry to develop a specification for logging traffic signal event data that could be retrieved via an Ethernet connection. This provided the research team access to event data for developing a series of performance measures that agency personnel could use to automatically evaluate quality of signal synchronization, efficient allocation of green time, identification of maintenance issues, and locations with high volume of red light running. Our early work resulted in attracting research funding from the National Cooperative Research Program (NCHRP) that provided increased national visibility.

However, as with many innovations, the private sector cannot effectively support 50 different state variations and we received feedback from the traffic signal community that it would be important to reach out to other states for input. In 2011, INDOT put together a Pooled Fund Study (PFS) solicitation that attracted investment from eleven states. More important than the financial investment however, was this cohort composed of Federal Highway Administration (FHWA) and eleven state DOTs coming together to collectively develop a common vision for data collection and performance measures that the traffic signal controller business partners could build. (Figure 3)

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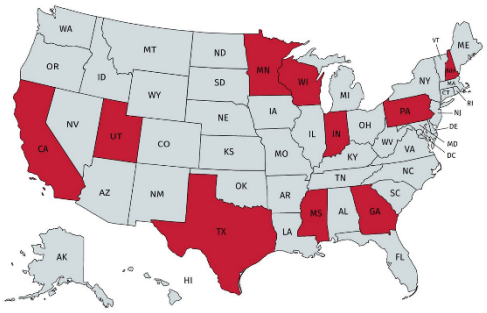
<td> 
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<td>Map of PFS partner states</td>
<td>Project closeout workshop
Salt Lake City, Utah; January, 2016
with representation from 30 states</td>
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<td colspan="2">Figure 3: Pooled Fund Study 5(258) Traffic Signal Systems Operations and Management</td>
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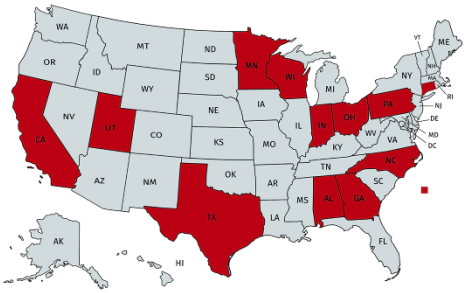
Throughout this research, the team actively published over a dozen papers that were presented at the annual Transportation Research Board Meeting and published in the Transportation Research Record, most involving co-authors from either agencies and/or private sector partners. Five of those papers received best paper awards from a TRB committee. As a result of this government, academia and industry collaboration, as well as students joining agencies or private sector companies after graduation, Purdue traffic signal performance measures have been integrated into most new traffic signal control systems in the United States. Hundreds of local and state agencies use these performance measures and refer to them as the "Purdue Performance Measures." (3) (4) These performance measures were recognized by American Association of State Highway and Transportation Officials in 2013 as a focus technology and also by FHWA as a 2016 Every Day Counts Initiative that advocates accelerated implementation. (Figure 4)

Figure 4: FHWA Every Day Counts 4 designation

Looking beyond performance measures that can be collected from roadway infrastructure, we have initiated a new PFS entitled "Enhanced Traffic Signal Performance Measures" to identify ways to integrate and leverage emerging connected vehicle data and provide improved traffic signal performance measures. The PFS includes representatives from 12 states, as well as partners from FHWA; College Station, TX; and West Lafayette, IN. Traffic signal vendor and auto manufacturer representatives are involved in this study focused on updates for the current Purdue Performance Measures and research to develop methodologies and tools for using high resolution vehicle probe data to compute traffic signal performance measures. Figure 5 shows the states involved with the PFS, as well as a picture from the PFS workshop on March 27-28, 2019, with representatives from state agencies, local agencies, traffic signal vendors, auto manufacturers, and academia. (Figure 5)



Map of PFS partner states

Workshop with agencies, academia, & industry
Purdue University; March, 2019

Figure 5: Pooled Fund Study TPF-5(377) Enhanced Traffic Signal Performance Measures

Open Access Dissemination Metrics

We place a high value on disseminating our results beyond traditional journals and are particularly interested in ensuring our publications are free and easy for public sector agencies to access. To promote knowledge sharing and increase impact, JTRP partnered with Purdue University Scholarly Publishing in 2011 to modernize report publishing and digitize previous reports. The JTRP technical report series contains 1,672 publications involving over 4,200 co-authors from academia, public agencies, and the private sector. To date, the JTRP technical research reports have been downloaded 1,777,673 times by 27,650 institutions representing 227 countries. Figure 6 shows the worldwide impact of this open access model. The JTRP technical report series is widely regarded as a best practice for rapid, cost effective dissemination to public agencies and other countries without requiring access to traditional academic journals, which often have costly fees. (5)

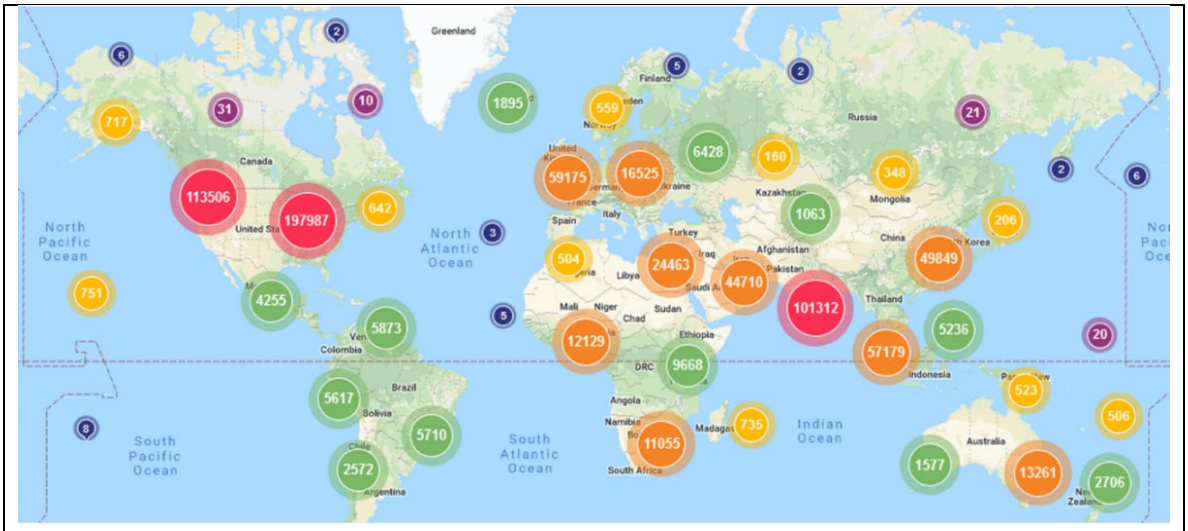


Figure 6: JTRP technical report download distribution as of July 4, 2019

Based upon the successful dissemination of research reports through the Purdue open access platform, JTRP began publishing additional series for conference proceedings, affiliated reports, posters, and monographs. Publications in the JTRP collection have been downloaded over 2.23 million times to date. The download count is dynamic, often with hundreds of downloads occurring daily within the collection. The distribution of the downloads in the JTRP collection among the commercial sector (40%), academia (44%) and government (16%) demonstrates the impact the research program has on the transportation community at large. (Figure 7)

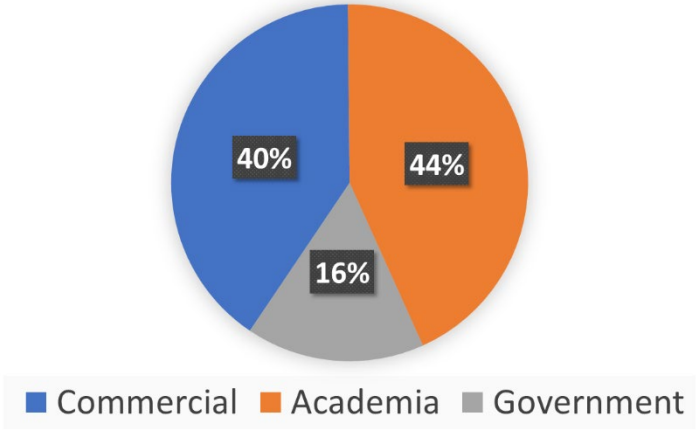


Figure 7: JTRP collection download distribution by sector
2,231,642 total downloads as of July 4, 2019

As I have indicated throughout this testimony, I believe successful research dissemination requires more than publishing reports. JTRP has a strong history of multi-faceted engagement activities to share information and best practices. We provide an annual legislative update to the Indiana Road and Transportation Committee. JTRP meets regularly with various stakeholders to solicit feedback on active transportation research and identify emerging issues. These stakeholders include private sector partners, public safety officials, associations of cities and towns, logistics associations, and other universities. Affiliated faculty make hundreds of presentations annually at technical conferences. These presentations amplify the impact of JTRP research and also stimulate additional publication downloads, as we frequently see surges in downloads after faculty presentations.

Engagement Activities

Beyond the tactical project-oriented interaction that occurs during the research process, JTRP and INDOT coordinate workshops and conferences to broadly disseminate innovation and best practices to the larger transportation community. One example is the Purdue Road School Transportation Conference and Expo, which had 3,015 participants attending over 150 sessions in 2019. The topics of

these sessions vary year to year and provide a forum for disseminating innovation and best practices to many INDOT partners, such as contractors, consultants and suppliers. Road School presentations are archived on the Purdue open access platform and have been downloaded 424,813 times to date, extending the impact of Road School well beyond the attendees.

Engagement activities also provide opportunities for academia, industry, and public agencies to interact with nationally recognized leaders in the transportation industry. For example, keynote speakers at the 2019 Road School included Brandye Hendrickson, Deputy Administrator Federal Highway Administration; Robert Martinez, Vice President Norfolk Southern; Jim Hackett, Chief Operating Officer Ford Motor Company; Tim Haak, Mayor of Zionsville, Indiana; Vanta Coda, Chief Executive Officer, Ports of Indiana; Chris Cotterill, Executive Vice President Indiana Development Corporation; and Joe McGuinness, Commissioner Indiana Department of Transportation. This engagement extends internationally as well. On March 27, 2019, Essam Sharaf, former Prime Minister of Egypt and Purdue student that worked on several JTRP projects (6) (7), attended the Traffic Signal Performance Measure Workshop and engaged with attendees from twelve state DOTs, industry, and Purdue faculty, staff and students.

Emerging Opportunities for Connected and Autonomous Vehicle Research: Vehicles often know more about the condition of our roadway infrastructure than we know.

As I have described earlier, INDOT partners with JTRP to develop long-term strategies for research, particularly related to adoption of new technologies and the transportation system's impact on economic development. In 2017, INDOT Commissioner Joe McGuinness made the following statement during Purdue Road School: "Autonomous, connected vehicles are a thing of the future, and the future is now. We have to start planning and making sure that we are prepared for what the automobile manufacturers are going to be putting on our roads." This statement is even more true today, as technology is evolving on a daily basis. In 2019, INDOT released a strategic plan that further emphasizes the need to enhance economic competitiveness and quality of life through increased understanding of Indiana's position as it relates to the autonomous/connected vehicle industry and initiatives to advance testing and research in the state. (8) The impact model employed by the JTRP program is critical to support INDOT's strategic initiatives. Obviously, Indiana is not unique. We are in a period where academia, public agencies, and the private sector must develop new partnerships to effectively deploy connected and autonomous transportation. A national agenda that promotes and facilitates this type of collaboration is essential.

Modern vehicles know more about infrastructure operations and condition than the transportation agencies operating the roadway system. For example, in 2012, the JTRP program proposed using crowd sourced data to develop nationwide performance measures, as shown in Figure 8. This graph depicts the 2012 monthly travel time deficit, normalized by length of Interstate in each state (hours/mile) for I-80 coast to coast. This performance metric can identify seasonal impacts of winter weather and summer construction, as well as congestion areas. Figure 9 shows the top 100 interstate segments, according to travel time deficit, that had the most severe congestion on I-80 in 2012. These types of performance metrics provide quantitative data to help understand the relative congestion along an entire interstate and can also be used to build consensus for capital investments on the interstate system, which ideally should be coordinated and prioritized on a national level. (9) In fact, the FHWA Everyday Counts Program (EDC5), identifies crowdsourced data as an important initiative and crowd source data will be an important research opportunity as we move forward.

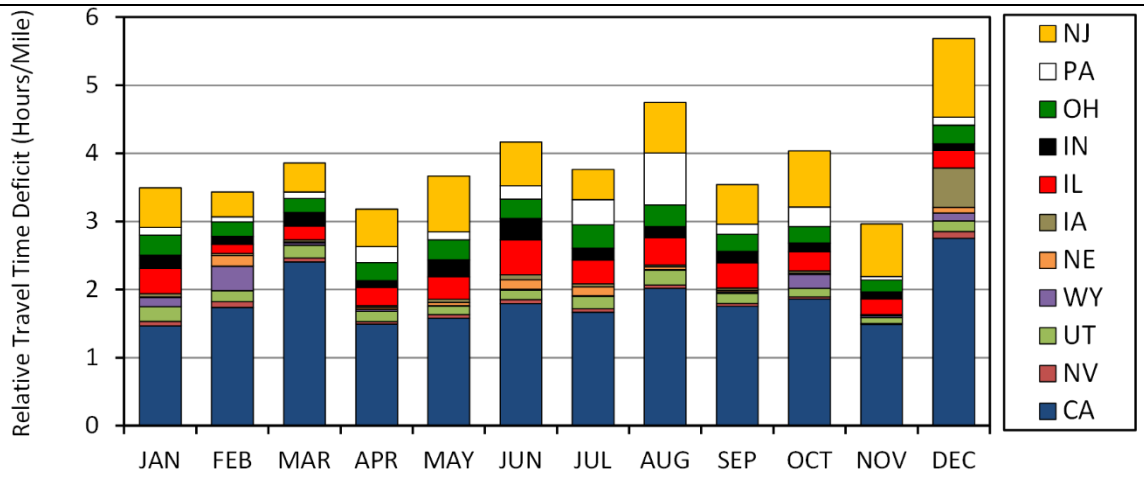


Figure 8: 2012 Monthly travel time deficit for I-80
Normalized by length of Interstate in the state (Hours/Mile)

Figure 9: Top 100 interstate segments on I-80 with highest travel time deficit (hours)

There are opportunities to further scale this crowd sourcing model. We still routinely identify maintenance and capital project needs using a combination of models, field observations of skid marks, telephone input from our users, and crash reports. (Figure 10) When one considers that most modern cars have a large collection of sensors that can provide this feedback, we must find ways to effectively and quickly share data between manufacturers and agencies in a manner that does not compromise privacy.

Figure 10: Traditional infrastructure feedback mechanisms need to evolve

As examples of emerging opportunities for transportation agencies to partner with the automotive industry, consider the following vehicle sensors and their ability to help us identify best practices and prioritize investments.

- Accelerometers used for air bags can also detect hard braking events to provide indications of “close calls” that are much better for identifying emerging hazards then waiting for skid marks or crashes to occur. (Figure 11) In fact, with the advent of anti-lock brakes, most modern vehicles don’t generate observable skid marks which further increases the importance of partnering with the automotive industry to develop crowdsourced techniques to identify roadway locations that have abnormally high numbers of “close calls” for further engineering assessment.

Figure 11: Hard braking event at signalized intersections (0.6g)

- Similarly, vehicle sensors associated with stability and ride quality can provide real-time mapping of emerging pot holes that can be used by agencies to prioritize maintenance activities, particularly in the spring when pot holes are rapidly emerging.
- Advance traction control systems, which allow vehicles to react to reduced friction during winter snow events, collect better real-time condition assessment of our roads then we can do with sparsely located sensors embedded in the pavement (10). Since many winter operations activities by agencies are based upon forecasts, this additional layer of vehicle data will provide more agile tactical allocation of plows and salt trucks during rapidly changing winter storms. (Figure 12)

Figure 12: Varying road conditions
due to drifting snow in rural area

- Sign reading technology emerging on cars will provide us with the ability to identify locations where vegetation growth is reducing visibility. (Figure 13)

Figure 13: Example of vegetation growth
reducing visibility of sign on right side of road

- Lane departure warning systems, which currently provide feedback to drivers regarding lane position, also know when they can't "see" the lines or are confused by the lane markings. Given the diversity of pavement markings used across the country, systematically identifying these areas where lane departure warning systems are experiencing problems will help us rapidly converge on best practices and be better partners with the automotive industry. (Figure 14)

Roadway with worn pavement markings

Figure 14: Example steering assist cockpit display on a road with worn pavement markings

In summary, I believe there are several near term opportunities for agencies, universities and the private sector to partner in sharing vehicle data in ways that protect the privacy of motorists and the intellectual property of automotive industry, while providing information that allows agencies to more effectively allocate scarce resources. Focusing on some of these near term benefits to agencies will also strengthen relationships and collaboration (Figure 1) that will be critical to the longer term deployment of autonomous vehicles.

Holistic Approach to Freight Movement

As many of you are aware, the Indiana state motto is "Crossroads of America." Our Governor has advocated that this is not just our motto, it is our mission. (11) Figure 15 shows a US Department of Transportation freight map and projections for 2040. As we look at the quantity and value of freight that is moved in this country (Table 1), we must continue to identify new opportunities for intermodal connectivity to not only improve our economic competitiveness, but also ensure our surface transportation system can effectively respond to future growth. When one looks at the top 100 congested sections of I-80 (Figure 9) and overlays that with state to state truck flow (Figure 15), it is not hard to envision how we can systematically and objectively prioritize infrastructure investments in highways, as well as multi-model facilities, that will be critical to sustained growth of domestic commerce.

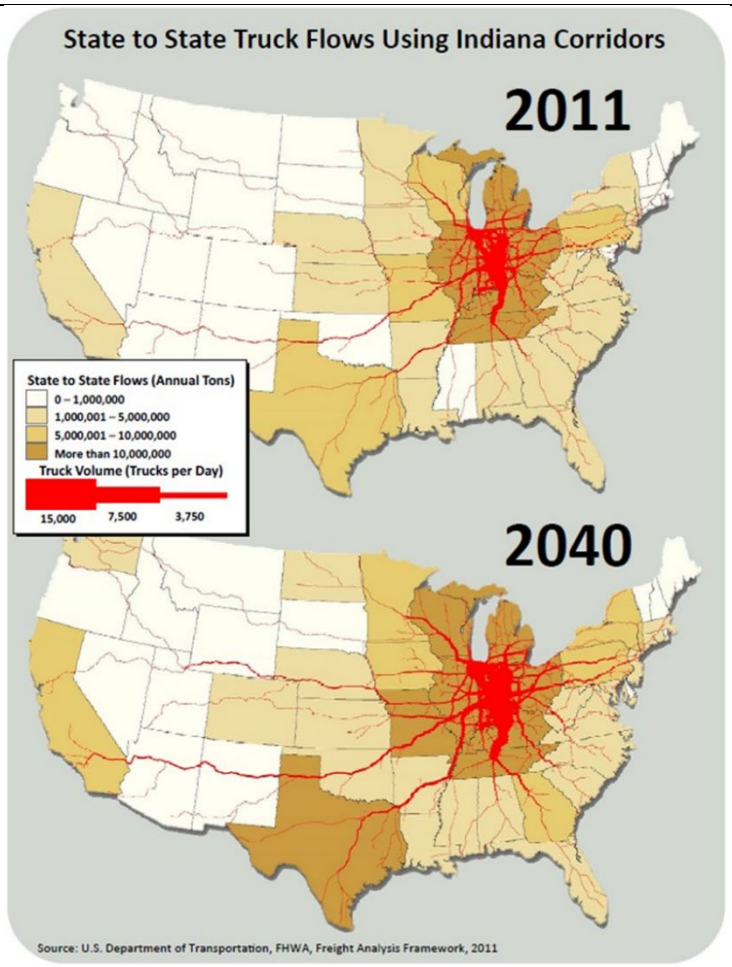


Figure 15: State to state truck flows using Indiana corridors

Table 1: Weight and Value of Freight Shipments by Domestic Mode: 2017		
Domestic Mode	Tons	Dollars
Truck	11,520,318,384	$12,421,510,923,492
Rail	1,738,345,508	$690,458,559,600
Water	766,322,366	$363,500,106,900
Air (including truck-air)	5,871,207	$591,253,478,699
Multiple modes and mail	495,680,450	$2,328,112,103,999
Pipeline	3,049,856,604	$942,007,459,500
Other and unknown	39,210,395	$97,632,790,600
No domestic mode	208,676,316	$66,410,035,300
Total (All modes)	17,824,281,230	$17,500,885,458,090
SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics and Federal Highway Administration, Freight Analysis Framework, version 4.5, 2019.		

Concluding Remarks

- We are very proud of our 82-year partnership between Purdue University and Indiana Department of Transportation (INDOT) through the Joint Transportation Research Program (JTRP). Not only have our research results been implemented at a state and national level, students who have participated in JTRP research projects have gone on to hold senior leadership roles at transportation agencies, private sector companies, and even lead other countries.
- Universities can play a critical role in the collaboration between transportation agencies and the private sector (Figure 1). The emerging area of connected and autonomous vehicles is particularly ripe for this collaboration model.
- A national surface transportation agenda should encourage collaboration among state agencies to help ensure that we are not creating 50 different solutions to the same problem. The current FHWA Pooled Fund Study mechanism is one of many important programs for incorporating perspectives from diverse states, while providing a mechanism to develop a consistent message for industry partners.
- Freight movement is critical to our nation's economy. Collaboration across all modes of transportation is essential to help ensure that we are moving freight in the appropriate mode that increases efficiency, improves safety, addresses environmental issues, and promotes economic competitiveness. I believe some of the emerging crowdsourcing transportation performance measures will be important tools to help us identify opportunities for further improving our nation's freight movement across all modes.

Finally, I would like to thank you for inviting me to engage with your committee. As I indicated earlier, I place a high value on identifying opportunities for our students and faculty to engage with both Industry and government officials. If any of you are interested in further dialog on some of the topics discussed today, I would welcome follow-up communication and the opportunity to host you in Indiana for further dialog with our students, faculty, and industry partners who are the foundation of our Joint Transportation Research Program. (Figure 1)

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