Development of an Implementation Plan for Sustainable Transportation Infrastructure Systems in Iowa

FINAL REPORT

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16. ABSTRACT

The need to incorporate sustainability principles and practices is increasing due to both environmental and economic reasons. It is critical to identify and operationalize sustainability strategies into core administrative, planning, design, construction, operational, and maintenance activities for the transportation infrastructure systems using a comprehensive systems approach and the integration of sustainability in decision-making processes.

The primary goal of this study is to develop an implementation plan for achieving more sustainable transportation infrastructure systems for Iowa DOT and local road agencies. The specific objective of this research is to develop a systemic methodology for identifying the best sustainable practices for implementation in transportation infrastructure practices in Iowa by developing a shelf-ready idea based on identified target areas to be put into practice through small-scale pilot projects. First, to develop goals and practices of sustainability for Iowa DOT, this report presents efforts to identify sustainability goals and practices by surveying 50 state DOT's. Second, this report discusses a development of a database of sustainable practices with implementation records (DOSPIR), which can serve as a central repository of construction, materials, and performance data of sustainable practices, allowing transportation engineers to access past performance data and identify the most appropriate sustainable practices. Third, the sustainability co-operative rating number (SCORN) that was specifically designed for Iowa DOT with relevant sustainability criteria with numerically oriented rating numbers. The sustainability tools developed from this study provide a roadmap for Iowa DOT to effectively implement sustainable practices.

For future studies, the prototype SCORN should be expanded to include and refine rating criteria after adjusting their relative weights based on normalized performance metrics so that the effect of meeting sustainability targets could be quantified. The prototype DOSPIR should be expanded to incorporate more sustainable practices with historical performance data along with their GIS locations. In the future, the research team should interview the top management of Iowa DOT to assess their perception and support for sustainability efforts through incentives for sustainable practices and possibly creating a separate sustainability office that can lead and oversee sustainability efforts.

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1. INTRODUCTION

Recent sustainability initiatives emphasize environmental stewardship and ecological preservation at national and local levels. Sustainability is not a new concept in design and construction of transportation projects. For example, the need for recycling asphalt pavements has been increasing from both economic and environmental viewpoints. However, the most limiting factor in the utilization of recycled asphalt pavement (RAP) is "low specification limits," i.e., a 20% limit of RAP in a surface layer.

Because Iowa DOT and local public agencies are building, operating, and maintaining their transportation infrastructure systems with constrained budgets, there are critical needs to: 1) maximize service and performance quality while controlling costs and environmental impact, 2) integrate sustainability in decision-making processes for planning, designing, building and managing transportation infrastructure systems, and 3) incorporate sustainability principles and practices in their everyday operations.

The need to incorporate sustainability principles and practices is increasing due to both environmental and economic reasons. It is critical to identify and operationalize sustainability strategies into core administrative, planning, design, construction, operational, and maintenance activities for the transportation infrastructure systems using a comprehensive systems approach and the integration of sustainability in decision-making processes.

The primary goal of this study is to develop an implementation plan for achieving more sustainable transportation infrastructure systems for Iowa DOT and local road agencies. The specific objective of this research is to develop a systemic methodology for identifying the best sustainable practices for implementation in transportation infrastructure practices in Iowa by developing shelf-ready ideas based on identified target areas to be put into practice through small-scale pilot projects.

This report discusses efforts to identify sustainable goals and practices by surveying 50 state Departments of Transportation (DOTs). This report then presents a comprehensive study on integrating sustainability in Iowa's transportation infrastructure by developing a new Sustainability Co-Operative Rating Number (SCORN) and the Database Of Sustainable Practices with Implementation Records (DOSPIR), which can serve as a sustainability rating system and a central repository of performance data of sustainable practices, respectively.

2. BACKGROUND

Sustainability is a concept that considers a long-term view of projects, considering costs and benefits over a lifetime rather than concentrating on a short-term cost. However, unlike buildings that adopted many sustainable practices through the LEED (Leadership in Energy and Environmental Design), transportation infrastructure has been largely neglected when it comes to sustainability. Transportation infrastructure is essential to sustainability for both urban and rural communities in the US. Therefore, the need to incorporate sustainability principles and practices in constructing and maintaining transportation infrastructure is growing rapidly due to both environmental and economic reasons.

Milani et al. (2021) provided a comprehensive framework for sustainable transport infrastructure and discussed the importance of flexibility in transport infrastructure. Mead (2021) provided a global perspective on sustainable transportation efforts and their impact on urban development, which discussed the progress and challenges in achieving sustainable transportation by promoting investments in walking and cycling infrastructure and various initiatives for creating more walkable and bike-friendly urban environments. Recently, a special issue was published on sustainable transportation infrastructure with a comprehensive view of the most recent research and advancements in sustainable transportation infrastructure, which covers a wide range of topics, including pedestrian and bicycle safety, complete streets, connected and automated vehicles, electric vehicles, and the impact of transportation infrastructure on urban heat and community severance (Molan et al., 2023).

To encourage public agencies to adopt more sustainable practices, several sustainability rating systems have been developed in the past. Agencies can use a sustainability rating system to evaluate the sustainability of their projects with a set of sustainability criteria. Each sustainability rating system differs in how to evaluate sustainable practices based on various criteria with a different weight given to each criterion. For example, the Federal Highway Administration (FHWA) is actively promoting sustainability through the INVEST (Infrastructure Voluntary Evaluation Sustainability Tool) rating system, which was developed to encourage efforts towards sustainability in transportation projects (FHWA 2012). As shown in Figure 2-1, FHWA supports activities to facilitate balanced decision-making among environmental, economic, and social values - the triple bottom line of sustainability (Adam 2006). As shown in Figure 2-2, seventy-one agencies adopted the INVEST in their 2,400 projects with over 2,000 registered users.

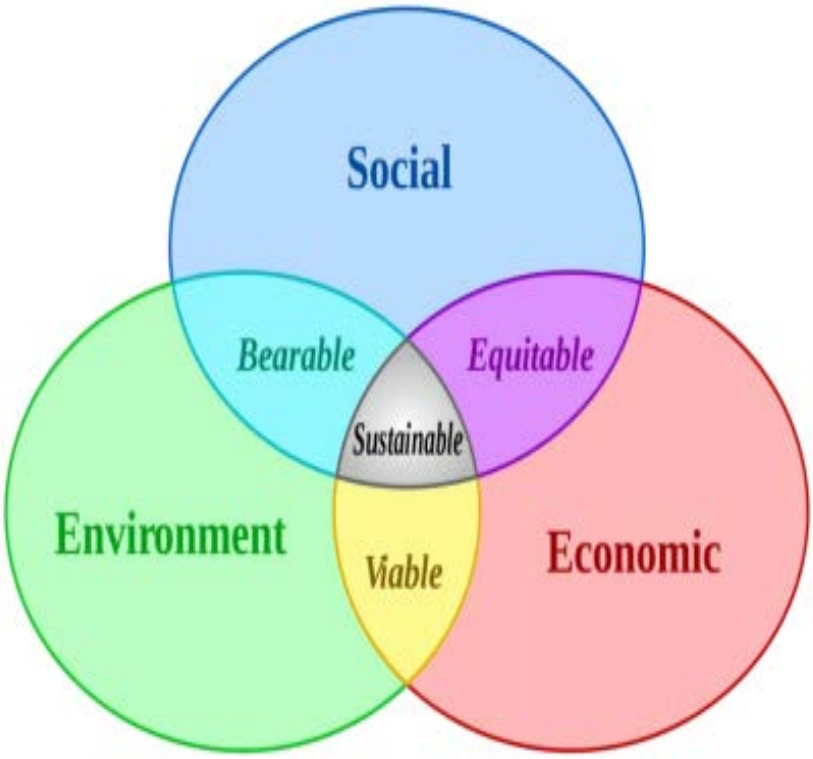


Figure 2-1. Triple Bottom Line of Sustainability (Adam 2006).

Figure 2-2. Users of INVEST (FHWA 2012).

In the past, the most common sustainability rating systems have been evaluated to identify how credits are distributed across three sustainability categories: economy, environment, and society. As shown in Table 2-1, we reorganized the table developed by Simpson et al. (2014) with respect to application areas, number of criteria, and main features. As can be seen from Table 2-1, all rating systems are only applicable to highway projects except "Envision," which is applicable to different types of infrastructure projects. Particularly, the "Green Guide for Road" rating system includes the industry's best practices, which have been adopted into the LEED program.

The 2019 Sustainability Report by Minnesota DOT lists 38 metrics in 7 areas of transportation (10 metrics for transportation modes), facilities (9 metrics related to energy and water, fleet (6 metrics of alternative fuels), highway operations (5 metrics for lighting and deicing), roadside management (2 metrics of native plantings and snow fences), construction (3 metrics for sustainable pavements and recycling) and climate resilience (3 metrics related to culverts and precipitation) (Minnesota DOT 2020). These 38 metrics are similar to 27 metrics developed by Iowa DOT's sustainability working group (Iowa DOT 2022).

In Iowa, significant efforts have been made to integrate social, economic, and natural resource needs while creating a community forum for discussing and sharing ideas for a more sustainable tomorrow for Greater Des Moines (Des Moines, 2013). The Iowa Economic Development Authority (IEDA) developed Iowa Green Streets Criteria to encourage sustainable community practices of: 1) integrative design, 2) location + neighborhood fabric, 3) site improvements, 4) water conservation, 5) energy efficiency, 6) materials, 7) healthy living environment, and 8) operations, maintenance, and occupant engagement (IEDA 2020).

Iowa DOT has always been at the forefront of sustainable project development and design practices. The Iowa DOT's project development process encompasses a design concept following a context-sensitive solutions (CSS) approach that fits the transportation infrastructure into the environment rather than altering a sensitive environment to fit the infrastructure (Iowa DOT 2013). For example, the Bridges and Structures Bureau has adopted the established Iowa DOT guidelines in using sustainable practices with the following concerns: 1) sedimentation and erosion control, 2) disturbance to wetland and farmland, 3) fastest track construction, 4) impact of footings and piers in surrounding environment, and 5) one new bridge to replace several old and smaller bridges (Iowa DOT 2020).

Table 2-1. Comparison of Ten Most Common Sustainability Rating Systems.

System	Developer	Applicability	Criteria	Main Features
BE2ST-in-Highways	University of Wisconsin-Madison	Planning/Design	7 categories 10 criteria	Recycling, weights life-cycle assessment
Envision	ISI, Harvard U.	Planning/Design Constr./Maint.	5 categories 60 credits	Self-assessment, any point in life cycle
Green Guide for Road	Stantec	Planning/Design	7 categories 35 credits	industry's best practices, into LEED
Greenlites	New York State DOT	Planning/Design Constr./Maint.	5 categories 175 credits	performance, identify areas of improvement
GreenPave	Ontario Ministry of Transportation	Planning/Design Constr./Maint.	4 categories 36 points	Focus on pavements
Greenroads	CH2M HILL/ U. of Washington	Planning/Design Construction	6 categories 31 criteria	roadway sustainability quantitative method
I-LAST	Illinois DOT, ACEC, IRTBA	Planning/Design Construction	8 categories 153 criteria	design and future construction phase
INVEST	CH2M Hill/FHWA	Planning/Design Constr./Maint.	68 criteria	Predefined/Custom scorecards
CEEQUAL	Institution of Civil Engineers (UK)	Planning/Design Constr./Maint.	9 categories	Applicable to a wide range of project types
STARTS	N. American Sustain. Transp. Council	Planning/Design Constr./Maint.	6 categories 29 credits	transportation and land use strategies

3. SURVEY OF STATE DOTS ON SUSTAINABILITY IMPLEMENTATION

We surveyed state DOT's that have or are currently implementing sustainability into their activities in order to identify: 1) agency-wide sustainability goals, 2) sustainability target areas and metrics, 3) sustainability attributes, criteria and rating system, 4) successful sustainable practices, 5) how to incorporate sustainability strategies into core administrative, planning, design, construction, operational, and maintenance activities, 6) how to integrate sustainability in decision-making processes in consideration of economic, social, and environmental effects, 7) sustainability outcomes and measures of progress, 8) implementation plan for building more sustainable transportation infrastructure systems, 9) incentives, risks and limitations of sustainability implementation, 10) agency-wide review process for sustainability practices, 11) methods to promote and institutionalize sustainability initiatives, and 12) efforts to enhance the public's perception of an agency as a leader on sustainability.

Selected state DOT's were surveyed after considering the results from the survey performed by the AASHTO Sustainability Working Group. Survey questions were prepared, which include questions about funding, sustainability attributes, definition of sustainability, and utilization of Sustainability Rating Systems (SRS).

3.1. Sustainability Survey by AASHTO

In 2016, AASHTO created the Committee on Environment & Sustainability (CES), which reflected the growing importance and consideration of sustainability among AASHTO members. In 2020, CES established the Sustainability Working Group (SWG) to begin integrating "sustainability," which included efforts to address climate change, reduce energy use, water use, and CO_2 emissions, and increase resilience, into the work of CES and other relevant AASHTO committees. The SWG conducted a survey of AASHTO members to better understand how state DOTs are managing their operations, programming, and other work related to sustainability. This survey was sent to all 118 CES members from 50 states and Washington D.C. This AASHTO survey consisted of 22 questions and received responses from 44 states, where some states replied with multiple responses from different departments.

According to the AASHTO survey, only 10 state DOTs have adopted a definition of "sustainability," and an additional 10 state DOTs consider sustainability as a factor in their strategic and project planning. Most state DOTs house sustainability initiatives and staff as part of existing offices except 5 state DOTs, which maintain a standalone sustainability office. 16 state DOTs have directives from governors or legislatures to address sustainability and implement formal sustainability programs. Most state DOTs plan to implement the following four sustainability goals: 1) reducing facilities' energy use, 2) increasing infrastructure resilience, 3) increasing electric vehicle infrastructure, and 4) considering climate change when planning and designing projects. To achieve these sustainability goals, many state DOTs provide direct general funds and indirect funds diverted from other programs, grants, and pilot programs. The detailed survey results are summarized in Appendix A.

3.2. Sustainability Survey by University of Iowa

Two surveys have been conducted by the University of Iowa, and out of 50 state DOTs, we received 9 and 16 responses from each of the two surveys. The first survey asked the following three questions: sustainability goals, successful sustainable practices, and means to incorporate sustainability into the decision-making process. The second survey asked questions in the following three categories: sustainability evaluation metrics, incentives for sustainability implementation, and lessons learned from sustainability implementation.

3.2.1. First Sustainability Survey

Based on the AASHTO survey results, as shown in Figure 3-1, 25 state DOTs, including 21 state DOTs with positive responses in the AASHTO survey and four surrounding states, were selected for our follow-up survey. It should be noted that the remaining 25 state DOTs did not fill out the AASHTO survey completely. To make it easier for state DOTs to fill out the survey, we prepared our survey with multiple-choice questions.

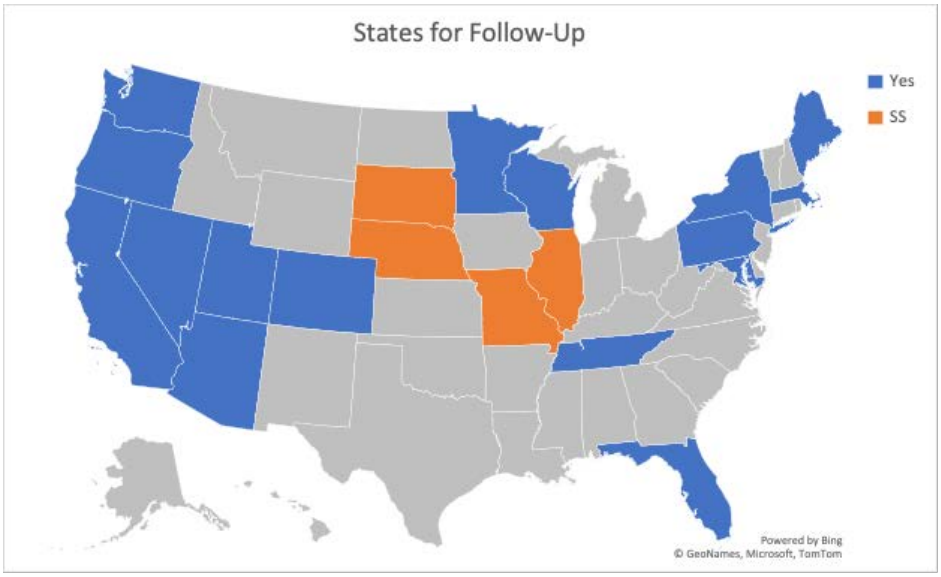


Figure 3-1. 21 Selected States plus 4 Surrounding States.

Out of 25 state DOTs, as shown in Figure 3-2, we received 10 responses, nine state DOTs of Vermont, Arizona, Washington, Iowa, Tennessee, Wisconsin, Colorado, Minnesota, and Utah, and the Federal Highway Research Institute in Germany. Overall, most state DOTs were interested in sustainability, but a small number of state DOTs have adopted the sustainability concept. Based on the survey results, the top five agency-wide sustainability goals are reuse and recycling, saving energy, increasing lifecycle, minimizing waste, and clean air and water.

The most common successful sustainable practices are to recycle asphalt and concrete pavements, install LED lights, plant native species, utilize recycled materials, keep a database of sustainable practices, and convert traffic signals to roundabouts. The most popular means to incorporate sustainability into the decision-making process are to modify specifications to allow sustainable practices, outreach to communities and stakeholders, create a sustainability working

group/department, measure economic/social/environmental effects, and prioritize sustainable strategies. Table 3-1 summarizes eleven multiple choice questions in Iowa survey. Survey results for each of the eleven questions are summarized below.

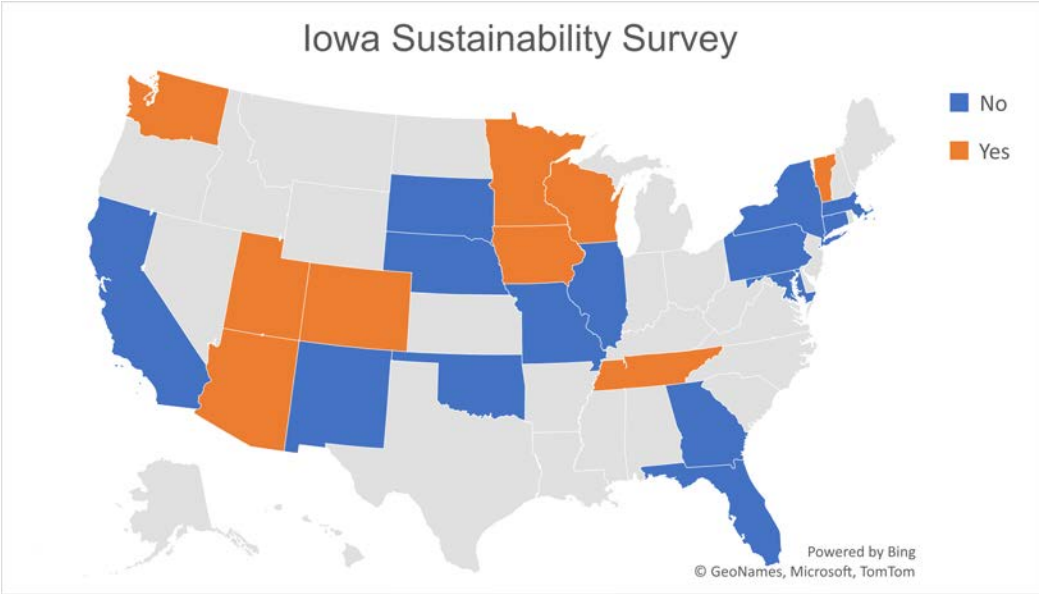
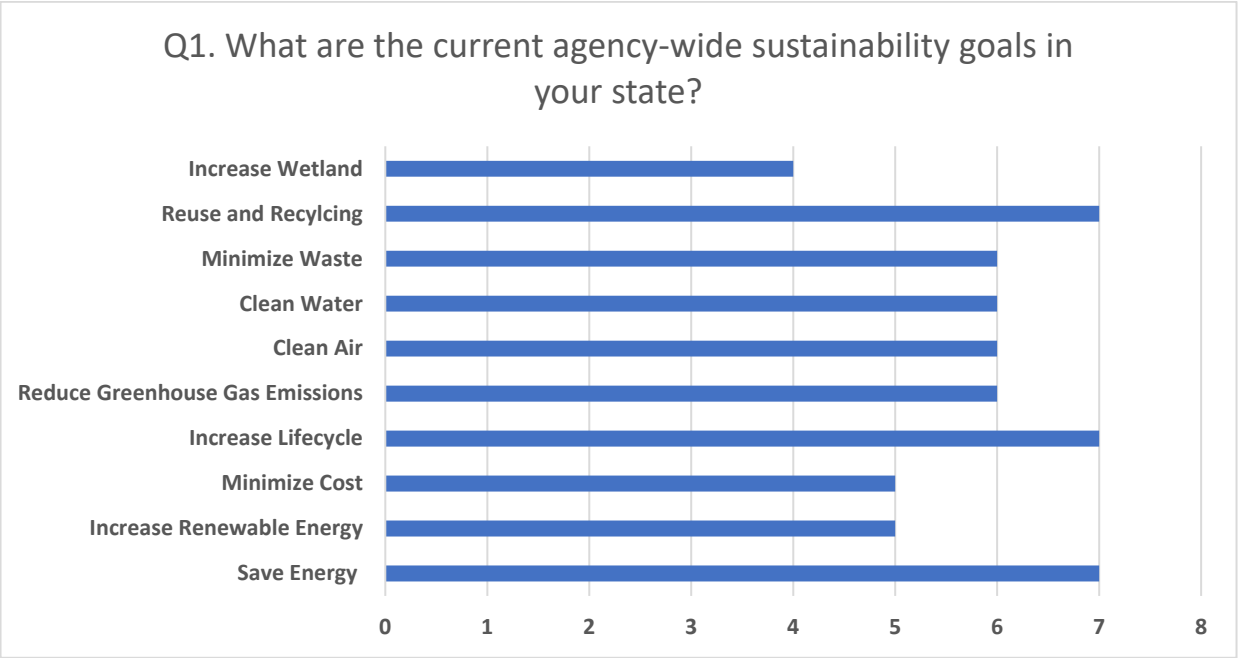


Figure 3-2. Responding state DOTs for our survey.

Table 3-1. Multiple Choice Questions in the Iowa survey.

1	What are the current agency-wide sustainability goals in your state?
2	What are the sustainability areas that your agency is interested in improving?
3	What are the sustainability attributes that your agency is concerned about?
4	Can you provide some examples of successful sustainable practices that your agency has implemented?
5	How does your DOT incorporate sustainability into decision-making processes in consideration of economic, social, and environmental effects?
6	Can you provide some thoughts or recommendations to enhance the public's perception of your agency as a leader on sustainability?
7	Does your agency provide grants or funds to promote sustainability? If yes, list name of grants with the funding amount. If not, how do you promote sustainability without grants or funds?
8	How do you fund your sustainability activities and practices, i.e., Public-Private Partnerships (P3)?
9	Which sustainability rating system has your agency used? Select more than one, if applicable.
10	Is your agency currently utilizing a Sustainability Rating System (SRS)? (Yes or No) If yes, please describe lessons learned from using your SRS. If no, please explain why your agency is not utilizing SRS?
11	We understand that not all states define sustainability the same way, and we are interested in all measures or practices. We would like to know if there are practices that you would like to highlight?

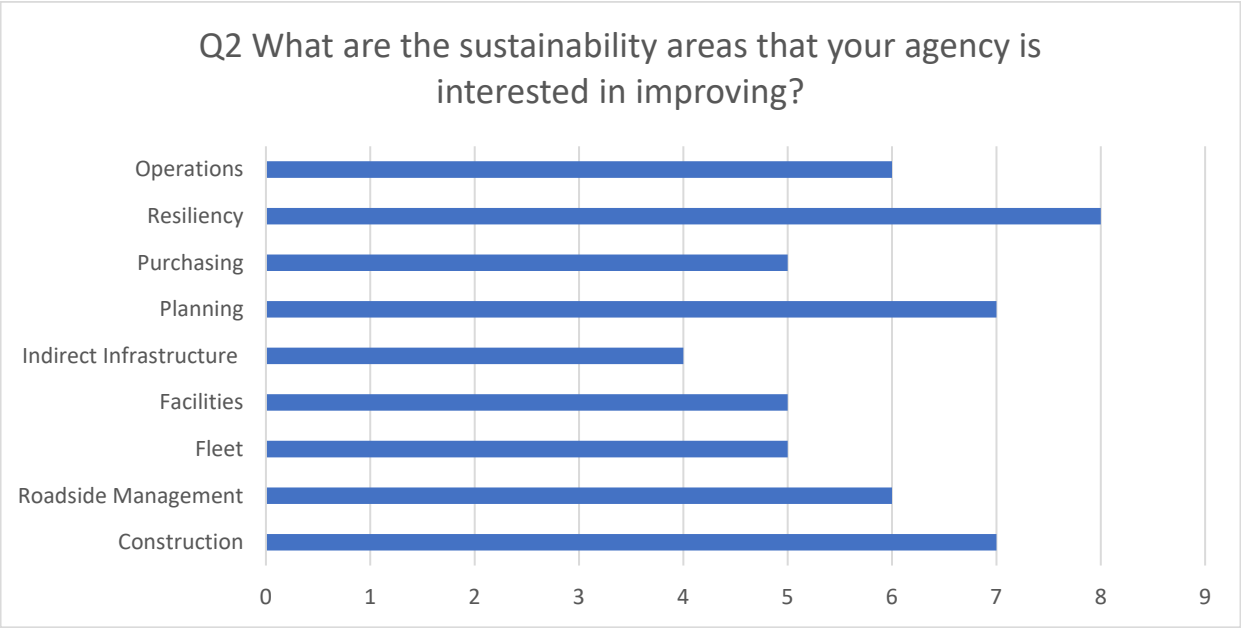
Table 3-2. First Survey Questions and Responses.



State	Other replies
Vermont	Infrastructure Resilience
Washington	Orca recovery, resiliency
Iowa	Our agency does not currently have an agency-wide sustainability goals.
Tennessee	advanced stream compensatory mitigation; manage stream ecological lift and loss balance
Colorado	As a note, these might not be specific goals called out in the Sustainability program, but they are goals various branches are working on within the agency.
Minnesota	Increase climate resilience

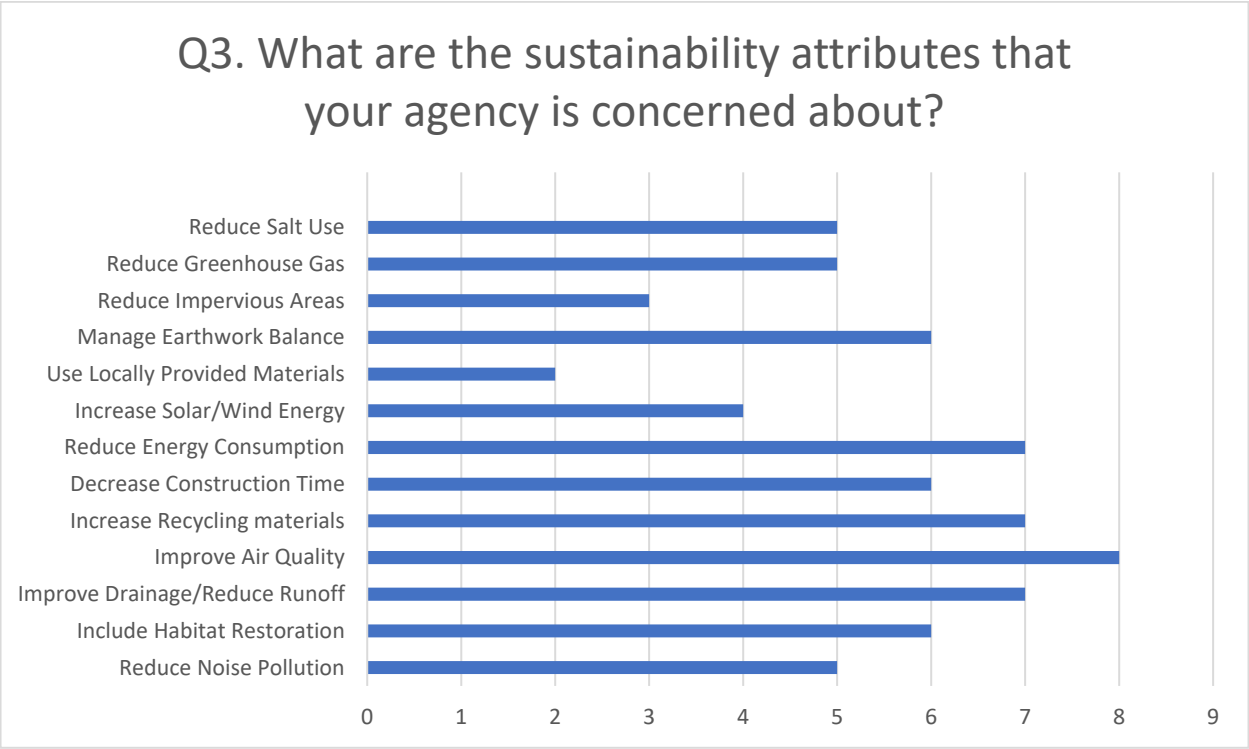
Q1. What are the current agency-wide sustainability goals in your state?										
Sustainability Goals	Vermont	Arizona	Washington	Iowa	Tennessee	Wisconsin	Colorado	Minnesota	Utah	FHRI*
Save Energy	X	X	X			X	X	X	X	
Increase Renewable Energy	X	X				X	X	X		
Minimize Cost	X					X	X	X	X	
Increase Lifecycle	X	X				X	X	X	X	X
Reduce Greenhouse Gas Emissions	X		X			X	X	X		X
Clean Air	X	X				X	X	X	X	
Clean Water	X	X				X	X	X	X	
Minimize Waste	X	X				X	X	X	X	
Reuse and Recycling	X	X				X	X	X	X	X
Increase Wetland	X					X	X	X		

* Federal highway Research Institute, German



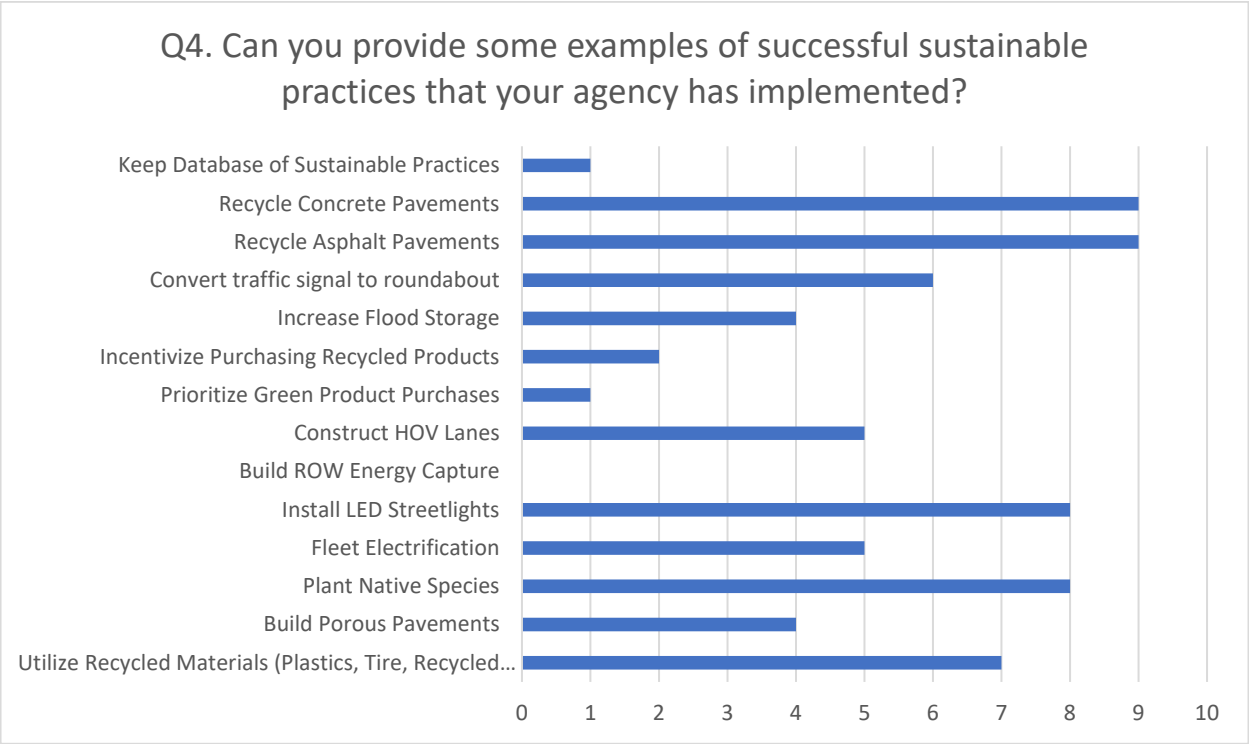
States	Other Replies
Vermont	wildlife and habitat
Washington	We are working in a variety of these areas, but do not have specific areas that we are focusing on exclusively. .
Colorado	Similar response to the first. These are areas other branches may be focusing on, not necessarily under the sustainability nexus.
Minnesota	Sector decarbonization, EV and EV charging

Q2. What are the sustainability areas that your agency is interested in improving?										
Sustainability Goals	Vermont	Arizona	Washington	Iowa	Tennessee	Wisconsin	Colorado	Minnesota	Utah	FHRI*
Construction	X	X		X		X	X	X		X
Roadside Management	X			X	X	X	X	X		
Fleet	X			X		X	X	X		
Facilities	X			X		X	X	X		
Indirect Facilities	X			X		X	X			
Planning	X	X		X		X	X	X		X
Purchasing	X	X		X		X	X			
Resiliency	X	X		X		X	X	X	X	X
Operation	X	X		X		X	X	X		



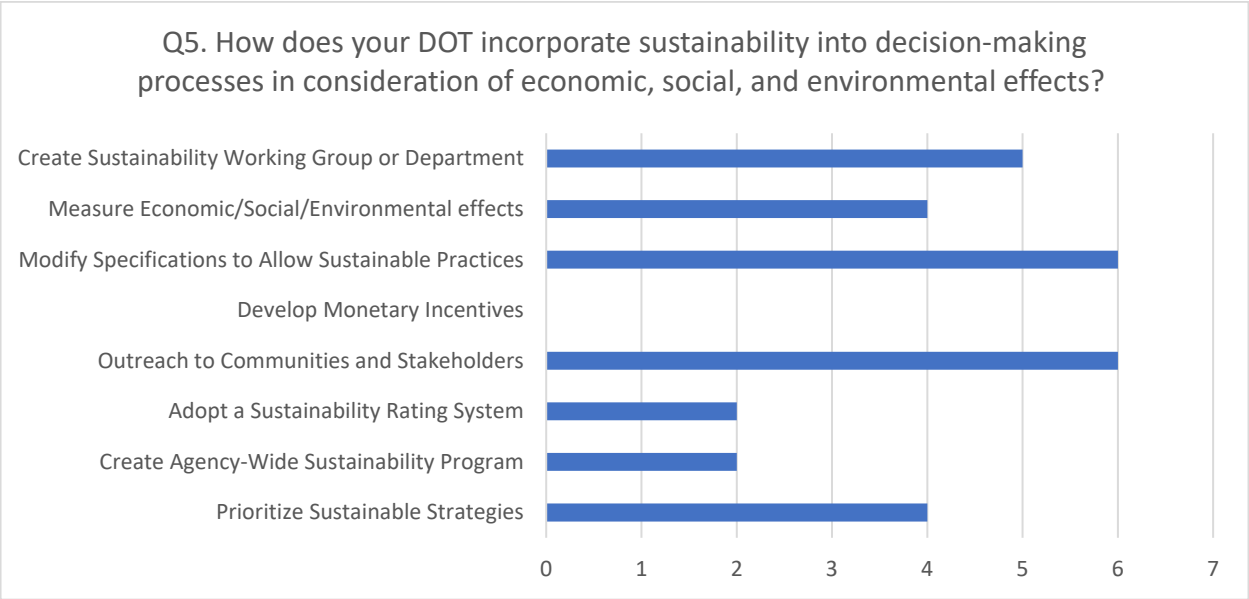
State	Other Replies
Washington	Improve resiliency, orca recovery
Colorado	Similar response to the first. These are areas other branches may be focusing on, not necessarily under the sustainability nexus.
Tennessee	Advanced stream compensatory mitigation; manage stream ecological balance
Minnesota	These are areas other branches may be focusing on, not necessarily under the sustainability nexus.

Q3. What are the sustainability attributes that your agency is concerned about?										
Select option	Vermont	Arizona	Washington	Iowa	Tennessee	Wisconsin	Colorado	Minnesota	Utah	FHRI*
Reduce Noise Pollution	X	X		X		X	X			
Habitat Restoration	X	X		X	X	X	X			
Improve Drainage/Reduce Runoff	X	X		X	X	X	X	X		
Improve Air Quality	X	X		X		X	X	X	X	X
Increase Recycling materials	X	X				X	X	X	X	X
Decrease Construction Time	X			X	X	X	X			X
Reduce Energy Consumption	X		X	X		X	X	X		X
Increase Solar/Wind Energy	X	X					X	X		
Use Locally Provided Materials	X						X			
Manage Earthwork Balance	X	X		X		X	X		X	
Reduce Impervious Areas	X				X		X			
Reduce Greenhouse Gas	X		X				X	X		X
Reduce Salt Use	X			X		X	X	X		



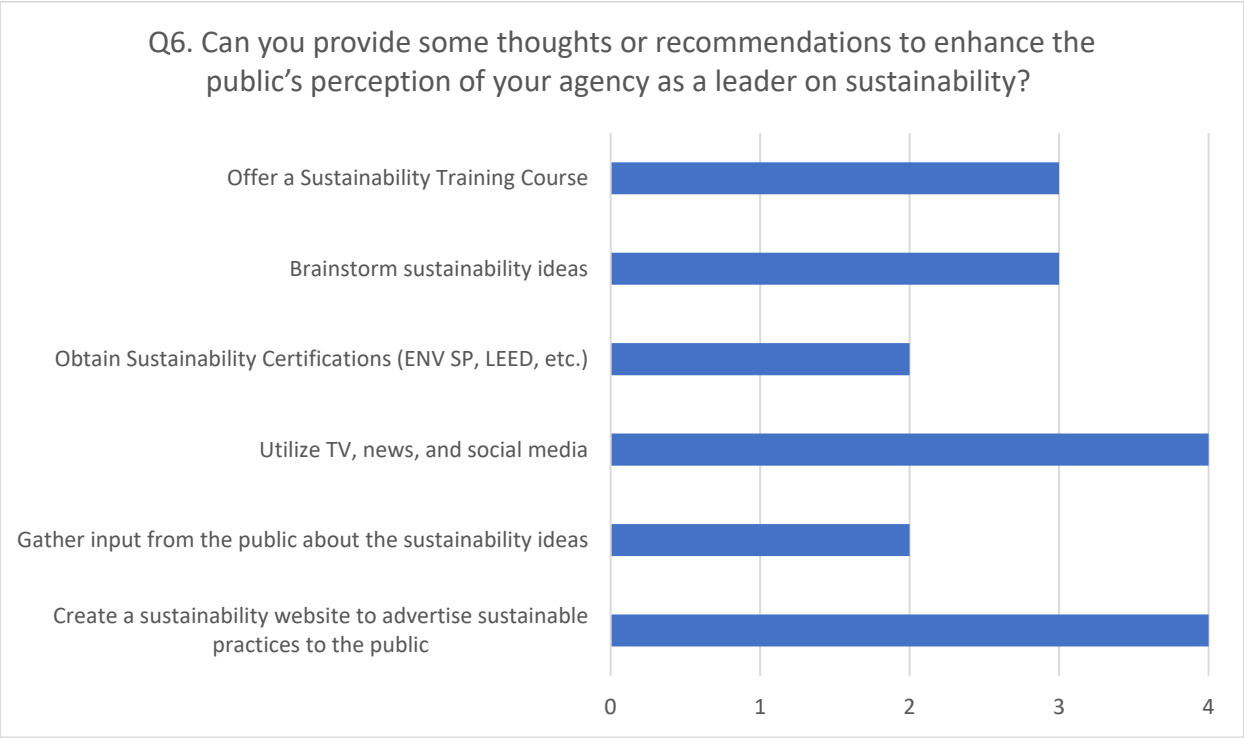
State	Other Replies
Colorado	These are not necessarily across the board practices/project specifications; they might be beta or research projects.
Minnesota	Annual sustainability report with updates on related measures being tracked

Q4. Can you provide some examples of successful sustainable practices that your agency has implemented?										
Select option	Vermont	Arizona	Washington	Iowa	Tennessee	Wisconsin	Colorado	Minnesota	Utah	FHRI*
Utilize Recycled Materials (Plastics/Tire/Aggregates)	X	X	X			X	X	X		X
Build Porous Pavements	X				X		X			X
Plant Native Species	X	X	X	X	X	X	X	X		
Fleet Electrification	X		X	X			X	X		
Install LED Streetlights	X	X	X	X	X		X	X	X	
Build ROW Energy Capture										
Construct HOV Lanes		X			X		X	X	X	
Prioritize Green Product Purchases			X							
Incentivize Purchasing Recycled Products			X			X				
Increase Flood Storage	X	X					X	X		
Convert traffic signal to roundabout	X	X	X	X	X		X			
Recycle Asphalt Pavements	X	X		X	X	X	X	X	X	X
Recycle Concrete Pavements	X	X		X	X	X	X	X	X	X
Keep Database of Sustainable Practices	X	X	X			X	X	X		X



State	Other Replies
Washington	Agency wide sustainability executive order directs all staff to improve energy efficiency, reduce GHGs, improve resiliency, and work towards orca recovery.
Colorado	Some projects (mountain corridor) may prioritize sustainable strategies, but not across the board. Some measurements have been captured under the resiliency umbrella vs sustainability.

Q5. How does your DOT incorporate sustainability into decision-making processes in consideration of economic, social, and environmental effects?										
Select option	Vermont	Arizona	Washington	Iowa	Tennessee	Wisconsin	Colorado	Minnesota	Utah	FHRI*
Prioritize Sustainable Strategies	X	X				X	X			
Create Agency-Wide Sustainability Program		X					X			
Adopt a Sustainability Rating System		X				X				
Outreach to Communities and Stakeholders	X	X		X			X		X	
Develop Monetary Incentives										
Modify Specifications to Allow Sustainable Practices		X		X		X	X	X	X	
Measure Economic/Social/Environmental effects	X	X		X			X			
Create Sustainability Working Group or Department		X		X			X	X		X
Prioritize Sustainable Strategies	X	X				X	X			
Create Agency-Wide Sustainability Program		X					X			



State	Other Replies
Washington	Improve internal coordination on sustainability efforts and communicate how we are doing business differently to support greater sustainability in our state.
Colorado	Some projects (mountain corridor) may prioritize sustainable strategies, but not across the board. Some measurements have been captured under the resiliency umbrella vs sustainability.
Minnesota	Sustainability newsletter, Public Sustainability Advisory Group

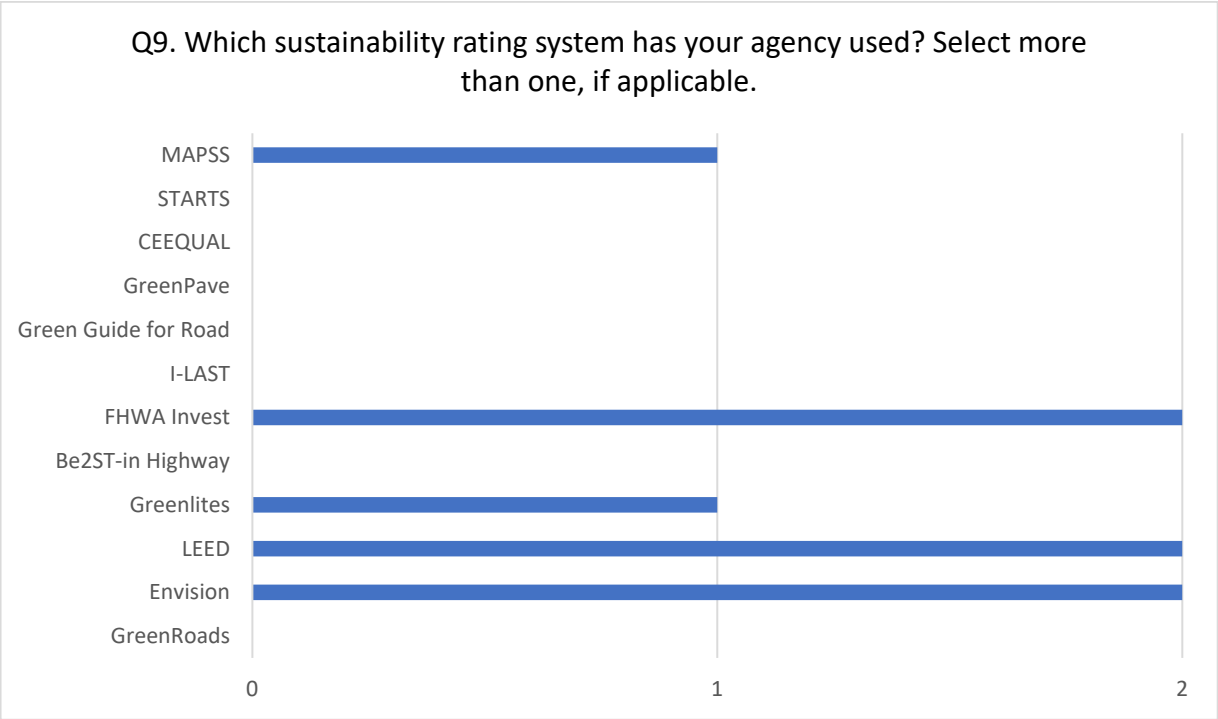
Q6. Can you provide some thoughts or recommendations to enhance the public's perception of your agency as a leader on sustainability?										
Select option	Vermont	Arizona	Washington	Iowa	Tennessee	Wisconsin	Colorado	Minnesota	Utah	FHRI*
Create a sustainability website to advertise sustainable practices to the public				X			X	X		X
Gather input from the public about the sustainability ideas	X			X						
Utilize TV, news, and social media		X		X		X	X			
Obtain Sustainability Certifications (ENV SP, LEED, etc.)				X			X			
Brainstorm sustainability ideas				X	X					X
Offer a Sustainability Training Course		X					X			X

Q7. Does your agency provide grants or funds to promote sustainability? If yes, list names of grants with the funding amount. If not, how do you promote sustainability without grants or funds?

Vermont	VTrans oversees grants for EVSE and incentives for new PEVS and used fuel efficient vehicles. A replace your ride program and electric bicycle incentive program will likely be authorized by this year's transportation bill. Incentive/grant funding varies from year to year.
Arizona	We are fortunate to get internal funding as justification warrants. We also already implement sustainable practices into the scoping/design eng phase as warranted.
Washington	We administer EV infrastructure grants and green transit grants (primarily electric buses and infrastructure). Bike and ped grants, as well.
Iowa	No; however, our agency promotes sustainability through the formation of a Sustainability Working Group. The agency also promotes stewardship of resources. One example of this is the Iowa Living Roadway Trust Fund.
Tennessee	CMAQ and Multi Modal Grants - don't know the funding amount
Wisconsin	Yes - Variable Fed/State - See WisDOT response answers in the AASHTO Sustainability Workgroup Survey Questions: 13, 17, 18 and call if questions.
Colorado	CMAQ funds through the Charge Ahead Colorado Program
Minnesota	Clean Transportation Grants
Utah	
FHRI	we are a research institute and therefore we can define projects on different topics related to the sustainability and get a fund for them.

Q8. How do you fund your sustainability activities and practices, i.e., Public-Private Partnerships (P3)?

Vermont	N/A
Arizona	We incorporate into all design engineering and alt delivery, including P3. So the funding is imbedded into the contracts
Washington	legislative appropriations
Iowa	We do not currently have any funding dedicated for sustainability practices.
Tennessee	standard funding
Wisconsin	State/Fed Funding - See WisDOT response answers in the AASHTO Sustainability Workgroup Survey Questions: 13, 17, 18 and call if questions.
Colorado	Find/demonstrate cost savings in operating budget items.
Minnesota	State and Federal funding
Utah	Implement sustainability insofar as they are cost saving measures (e.g. increasing lifecycle, recycled asphalt, etc.)
FHRI	our fund comes from Ministry of road and Transportation



State	Other Replies
Washington	Our ferries division is using Envision. In the past, we have done pilot cases with several different tools.
Wisconsin	https://wisconsindot.gov/Pages/about-wisdot/performance/mapss/default.aspx
Colorado	3 New Builds were LEED Certified

Q10. Is your agency currently utilizing a Sustainability Rating System (SRS)? (Yes or No) If yes, please describe lessons learned from using your SRS. If no, please explain why your agency is not utilizing SRS?

Arizona	Yes - we score on average 50 projects a year
Wisconsin	Yes, partially, and difficult to quantify - https://wisconsindot.gov/Pages/about-wisdot/performance/mapss/default.aspx
Washington	No. Multiple reasons. Different rating systems emphasize different elements of sustainability. They add to workload without consistently adding benefit.
Colorado	No, although a beta was completed in the past evaluating GreenLITES and INVEST. The rating process was determined to be too time consuming without a dedicated department/team to manage/score.
Vermont	No
Iowa	No; the state of Iowa does not currently have a mandate to implement an SRS. Our sustainability implementation is still early in the process.
Tennessee	No or its unknown to me that it is being used. We would need to identify an 'owner'.
Minnesota	No, haven't found one the fits an identified need clearly (and worth the cost)
Utah	No

Q11. We understand that not all states define sustainability the same way, and we are interested in all measures or practices. We would like to know if there are practices that you would like to highlight?

Vermont	N/A
Arizona	N/A
Washington	We are part of an interagency group, under an executive order from our Governor, working to reduce agency emissions. Through this work, we have secured a contract for renewable electricity from our largest provider, collectively received funding for additional energy efficiency improvements and EV infrastructure.
Iowa	Our state agency chooses to look at the relationship between sustainability and resiliency. We currently are working with a team from the University of Iowa to figure out a way to implement sustainability into our practices and develop two shelf-ready pilot projects.
Tennessee	use of recycled asphalt and concrete; Nobody Trashes Tennessee litter prevention campaign
Wisconsin	See the WisDOT answers provided in the AASHTO Sustainability Workgroup Survey. Responses were thorough.
Colorado	N/A
Minnesota	We have 3 sustainability focus areas: a) Reduce carbon pollution from the transportation sector, b) Increase operational efficiencies that support Executive Orders, including efforts to reduce fuel consumption and energy use, c) Improve resilience of the transportation system to climate change and other natural and human disruptions.
Utah	While not part of a formalized program, many of our sustainable practices come from various parts of our department through projects such as: Solar Panel installation, EV charging stations, Travelwise program, increase mode split for active transportation and transit, Remote Work, cold in place recycle, RAP, crushed concrete for base.
FHRI	N/A

3.2.2. Second Sustainability Survey

For the second round of the survey, as shown in Figure 3-3., surveys were sent to all fifty State DOTs, and we received responses from 16 states. The responder's names and their affiliations are summarized in Table 3-3. Table 3-4 lists 9 questions for the second survey and the survey results are summarized in Table 3-5. Regarding sustainability evaluation metrics, only 3 states replied that they have such metrics, whereas the remaining 13 states did not. Regarding the lessons learned from sustainable practices, 8 states implemented the sustainable practices with lessons learned such as engagement with key staff members, reaching out to other agencies, support from leadership, adequate funding, not overthinking, not being afraid to make mistakes, need standard measurable metrics, incentivize contractors for more sustainable practices, and sharing best practices. Regarding providing incentives for implementing sustainable practices, no state is currently providing any incentive for sustainable practices.

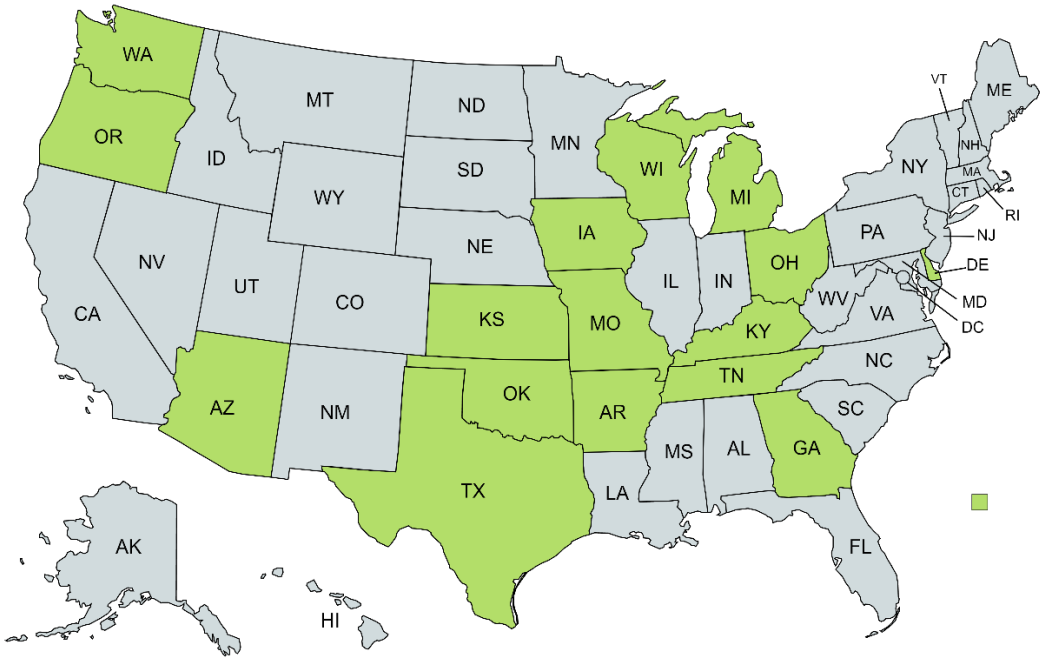


Figure 3-3. 16 states responded to the Second Survey.

Table 3-3. 16 Survey Responders' Names and Affiliations.

First Name	Last Name	Affiliation	State	E-mail Address
Kayti	Ewing	Arkansas DOT	AR	kayti.ewing@ardot.gov
Steve	Olmsted	Arizona DOT	AZ	solmsted@azdot.gov
Jim	Pappas	Delaware DOT	DE	james.pappas@delaware.gov
Emily	Fish	Georgia DOT	GA	efish@dot.ga.gov
Madeline	Schmitt	Iowa DOT	IA	Madeline.Schmitt@iowadot.us
Allison	Smith	Kansas DOT	KS	Allison.Smith@ks.gov
Danny	Peake	Kentucky DOT	KY	Danny.Peake@ky.gov
Hal	Zweng	Michigan DOT	MI	zwengh@michigan.gov
Travis	Koestner	Missouri DOT	MO	Travis.Koestner@modot.mo.gov
Tim	Hill	Ohio DOT	OH	Tim.Hill@dot.ohio.gov
Siv	Sundaram	Oklahoma DOT	OK	ssundaram@odot.org
Zechariah	Heck	Oregon DOT	OR	Zechariah.HECK@odot.state.or.us
Susannah	Kniazewycz	Tennessee DOT	TN	susannah.kniazewycz@tn.gov
Rodney	Concienne	Texas DOT	TX	rodney.concienne@txdot.gov
Kevin	Bartoy	Washington DOT	WA	bartoyk@wsdot.wa.gov
Bob	Pearson	Wisconsin DOT	WI	robert.pearson@dot.wi.gov

Table 3-4. List of Nine Questions for the Second Sustainability Survey.

1	What are your organization's sustainability goals?
2	What are the action items performed to achieve your organization's sustainability goals?
3	What sustainability performance metrics has your agency adopted?
4	What are the most successful sustainable practices implemented in your organization?
5	What are the lessons learned from implementing sustainability in practice?
6	How has your organization integrated sustainability into planning, design, construction, operational and maintenance activities?
7	Does your organization provide any incentives for implementing sustainable practices? Please list any sustainability incentive programs.
8	How does your organization encourage the sustainability? Please list all organizational activities to promote sustainability in your organization.
9	Does your organization uses a sustainability rating system, i.e., Greenroads, Envision, etc.? If yes, what is the name of the sustainability rating system?

Table 3-5. Second Sustainability Survey Results.

Q1. What are your organization's sustainability goals? (4 Yes; 12 No)

Arizona	(1) addresses a true operational need, (2) aligns with continuous improvement and performance-based practical design goals, (3) furthers environmental, economic, social, and environmental stewardship and improves environmental risk management overall. (https://azdot.gov/sites/default/files/media/2020/10/Final-Report-June20-V6.pdf)
Arkansas	Provide safe and efficient transportation solutions
Delaware	Our Resiliency Sustainability division is less than a year old so no specific goals have been established yet
Iowa	1. Support Workforce Sustainability- Attract and Retain a Quality Workforce 2. Employ Renewable Energy Generation-DOT ROW, Rest Areas, Maintenance Garages, and Facilities 3. Utilize Long-life Pavements and Research Recycled/Sustainably Sourced Materials 4. Invest in Innovation 5. Collaborate with Other State Agencies (Within and Between States) 6. Reduce Energy Use and Explore Opportunities to Improve Efficiency 7. Maintain a Rightsized Infrastructure Footprint 8. Incorporate Sustainable Design Methods (Facilities and Rest Areas) 9. Expand Alternative Uses of Roadsides and Roadside Vegetation Management 10. Promote Electric and Alternative-Fueled Vehicles
Kentucky	Our organization is studying actions that should take to implement a sustainability plan.
Oregon	Document use of "green" janitorial supplies in ODOT major facilities, and other office facilities as appropriate.
Washington State	Invest in infrastructure and operations to maintain reliable service in a changing climate and reduce the ferry system's environmental impact. (https://wsdot.wa.gov/sites/default/files/2021-10/WSF-SustainabilityActionPlan-2021-2023.pdf)
Wisconsin	Undefined presently

Kansas	Stewardship - Continuously improve the quality of the transportation system and surrounding communities and the natural and historic environment through strong partnerships and focused, lower cost, and higher value improvements that avoid or minimize adverse impacts
Ohio	No statewide goals
Tennessee	While there are sustainable practices at TDOT, I'm not aware that TDOT has specific written sustainability documents for goals, action items, or implementation records; nor do we use Greenroads or Envision. Although some TDOT divisions may acknowledge sustainable practices, I could not readily locate documentation. Our Long Range Planning division did complete some research in 2018: RES2016-10 Green Generates Green Final Report_approved.pdf (tn.gov) Sustainable practices are threaded through TDOT programs, but I am not aware of collective documentation.
Texas	TxDOT currently does not have a formal sustainability program nor is there, at this time, a centralized effort or formal charter to develop a sustainability program. Consequently, my answers to your survey questions would reflect our current situation. Like most state DOTs, TxDOT has many practices and operations that could be described as sustainable, and there have been some isolated efforts to identify these practices and operations.
Michigan	Goals are not explicitly outlined, but the Department uses sustainable practices such as pavement recycling.
Missouri	Category:127 MoDOT and the Environment - Engineering_Policy_Guide
Oklahoma	Oklahoma Department of Transportation currently does not have any formal goals for sustainability. However, we have implemented several sustainability measures in our construction and routine maintenance practices.
Georgia	We are still implementing goals but mitigation and resiliency and funding these initiatives through federal grants are our broad spectrum plans.

Q2. What are the action items performed to achieve your organization's sustainability goals? (6 Yes; 6 No)

Arizona	Three complete programs - sustainable transportation, sustainable pavement, ADOT / USGS Partnership
Arkansas	Distributing and implementing FHWA's Transportation Alternative Program
Delaware	We are currently partnering with other stakeholders to discuss risks across the state and ways we can help mitigate those risks
Iowa	The Iowa DOT has created a Sustainability Working Group which meets on a monthly basis to discuss strategies to achieve our sustainability goals.
Kentucky	Still in the research phase.
Oregon	Maintain up-to-date Sustainability Plan and report on annual progress. Established emissions baseline (GHG inventory). Developed list of recommendations to pursue with agency managers and industry stakeholders. Set up regular meetings to discuss progress and overcome challenges.
Washington State	Take climate action, clean air, clean water, increase biodiversity, achieve zero waste, enhance and support thriving communities. (https://wsdot.wa.gov/sites/default/files/2022-03/WSF-SustainabilityPlanPerformanceDashboard-FY22Q3.pdf)
Wisconsin	Undefined presently
Kansas	Act as a good neighbor and steward for our natural, cultural, and environmental resources. Maximize value by directing resources to the most pressing community needs through fast, flexible, easy, and streamlined project delivery. Improve access to jobs, services in, and products from existing and emerging economic and social centers.
Ohio	Did a climate change impact study and risk assessment and project specific goals on certain projects
Tennessee	N/A
Texas	N/A
Michigan	N/A
Missouri	Nepa process to minimize impacts to environment on projects Specifications throughout allow recycled materials Being Green | Missouri Department of Transportation (modot.org)
Oklahoma	ODOT has adapted areas within our right-of-way for conservation of recently listed monarch butterflies. We have identified conservation measures to address key threats to the species within our adopted areas. These include native seeding to restore or create suitable monarch habitat, brush removal, conservation mowing, targeted herbicide treatments, and managing suitable habitat set asides and idle lands using

	integrated vegetative best management practices for on the ground monarch benefit. ODOT also actively looks for opportunities to re-vegetate sites post construction with native species where feasible. We use a variety of recycled material and reuse of waste from other industries in construction. These include Fly Ash, Ground Tire Rubber (GTR), Cement Kiln Dust (CKD), Mine Chat, Recycled Concrete Aggregate (RCA), and Recycled Asphalt Pavement (RAP). In addition, Oklahoma is increasing the use of Warm Mix Asphalt (WMD). Other areas we are exploring in concrete pavements are Reduced Cement Content, Cement Substitution with fly ash and use of Type IL Cement with increased limestone content.
Georgia	We have created a resiliency committee and are exploring the sustainability portion currently.

Q3. What sustainability performance metrics has your agency adopted? (3 yes; 13 No)

Arizona	Developing those in 2022 with Texas A&M CARTEEH group
Arkansas	N/A
Delaware	N/A
Iowa	Metrics within each of the strategies are in progress.
Kentucky	none as of yet
Oregon	See ODOT Sustainability Plan - metrics are listed for each category of goals. Energy/Fuel use (GHG gas emission, Building energy use, Fleet fuel use) Material resource flows (Waste and recycling at major facilities) Environmental stewardship (Hazardous materials, water use at major facilities) (https://www.oregon.gov/odot/Programs/TDD%20Documents/2020%20Sustainability%20Progress%20Report%20-%20FINAL.pdf)
Washington State	Take climate action: percentage of GHG emission Clean air: annual inventory of NOx, SOx, and PM Clean water: inventory of stormwater, remaining creosote (https://wsdot.wa.gov/sites/default/files/2022-03/WSF-SustainabilityPlanPerformanceDashboard-FY22Q3.pdf, https://wsdot.wa.gov/sites/default/files/2021-10/WSF-SustainabilityActionPlan-2021-2023.pdf)
Wisconsin	Specific to recycled re-use materials, Google WisDOT MAPSS preservation performance scorecard. Look at Metric: Preservation - Material Recycling. The goal is to have 10% of newly produced materials replaced by recycled, No other sustainability themes and metrics identified and adopted yet. materials on construction projects each year.
Kansas	Year-to-year change in statewide average job accessibility (auto/transit) (measure under development)
Ohio	None
Tennessee	N/A
Texas	N/A
Michigan	None
Missouri	Sustainability and environmental awareness has been part of normal business practice for decades. all jobs are considered part of the overall process to be good stewards to the taxpayer dollar and their environment. Items such as timely environmental clearance, fleet efficiency/cost.
Oklahoma	We have not established any performance metrics.
Georgia	Unestablished at this time

Q4. What are the most successful sustainable practices implemented in your organization? (7 yes; 9 No)

Arizona	Three complete programs and assisting FHWA for the last decade with rolling out INVEST – https://www.sustainablehighways.org/
Arkansas	FHWA Transportation Alternatives Program
Delaware	Nothing specific yet but we are actively working with stakeholders across the state.
Iowa	Incorporating sustainable methods in infrastructure and facility design.
Kentucky	N/A
Oregon	Water use conservation, Larger building energy use conservation, Renewable fuels in fleet vehicles
Washington State	We have made impressive fuel savings through our Operational Efficiency Work Group. We have also been successful in gaining the support of our legislature as well as federal and state funding partners to move towards electrifying the largest ferry fleet in the US. We have had the most success by using a work group model to cut across departmental silos and undertake collaborative initiatives. Keeping continuous improvement in mind and not being afraid of making mistakes is key.
Wisconsin	None identified yet.
Kansas	To be determined after delivery of the Eisenhower Legacy Transportation Program
Ohio	All project specific items
Tennessee/Texas/Michigan	N/A
Missouri	Allowing Recycling throughout our specifications. Keeping Project Managers and Designers and Construction staff involved in NEPA throughout.
Oklahoma	We are developing native seed mixes with monarch and pollinator beneficial plant species, which will be used to enhance existing native vegetation areas, restore native vegetation areas, and create new native vegetation areas appropriate to our rights-of-ways use. Brush/trees outside clear/safety zones and in monarch habitat areas will be assessed for selective thinning and removal of unhealthy and invasive woody vegetation. Conservation mowing on the adopted acres is implemented in a way to promote and enhance floral resources during migration and breeding in suitable monarch habitat areas. While our targeted species is the Monarch Butterfly, these efforts provide benefits to a myriad of species. We have been using recycled material and reusing waste from other industries in construction for more than 30 years. We are increasing the use of Warm Mix Asphalt in construction.
Georgia	We are tracking historic repetitive losses and problem issues and working with our districts to gather data but we are still in the phase of development.

Q5. What are the lessons learned from implementing sustainability in practice? (8 yes; 8 No)

Arizona	That although difficult, developing sustainable infrastructure agency level program is possible
Arkansas	N/A
Delaware	Engagement with key staff members of the various agencies working on the projects
Iowa	Do not recreate the wheel- Reach out to other agencies to learn about their best practices.
Kentucky	N/A
Oregon	It takes time Support from leadership is helpful Adequate funding is crucial. Market dynamics likely have huge impact on success / failure
Washington State	The most important thing for us was to hit the ground running. Not spend too much time overthinking the entire program. We then were able to build the program organically based on the actions that we were taking. We continue to learn and build, so I would say a continuous improvement mindset is critical and to not be afraid to make mistakes.
Wisconsin	The need to identify broader range of sustainability themes and goals and standard measurable metrics.
Kansas	N/A
Ohio	None yet- rather focus on statewide risk assessment and planning. We really don't have any extremely large projects that have sustainability goals assigned to them right now.
Tennessee	N/A
Texas	N/A
Michigan	N/A
Missouri	Has been part of our business for decades. Most highway materials are recycled. Designing to minimize Right of Way impacts minimizes environmental concerns.
Oklahoma	Sustainability practices in mowing helped us save on maintenance costs. We do need to implement public outreach to better communicate to our users the change in maintenance practices to gain public support for the efforts. Use of recycled material has resulted in reduction in construction cost. We do need to look more into educating and incentivizing contractors for more sustainable practices.
Georgia	Employees who specifically know how to incorporate this role are beneficial, implementation is slow but supported agency wide. Federal guidance would be helpful. Agencies sharing best practices would be wonderful but is limited at this time.

Q6. How has your organization integrated sustainability into planning, design, construction, operational and maintenance activities? (9 Yes; 7 No)

Arizona	Yes - total life cycle implementation including LCA and LCCA efforts
Arkansas	Our Transportation Alternatives Program provides funding to implement sustainable, walkable designs in order to connect communities.
Delaware	We are working toward that goal through risk analysis at this time
Iowa	Sustainability is beginning to be incorporated into various planning documents including the State Long-Range Transportation Plan. We are exploring and incorporating sustainable and long life materials in our pavements. We measure salt usage, utilize living snow fences, and are researching other sustainable maintenance activities.
Kentucky	have not.
Oregon	We are in the process of integrating best practices identified from a year-long project that included a GHG inventory.
Washington State	This is something we continue to work on, but we are building Envision into our Terminal Design Manual. We have also set one of our objectives as considering sustainability in all of our decision making. That is the ultimate measure of success for us in our sustainability journey and will show that we have really achieved what we set out to.
Wisconsin	Broadly in long-range plans and less specific throughout organization with the exception of recycle pavement use.
Kansas	N/A
Ohio	No- again, project by project review.
Tennessee	N/A
Texas	N/A
Michigan	Recycled and reclaimed materials are allowed per our specifications, provided they are able to meet applicable criteria.
Missouri	Nepa process on every project. Projects planned and designed to minimize Right of Way therefore minimize impacts
Oklahoma	ODOT encourages vegetative buffers as much as possible on active construction. These help to reduce the need for temporary controls that become damaged and eventually waste and also maintaining original site.

	ODOT is also funding research on compost filter socks. The process to pilot and implement this BMP is underway and could help reduce waste of silt fences and fiber logs, where applicable, but also help with revegetation of disturbed grounds. ODOT has a Storm Water Action Team (SWAT) which is currently working on adding Sediment and Erosion Control to the Approved Product List (APL). This will help get new and sustainable practices in the field. Items like Flexamat or Open Cell articulated concrete block allow for vegetative cover in additional to the structure of a concrete cell and are a more sustainable option over traditional rip rap methods. ODOT allocates funding for littler pick up, street sweeping and also has a robust poster contest about "Keeping Our Land Grand". This along with trash pickup opportunities for the public allow both efforts from ODOT and educational opportunities for our state. These efforts are being furthered through social media between events as well. We are in the process of evaluating the baseline environmental impacts of current Oklahoma mixtures and paving practices, implementation of innovative specifications and incentives for chemical WMA with low-temperature Balanced Mix Design (WMA) and incentivizing contractors to invest in cleaner burning vehicles to lowering the emission levels of construction activities.
Georgia	We are working to do this - long term solutions, mitigation, nature based solutions, preventative maintenance, etc.

Q7. Does your organization provide any incentives for implementing sustainable practices? Please list any sustainability incentive programs (0 Yes; 16 No)

Arizona	None
Arkansas	N/A
Delaware	N/A
Iowa	No, we do not currently provide incentives for implementing sustainable practices.
Kentucky	No.
Oregon	Not at this time
Washington State	No. We do have regular recognition awards, kudos, etc. that are not specific to sustainability but which do recognize individuals for doing sustainability initiatives and efforts.
Wisconsin	None yet.
Kansas	None
Ohio	None
Tennessee	N/A
Texas	N/A
Michigan	None
Missouri	Allowance of recycled materials in items like asphalt paving allow contractors to lower their material input cost. Reuse of construction materials results in overall lower cost including less hauling and quarrying/manufacture of new materials.
Oklahoma	Our organization does not currently provide incentives.
Georgia	Unknown

Q8. How does your organization encourage the sustainability? Please list all organizational activities to promote sustainability in your organization. (9 Yes; 7 No)

Arizona	Award programs for internal and external excellence
Arkansas	FHWA's competitive Transportation Alternatives Program.
Delaware	Created a new division last summer to focus specifically on this for the department and the state
Iowa	We are trying to make sustainability a departmentwide effort building off of the work that is already being done. In the near future, we are planning to start a website for the Sustainability Working Group which will be available for internal and external use.
Kentucky	A working group led by FHWA was initiated in 2021 and meets quarterly.
Oregon	Included in our Strategic Action Plan. Regular meetings with decision makers and industry Communication stories in email blasts, webinars, etc.
Washington State	We try to be a force for change within our industry as a member of Green Marine, the ECHO Program, Quiet Sound, various AASHTO and TRB committees and work groups, etc. One of our internal objectives for our Sustainability Action Plan 2021-2023 is to build a culture of sustainability and it is something we are really trying to work on so that it is not just the work of a few individuals but so everyone in the organization can see how their work leads to our success and continuous improvement.
Wisconsin	Currently evaluating. There is a need to communicate and encourage sustainability goals and objects throughout WisDOT and while also linking to the 2019 Governor Evers Executive Order 38. This Order created the WI Office of Sustainability & Clean Energy.
Kansas	N/A
Ohio	Just on a project by project needs- has only been reserved for our largest projects so far.
Tennessee	N/A
Texas	N/A
Michigan	N/A
Missouri	Category:127 MoDOT and the Environment - Engineering_Policy_Guide
Oklahoma	Our organization is currently undergoing a modernization effort. Key objectives of the effort are to streamline processes and identify opportunities for efficiencies. Through this activity we have removed barriers to communication and maximized our resources resulting in sustainability being identified as a common goal for many departments. We currently have a Stormwater Advisory Team looking at ways to improve erosion control and runoff during and after construction through best management practices. Moving forward we will continue to work collectively to make progress on the shared sustainability effort. We are working with our Asphalt and Concrete industry to explore additional sustainability methods.
Georgia	Unkown

Q9. Does your organization uses a sustainability rating system, i.e., Greenroads, Envision, etc.? If yes, what is the name of the sustainability rating system? (2 Yes; 14 No)

Arizona	INVEST
Arkansas	No.
Delaware	N/A
Iowa	No, we do not currently use a sustainability rating system.
Kentucky	not that I know of.
Oregon	Not at this time but are looking into Greenroads and Envision as options.
Washington State	Envision. We are also members of and certified by Green Marine.
Wisconsin	No
Kansas	No
Ohio	No system- we used Invest in the past on other projects.
Tennessee	N/A
Texas	N/A
Michigan	No.
Missouri	No
Oklahoma	Our organization does not use a sustainability rating system.
Georgia	Unknown

During the second sustainability survey, as summarized below, the successful sustainability programs were suggested by some state DOTs.

ORCA (One Region Card for All)

The ORCA card is a contactless, stored-value smart card system for public transit in the Puget Sound region of Washington, United States. The ORCA card is all you need to pay your fare on buses and trains in the Puget Sound region. After you load E-purse (electronic purse) value or a monthly pass on it, your ORCA card works like cash or a pass, automatically tracking the value of different fares and transfers.

Iowa Living Roadway Trust Fund

In 1988, the Iowa Legislature established the Living Roadway Trust Fund (LRTF) within Iowa Code 314.21. The Iowa DOT administers this fund, including an annual, competitive grant program that provides funding for integrated roadside vegetation management (IRVM) activities to eligible cities, counties, and applicants with statewide impact. In doing so, the Iowa DOT and its partners promote and educate the public about the need for an integrated approach to managing the vegetation along Iowa's roadsides. This approach ensures that roadside vegetation is preserved, planted, and maintained to be safe; visually interesting; ecologically integrated; and useful for many purposes.

FHWA CMAQ

The FAST Act continued Congestion Mitigation and Air Quality (CMAQ) improvement program to provide a flexible funding source to State and local governments for transportation projects and programs to help meet the requirements of the Clean Air Act. Funding is available to reduce congestion and improve air quality for areas that do not meet the National Ambient Air Quality Standards for ozone, carbon monoxide, or particulate matter (nonattainment areas) and for former nonattainment areas that are now in compliance (maintenance areas).

MAPSS (Mobility, Accountability, Preservation, Safety, Service)

The Wisconsin Department of Transportation MAPSS Performance Improvement Program focuses on the five core goals, Mobility, Accountability, Preservation, Safety, Service, and associated performance measures that guide WSDOT in achieving their mission "to provide leadership in the development and operation of a safe and efficient transportation system." Establishing goals and measuring results is essential to running a successful and efficient organization and meeting public expectations. Wisconsin DOT has reported significant savings through the innovative Project Management, System Operations, and Innovation, Research, & Technology. Examples of Wisconsin State highway maintenance and material recycling dashboard from MAPSS is shown in Table 3-6.

Table 3-6. MAPSS Dashboards of Highway Maintenance and Material Recycling.

State Highway Roadside Maintenance **Calendar year 2017**	Grade point average for the maintenance condition of state highways	2.55	3.0		↓	The department is working with Wisconsin's 72 counties to enhance statewide focus on the preservation of infrastructure.	4/2018
Material Recycling **State fiscal year 2020**	Percent of newly produced materials replaced with recycled materials	13.33	10.0	✓	↓	Recycled materials create quality, performance and efficiency benefits on nearly all WisDOT projects.	1/2021

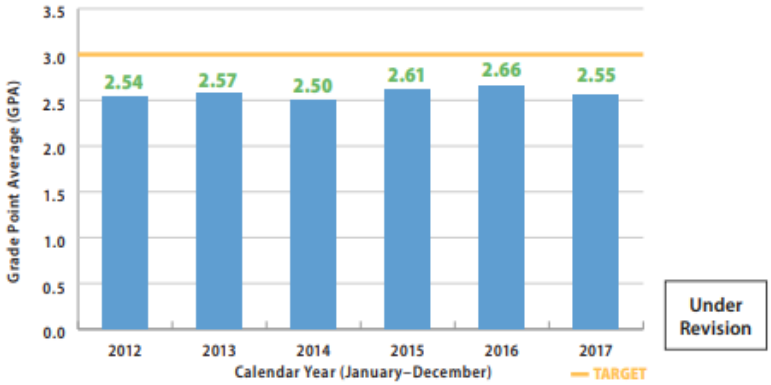
Preservation: State Highway Roadside Maintenance

Report Date: April 2021 | **Data Frequency:** Annual (Calendar Year) | **Division:** Transportation System Development

Why is this important? Effective and consistent maintenance efforts preserve our investment in the highway system, enhance safety and economic productivity, and minimize the impact to the natural environment.

Performance measure target: The department's goal is to reach and maintain a 3.0 out of 4.0 grade point average (GPA) for 29 features evaluated each year.

Figure: Grade point average for the maintenance condition of state highway roadsides



How do we measure it? Twenty-nine features are evaluated under five contributing categories: Critical Safety, Safety/Mobility, Stewardship, Driver Comfort and Aesthetics. Condition data is collected each fall as part of a field review process. Rating teams composed of WisDOT region maintenance coordinators and county patrol superintendents evaluate a random sample of 1,200 one-tenth mile segments around the state. Conditions of the features are assessed, documented and used in creating grading curves. Pre-established grading curves help identify areas for improvement.

How are we doing? The statewide GPA shows a 0.11-point decrease from 2016 with the largest changes experienced in three areas: routine replacement of other signs, protective barriers and storm sewers. Routine replacement of other signs marked a positive step forward to a B grade as the department focuses on infrastructure preservation and more efficient deployment of resources. However, the marks for storm sewer condition and protective barriers each declined to a C. In the case of protective barriers, the department intensified training to uncover previously undetected issues. The department is now working to prioritize and remedy these issues to enhance safety and foster greater longevity of the infrastructure.

What factors affect results? The annual GPA is affected by baseline conditions, maintenance budget levels and policies, winter maintenance costs and improvement program investments. The department's first maintenance priority is snow and ice removal, while the balance is spent on non-winter activities. Historically, about three-quarters of each maintenance dollar is programmed to winter, pavement and structure maintenance activities, with the balance used on system needs associated with the 29 evaluation features. The highway maintenance condition largely depends on the balance of routine maintenance agreement funding remaining after winter operations, as well as improvement project programming levels.

What are we doing to improve? The department is focusing on preservation of infrastructure and is continuing to work with Wisconsin's 72 counties to create best practices. Over the past several years, the department has modernized the approach to winter maintenance, using technology to prescribe the most effective snowplow routes to reduce man-hours and equipment needs. Additionally, the department has been working with counties to collect data on non-winter activities in order to strategize for less costly, more efficient routine maintenance. By data-banking good construction practices and sharing these practices with other counties, it is reasonable to expect additional benefit in the quality and effectiveness of treatments to overall pavement service life.

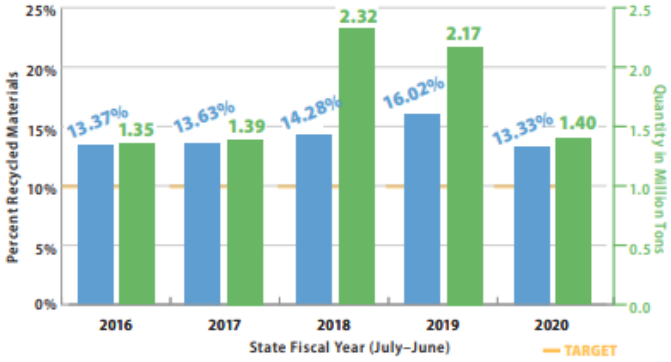
Preservation: Material Recycling

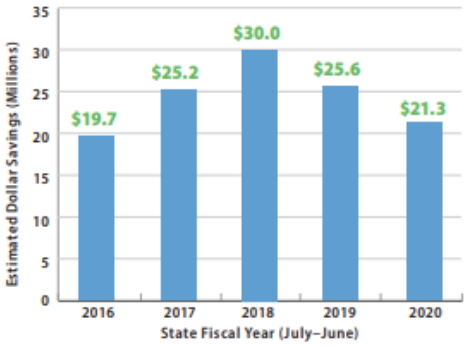
Report Date: April 2021 | **Data Frequency:** Annual (State Fiscal Year) | **Division:** Transportation System Development

Why is it important? The department strives to incorporate environmental sustainability or green initiatives in its vision for providing a safe and efficient transportation system. This includes incorporating the use of recycled materials in improvement projects to lessen the impact on Wisconsin's environment and to preserve resources for future generations. WisDOT's recycled materials efforts help to prevent waste and create opportunities for savings. In the eight years WisDOT has tracked performance with this measure, more than 15 million tons of materials were reused on projects, creating a savings of over $170 million to benefit additional projects.

Performance measure target: The department's goal is to make sure recycled materials are incorporated into projects. The goal is to have 10 percent of newly produced materials replaced with recycled materials in construction projects.

Figures: Recycled materials used in pavement and bridge construction





How do we measure it? The department calculates the tonnage of recycled materials through a standard review of common bid items each fiscal year. Steel that is extracted and recycled by the construction contractor is also included in the total tonnage. The use of recycled materials is measured by the percentage of newly produced material replacement in some key construction materials. By reporting the use of recycled materials by percentage of the product being placed, we will be able to better track usage based on design and material policies.

How are we doing? Much of the positive upswing in 2018 and 2019 was driven by the pace, size and complexity of the I-94 North/South project in Southeastern Wisconsin. With that project now open to traffic, the department expected pavement replacement numbers to normalize, creating recycling opportunities more in line with previous years. The department remains committed to the beneficial reuse of highway products such as concrete and reclaimed asphalt where the materials can gain new life in a quality finished product. Incorporating recycled materials helps to conserve resources, minimize waste and simplify work zone logistics, as fewer trucks are needed to haul material.

What factors affect results? The department wants to encourage the use of recycled materials and has written project specifications to allow recycled materials in a sustainable way. Ultimately, the contractor makes the decision on the materials to use based on market conditions. The economy, fuel costs and landfill tipping fees affect the cost effectiveness and attractiveness of recycling.

What are we doing to improve? The department continues its focus on research by collaborating with other states and universities to explore technology, methods and materials aimed at reducing waste while creating high-quality, high-performing pavements. The Wisconsin Highway Research Program (WHRP) recently completed a pilot project using recycled rubber as a modifier of asphalt and will continue to monitor the performance of the test section of highway. WisDOT continues to work with the Recycled Materials Resource Center (RMRC) project to determine other ways to leverage recycling for transportation benefits. Additionally, policy revisions on Beneficial Reuse of Industrial Waste (NR 538) are creating potential opportunities. The department also is tracking national research on the feasibility of recycled plastic in roadways.

Delaware DOT created a new transportation resiliency and sustainability division less than a year ago. Washington State DOT issued Secretary's Executive Order (E 1113.00) on April 29, 2020, to direct WSDOT employees to take actions that enhance sustainability through a focus on energy efficiency, pollution reduction, and enhanced resilience (https://wsdot.wa.gov/sites/default/files/2021-10/WSDOT-ExecutiveOrder-111300.pdf).

In September 2008, Oregon DOT released Volume I of the sustainability plan, which contains both statewide strategic goals and indicators (https://www.oregon.gov/odot/Programs/TDD%20Documents/ODOT-Sustainability-Plan-Volume-1.pdf). In October 2010, Volume II was published to addresses the management of ODOT's internal operations towards sustainability. It complements Volume I which presents the overall context of sustainability at ODOT and defines the seven focus areas (https://www.oregon.gov/odot/Programs/TDD%20Documents/ODOT-Sustainability-Plan-Volume-2.pdf).

In December 2018, University of Tennessee published a report titled "Green Generates Green," which provides a summary of current and desired sustainability actions planned by TDOT personnel based on a survey of fifteen TDOT Division Directors. (https://www.tn.gov/content/dam/tn/tdot/long-range-planning/research/final-reports/res2016-final-reports/RES2016-10%20Green%20Generates%20Green%20Final%20Report_approved.pdf).

4. SUSTAINABILITY CRITERIA FOR SUSTAINABLE PRACTICES

One of the main purposes of the project is to identify existing sustainability attributes in environmental (i.e., air quality, noise, and GHG emission), water quality (i.e., stormwater runoff quality and drainage), energy use (i.e., fuel efficiency and renewable energy), materials (i.e., bio-materials and recycling) and other areas, inherent in Iowa transportation planning processes, design manuals, and construction specifications. Suprayoga et al. (2020) presented a systematic approach to evaluating the sustainability of road infrastructure projects, which includes a detailed analysis of sustainability criteria to cluster and group various sustainability indicators. It provided a robust framework for implementing sustainability criteria in transportation infrastructure projects. However, it is challenging to identify sustainability attributes since it is difficult to identify sustainability attributes that are critical to different bureaus within the agency.

4.1. Most Common Evaluation Criteria in Five Sustainability Rating Systems

Table 4-1 summarizes points allocated in five sustainability rating systems of Envision, Greenlites, Greenroads, I-LAST, and INVEST for each sub-criterion under four categories of 1) environment, 2) water quality and usage, 3) materials, and 4) energy (Clevenger et al. 2013). In Table 4-1, "∞" indicates that the sub-criterion is represented elsewhere, and "-" indicates the sub-criterion is not represented in the given system. Based on the percentage of the systems on the rightmost column in Table 4-1, the criteria under the environment category received the highest weight of 16.4%, followed by materials (14.2%), water quality and usage (11%), and energy (5.8%) categories.

To determine the most common sustainability criteria among five existing sustainability rating systems, as shown in Table 4-2, if each criterion is included in a rating system, "1" was assigned, and otherwise, "0" was assigned. These numbers were summed for each criterion to compute a total score shown in the rightmost column. The highest score, "5," indicates all five sustainability rating systems contain this criterion, indicating the most common criterion. As can be seen from Table 4-2, the most common criteria are recycled content/materials and locally provided/regional material (score of 5), followed by stormwater treatment and reduced electricity/energy consumption (score of 4) and habitat restoration, noise abatement, energy efficiency, stray light reduction, and pavement reuse (score of 3). Based on the total number at the bottom row of Table 4-2, INVEST shows the highest score of 12 indicating INVEST can represent the criteria most among five rating system, followed by Envision, GreenLite, I-LAST, and Greenroads. As shown in Table 4-3, to determine the most common sustainability attributes selected for Iowa DOT's 9 categories, a total score was made for each attribute.

Table 4-1. Points Allocated for each Sub-criterion under Four Categories (Clevenger 2013).

(a) Environment Category

SUB-CRITERIA COMPARISON FOR ENVIRONMENTAL CATEGORY													
Rating System	Environmental Management Systems	Site Vegetation/Trees and Plant Communities	Protect Enhance or Restore Wildlife (Habitat Restoration)	Ecological Connectivity	Environmental Training	Improve Air Quality by Improving Traffic Flow	Improving Bicycle and Pedestrian Facilities	Noise Abatement	Integrated Planning Natural Environment	Siting	Biodiversity	Total achievable for Environment	Percentage of system
Be2st-in-hwys	Points determined by project team												
Envision	-	∞	∞	∞	∞	∞	∞	∞	∞	156	99	255	36%
Greenlites	-	∞	∞	∞	-	6	6	4	∞	∞	-	16	6%
Greenroads	2	3	3	3	1	∞	∞	∞	∞	∞	-	12	10%
I-LAST	-	21	20	∞	-	∞	∞	10	∞	∞	-	51	22%
INVEST	5	3	3	∞	1	15	∞	2	15	∞	-	44	8%

(b) Water Quality and Use Category

SUB-CRITERIA COMPARISON FOR WATER QUALITY AND USE CATEGORY										
Rating System	Stormwater Treatment / Management	Reduce runoff and treat stormwater runoff	Runoff Flow Control	Runoff Quality	Stormwater Cost Analysis	Reduce Impervious Areas	Construction Practices to Protect water Quality	Water Tracking	Total achievable for water quality	Percentage of system
Be2st-in-hwys	Points determined by project team									
Envision	14	∞	∞	57	-	-	-	106	177	25%
Greenlites	3	5	∞	∞	-	-	-	-	8	3%
Greenroads	∞	∞	3	3	1	3	-	2	12	10%
I-LAST	10	∞	∞	∞	-	14	11	-	35	15%
INVEST	9	∞	∞	∞	-	-	-	-	9	2%

(c) Materials Category

SUB-CRITERIA COMPARISON FOR MATERIALS CATEGORY											
Rating System	Reuse of Materials	Recycled Content/ Materials	Locally Provided/ Regional Materia	Bioengineering Techniques	Hazardous Material Minimization	Life Cycle Assessment	Pavement reuse	Earthwork Balance	Energy Efficiency	Total achievable for Materials	Percentage of system
Be2st-in-hwys	Points determined by project team										
Envision	21	57	50	-	-	-	-	-	-	128	18%
Greenlites	7	2	2	3	6	-	-	-	-	20	7%
Greenroads	∞	5	5	-	-	2	5	1	5	23	19%
I-LAST	∞	22	6	-	-	-	12	-	-	40	17%
INVEST	∞	31	3	-	-	8	15	∞	-	57	10%

(d) Energy Category

SUB-CRITERIA COMPARISON FOR ENERGY CATEGORY								
Rating System	Energy and Fuels	Energy Efficiency	Reduce Electrical/Energy Consumption	Reduce Petroleum Consumption	Stray Light Reduction	Renewable Energy Consumption	Total achievable for Energy	Percentage of system
Be2st-in-hwys	Points determined by project team							
Envision	∞	21	21	∞	∞	15	57	8%
Greenlites	∞	∞	3	6	3	-	12	4%
Greenroads	∞	5	-	-	3	-	8	7%
I-LAST	∞	∞	12	∞	4	∞	16	7%
INVEST	15	11	15	∞	-	∞	41	7%

Among five sustainability rating systems, we further evaluated the "Illinois - Livable and Sustainable Transportation (I-LAST)," developed by our neighboring state. I-LAST provides a comprehensive list of sustainable practices while recording the use of sustainable practices in the transportation industry (Knuth and Fortmann 2010). As shown in Table 4-4, I-LAST is based on a checklist of an extensive number of 159 sustainable practices in 22 sustainability categories to earn up to 320 points (Illinois 2012). I-LAST was designed to be used during project scoping, at the end of the design phase, and during construction and continuously revised while utilizing the inputs from industry users. Based on the available points in Table 4-4, materials (44 pts) was the most important sustainability category, followed by construction practices (38 pts) and trees and plant communities (31 pts).

Table 4-2. Criteria adopted by Five Sustainability Rating Systems.

Criteria Adopted by the Five Sustainability Rating Systems for Planning and Design							
		Rating Systems					
Category	Criteria	Envision	GreenLITES	Greenroads	I-LAST	IN-VEST	Total
Environmental	Environmental Management Systems			1		1	2
	Site Vegetation and Plant Communities			1	1		2
	Habitat Restoration			1	1	1	3
	Ecological Connectivity			1			1
	Environmental Training			1		1	2
	Improve Air Quality by Improving Traffic Flow		1			1	1
	Improving Bicycle and Pedestrian Facilities		1				1
	Noise Abatement		1		1	1	3
	Integrated Planning Natural Environment					1	1
	Siting	1					1
	Biodiversity	1					1
Water Quality	Stormwater Treatment	1	1		1	1	4
	Reduce runoff/ treat stormwater runoff		1				1
	Runoff Flow Control			1			1
	Runoff Quality	1		1			2
	Stormwater Cost Analysis			1			1
	Reduce Impervious Areas			1	1		2
	Construction Practices to Protect Water Quality				1		1
	Water Tracking	1		1			2
Energy Usage	Energy and Fuels					1	1
	Energy Efficiency	1		1		1	3
	Reduce Electrical/Energy Consumption	1	1		1	1	4
	Reduce Petroleum Consumption		1				1
	Stray Light Reduction		1	1	1		3
	Renewable Energy Consumption	1					1
Materials	Reuse of Materials	1					1
	Recycled Content/ Materials	1	1	1	1	1	5
	Locally Provided/ Regional Material	1	1	1	1	1	5
	Bioengineering Techniques		1				1
	Hazardous Material Minimization		1				1
	Life Cycle Assessment			1		1	2
	Pavement reuse			1	1	1	3
	Earthwork Balance			1			1
	Energy Efficiency			1			1
	Total	11	12	18	11	14	

Table 4-3. Attributes Adopted by Five Sustainability Rating Systems.

Category	Attributes	Rating Systems					
		Envision	Greenroads	INVEST	GreenLite	I-LAST	Total
Indirect Infrastructure	Reduce Energy use	1		1	1	1	4
Construction	Conserving Construction Materials	1	1	1	1	1	5
	Reduce Energy use	1	0	1	1	1	2
	Reduce GHG emission	1	0	0	0	0	1
	Reduce Noise	0	0	1	1	1	1
	Better Drainage (Reduce Runoff)	0	0	0	1	0	0
	Extend life cycle	0	1	1	0	0	2
	Reduce life-cycle cost	0	1	1	0	0	2
	Reduce accidents	0	1	1	0	0	2
Operation	Reduce Material use	1	1	1	1	1	5
	Reduce Energy use	1	0	1	1	1	4
Roadside Management	Reduce maintenance cost	1	1	1	0	0	3
Facilities	Reduce Energy use	1	0	1	1	1	4
Fleet	Reduce Energy use	1	0	1	1	1	4
Total		9	6	12	9	8	

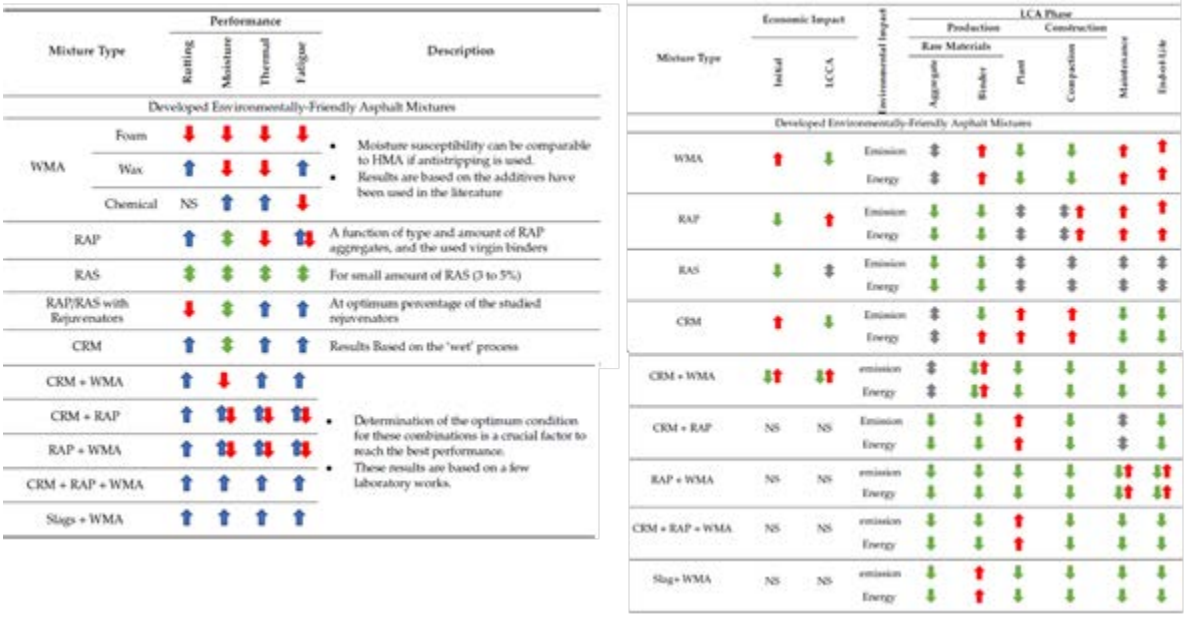
Table 4-4. Sustainability Categories and Activities with Maximum Points.

Sustainability Category	Select Sustainability Activities (No. of items)	Pts
Context Sensitive Solutions	Identify, engage and Involve Stakeholders (4)	8
Land-Use Community Planning	Transits, intermodal, freights, regional plan (6)	11
Alignment Selection	Provide Buffer, Right of Way, Minimize Earthwork (7)	17
Context Sensitive Design	Incorporate local materials and reduce urban “heat island” (6)	11
Protect Wildlife and Habitat	Restore wetland and minimize land disturbance (13)	23
Trees and Plant Communities	Plant trees of native species and coordinate with local stakeholders (12)	31
Noise Abatement	Build noise barriers and incorporate traffic system management (6)	10
Reduce impervious area	Replace paved median with permeable pavement (5)	10
Stormwater treatment	Build bioretention cells, rain gardens, sand filters, sediment traps (13)	20
Protect water quality	Reduce fertilizer use and protect erodible soils (8)	11
Traffic Operations	Build HOV lane, innovative interchange and bus turnouts (6)	12
Transit	Build Park and Ride, bike accommodations, multi-modal (7)	10
Bicycle and Pedestrian Facility	Provide parallel bike routes and rehabilitate sidewalks (12)	20
Reduced Electricity	Retrofit existing street lighting with alternative energy sources (7)	12
Stray Light Reduction	Retrofit existing roadway lighting fixtures (2)	4
Materials	Use recycling, rubblization, local material and balance cut and fill (16)	44
Innovation	Any experimental features to improve sustainability (1)	3
Maximize Trucking Efficiency	Proximity to job, in-place recycling, and efficient backhauls (4)	4
Use Certified Suppliers	Diamond Achievement Commendation and Green Star Certification (2)	5
Reduce Impervious Area	Prevent runoff with infiltration system (1)	2
Protect Water Quality	Perform erosion and sediment control practices (7)	14
Construction Practices	Use recycled materials, scrap metals, fly ash, slag aggregate (14)	38

4.2. Sustainable Practices

A sustainable practice can be defined as a method or a procedure to lower negative impacts on society and the environment. Although it is difficult to distinguish sustainable practices clearly from non-sustainable practices, many sustainable practices have been already implemented. However, their relative impacts on society and the environment are difficult to quantify. For example, Table 4-5 shows a more detailed analysis of various asphalt mix types with respect to their performance and economic and environmental impacts (Pouranian and Shishehbor, 2019).

Table 4-5. Impacts of various asphalt mix types on performance, economic and environment (Pouranian and Shishehbor, 2019).



Mixture Type		Performance: Rutting	Performance: Moisture	Performance: Thermal	Performance: Fatigue	Description
Developed Environmentally-Friendly Asphalt Mixtures						
WMA	Foam	↓	↓	↓	↓	• Moisture susceptibility can be comparable to HMA if antistripping is used. • Results are based on the additives have been used in the literature
	Wax	↑	↓	↓	↑	
	Chemical	NS	↑	↑	↓	
RAP		↑	↕	↓	↑↓	A function of type and amount of RAP aggregates, and the used virgin binders
RAS		↕	↕	↕	↕	For small amount of RAS (3 to 5%)
RAP/RAS with Rejuvenators		↓	↕	↑	↑	At optimum percentage of the studied rejuvenators
CRM		↑	↕	↑	↑	Results Based on the 'wet' process
CRM + WMA		↑	↓	↑	↑	• Determination of the optimum condition for these combinations is a crucial factor to reach the best performance. • These results are based on a few laboratory works.
CRM + RAP		↑	↑↓	↑↓	↑↓	
RAP + WMA		↑	↑↓	↑↓	↑↓	
CRM + RAP + WMA		↑	↑	↑	↑	
Slags + WMA		↑	↑	↑	↑	

Mixture Type	Economic Impact: Initial	Economic Impact: LCCA	Environmental Impact	LCA Phase: Production – Raw Materials: Aggregate	Production – Raw Materials: Binder	Production: Plant	Construction: Compaction	Maintenance	End-of-Life
Developed Environmentally-Friendly Asphalt Mixtures									
WMA	↑	↓	Emission	↕	↑	↓	↓	↑	↑
			Energy	↕	↑	↓	↓	↑	↑
RAP	↓	↑	Emission	↓	↓	↕	↕↑	↑	↑
			Energy	↓	↓	↕	↕↑	↑	↑
RAS	↓	↕	Emission	↓	↓	↕	↕	↕	↕
			Energy	↓	↓	↕	↕	↕	↕
CRM	↑	↓	Emission	↕	↓	↑	↑	↓	↓
			Energy	↕	↑	↑	↑	↓	↓
CRM + WMA	↓↑	↓↑	emission	↕	↓↑	↓	↓	↓	↓
			Energy	↕	↓↑	↓	↓	↓	↓
CRM + RAP	NS	NS	Emission	↓	↓	↑	↓	↕	↓
			Energy	↓	↓	↑	↓	↕	↓
RAP + WMA	NS	NS	emission	↓	↓	↓	↓	↓↑	↓↑
			Energy	↓	↓	↓	↓	↓↑	↓↑
CRM + RAP + WMA	NS	NS	emission	↓	↓	↑	↓	↓	↓
			Energy	↓	↓	↑	↓	↓	↓
Slag+ WMA	NS	NS	emission	↓	↑	↓	↓	↓	↓
			Energy	↓	↑	↓	↓	↓	↓

We developed Table 4-6, which summarizes 19 sustainable practices in construction and maintenance areas with their estimated impacts on cost, performance, sustainability attributes, and potential limitations, along with references. As summarized in Table 4-7, we categorized selected sustainable practices for nine potential target areas. We focused our efforts on selected sustainable practices from Table 4-7, which served as a starting point for developing a prototype Database Of Sustainable Practices with Implementation Records (DOSPIR).

Table 4-6. Estimated Impacts on Cost and Performance, Sustainability Attributes and Limitations of Sustainable Practices in Iowa.

Sustainable Practices	Cost	Perf.	Sustainability Attributes	Potential Limitations	References
HMA-High RAP	-	=	Increased use of RAP Rutting Resistant	Low temperature crack Cost of rejuvenator	Lee et al. 2018
Recycled Concrete Aggregates (RCA)	-	=	Conserves aggregates Freeze-thaw resistant	Dust/Noise/wastewater Lower RCA strength	Cackler et al. 2018
Plastics Recycling	-/=	+	Saves asphalt. market for recycled plastics.	Unknown Recyclability	Gawande 2013 Oropeza 2019
HMA-RAS	-	-	Rutting resistance Increase PG grade	Transverse cracking Processing cost	Williams 2013
UHPC Concrete	+	+	Increased strength Smaller section	Cost of steel fibers and admixtures	Shafei et al. 2019
Porous Asphalt pavement	+	-	Noise reduction (-3.8 dB), storm water management	Clogging of pores	Mrugacz 2017
Pervious Concrete pavement	+	-	Quiet (3-8% lower) Reduce splash/hydroplaning	Joint deterioration Debonding/local distress	Schaefer and Kevern 2011
Ground Tire Rubber (GTR)	+	+	Better perform than PMA mix Abundant supply	Hard to work with Hard to compact	Buttlar et al. 2019
Railcar Bridge	-	=	Recycle railcars, conserves materials	Lack of Availability Durability	Doornink et al. 2003
Cold In-place Recycling	-	=/+	Saving asphalt and gravel, reduced reflective cracking	May not be the best use of RAP	Lee and Kim 2011 Buss et al. 2017
Hot In-place Recycling	-	-	Saving asphalt and gravel, less transportation cost	Smoke premature cracking	Hafeez et al. 2014
Rubblization of Concrete Pavement	-	-/=	Less construction time	Lower strength Subgrade Failure	ACPA 1998
Open Graded Friction Course	=	=	Noise reduction (-4 dB) cost-effective in rural areas	Not cost-effective, No Perform in cool climates	Root 2009 Watson et al. 2018
Diamond Grinding CPR	-	+	Noise reduction, better ride quality, friction resistance	Dust during grinding	Rao et al. 1999
Bio Binder	-	-/=	Rutting and cracking resistant Eco-friendly	Increase fatigue cracking	Williams 2014
High Friction Surf. Treatment	-	+	Reduces crashes and fatalities	Delamination of Bond on concrete surface	Florida DOT. n.d.
Otta Seal on Gravel roads	+	+	Use of uncrushed aggregates Impermeable surfaces	Cont. rolling (8 wks) No structural capacity	Ceylan et al. 2018
Warm Mix Asphalt	+	=	Reduce energy cost Reduce asphalt fume	Moisture susceptibility Cost of additives	
Roundabout	-	+	Reduce accidents Reduce gas and electricity	Lower speed Not for high traffic	

Table 4-7. Impacts on Cost and Performance, Attributes of Sustainable Practices for Each Sustainability Category.

Categories	Sustainable Practices	No of Sites	Attributes	Unit	Impact	Cost	Reference
Indirect Infrastructure	ROW Energy Capture	8	Reduce Energy use	MWh	10,750 megawatt-hours	-	FHWA, 2019, MassDOT
Construction	Reclaimed Asphalt Pavement (RAP)	1000+	Conserving Construction Materials	Tons	4.1 million tons of asphalt and 78 million tons of aggregate saved	-	NAPA 2018
			Reduce Energy use	MJ/ton	680 to 454 MJ/ton Reduction	-	NYS DOT, 2009
			Reduce GHG emission	Kg/Ton	53.3 to 36.9 Kg/ton GHG reduction	-	NYS DOT, 2009
	Cold in place recycling	100+	Conserving Construction Materials	Tons	37% reduction of virgin aggregates	-	Buss et al. 2017
			Reduce Engergy use	MJ/m^2	20% and 50% energy reduction	-	Guillermo et al. 2007
			Percent of GHG emission reduction	%	9% GHG reduction	-	Martina et al. 2015
	Berms/Vegetated Screen	100+	Reduce Noise	dBA	4 dB noise reduction	+	Kalansuriya et al, 2009
	Porous Pavement	1	Reduce Noise	dBA	4 to 8 dB noise reduction	=	Tian et al. 2014
			Better Drainage (reduce runoff)	m^3	93% less runoff	=	Erin et al. 2006
	Otta Seal on Gravel roads	1	Extend life cycle	Year	18 to 27 years	-	Ceylan et al. 2018 (InTrans Project 14-497)
			Reduce life-cycle cost	%	43% life cycle-cost reduction	-	Ceylan et al. 2018 (InTrans Project 14-497)
	Roundabout	61	Reduce accidents Reduce gas and electricity	No	40% reduction in all crashes and 80% reduction in injury crashes	-	IADOT, 2008(CTRE Project 06-255)
	Warm Mix Asphalt		Reduce energy cost Reduce asphalt fume				
	High Friction Surf. Treatment		Reduce Accident				
Operation	Deicer	?	Reduce Salt use	Kg/m^2	Beet juice, Grape juice, etc.		
	Convert to LED Bulbs	?	Reduce Energy use	kWh	2.6 million kWh reduction	-	WSDOT, 2017
Resiliency	Mitigate Flood						
Purchasing	Buy Sustainable Products						
Planning	Context Sensitive Solutions						
Roadside Management	Plant Native Species	1,000+	Reduce maintenance cost	$	Maintenance Cost Reduction	-	
Facilities	Solar panel on truck station	?	Reduce Energy use	$	$40,000 saving (40kW panel)		MnDOT, 2019
Fleet	Use fleet vehicles on travel	?	Reduce Energy use				
	Use low GHG-emitting vehicles	?	Reduce Energy use				

5. DEVELOPMENT OF "SCORN" SUSTAINABILITY RATING SYSTEM

To encourage public agencies to adopt more sustainable practices, many sustainability rating systems have been developed in the past. The existing sustainability assessment tools have been evaluated to identify gaps in Iowa transportation infrastructure projects amenable to sustainability. Most rating systems follow a similar process where they include a number of criteria that are applicable to aspects of project planning, development, construction, and maintenance. The criteria are a collection of various sustainability attributes such as recycling, noise reduction, water permeability, etc. Different credits are then awarded to criteria, which are weighted based on the significance of sustainability and are totaled for a final score. The numerical score is useful for tracking progress for the integration of sustainability attributes into practices leading towards more sustainable facilities, maintenance, and operations. Each sustainability rating system differs in how to evaluate sustainable practices based on various criteria with a different weight given to each criterion.

First, we evaluated sustainability assessment tools from surrounding states, such as "BE2ST-in highway" in Wisconsin and "I-LAST" in Illinois. We thoroughly evaluated the "BE2ST-in-Highways" rating system with a potential of being broadened to encompass nine areas identified by the Iowa DOT's sustainability working group. Based on a recent email communication with Illinois DOT staff, however, Illinois has discontinued its use of I-LAST. Based on the evaluation results of the existing sustainability rating systems, we decided to develop a sustainability rating system named "Sustainability Co-Operative Rating Number (SCORN)," following the guidelines used for "INVEST" rating system for Iowa DOT since it has many criteria with numerical ratings. INVEST also provides an option of developing a custom checklist based on the type of project being assessed by any government agency. We selected numerically based criteria from INVEST and further added additional criteria relevant to Iowa DOT's own sustainability criteria.

5.1. Existing Sustainability Rating Systems

The ten most common sustainability rating systems have been evaluated to identify how credits are distributed across three sustainability categories: economy, environment, and society (Simpson et al., 2014). As can be seen from Table 5-1, six rating systems were developed by public agencies and associations, three by academia, and one by a private company. All rating systems are applicable to the planning and design phases of projects, whereas some rating systems can also be applied to the construction and maintenance phases. All rating systems are only applicable to highway projects except "Envision," which is applicable to different types of infrastructure projects. Particularly, the "Green Guide for Road" rating system, which was adopted into the LEED program, includes the industry's best practices.

Table 5-1. Comparison of Ten Most Common Sustainability Rating Systems

System	Developer	Applicability	Criteria	Main Features	References
BE2ST-in-Highways	University of Wisconsin-Madison	Planning/Design	7 categories, 10 criteria	Recycling, weights life-cycle assessment	Lee et al. 2013
Envision	ISI, Harvard U.	Planning/Design Constr./Maint.	5 categories 60 credits	Self-assessment, any point in life cycle	ISI 2012
Green Guide for Road	Stantec	Planning/Design	7 categories 35 credits	industry's best practices, into LEED	Clark et al. 2009
Greenlites	New York State DOT	Planning/Design Constr./Maint.	5 categories 175 credits	performance, identify areas of improvement	NYSDOT 2012 Krekeler 2010
GreenPave	Ontario Ministry of Transportation	Planning/Design Constr./Maint.	4 categories 36 points	Focus on pavements	Kazmierowski 2014
Greenroads	CH2M HILL/ U. of Washington	Planning/Design Construction	6 categories 31 criteria	roadway sustainability quantitative method	Greenroads 2012
I-LAST	Illinois DOT, ACEC, IRTBA	Planning/Design Construction	8 categories 153 criteria	design and future construction phase	IDOT & IJSG, 2010
INVEST	CH2M Hill/FHWA	Planning/Design Constr./Maint.	68 criteria	Predefined/Custom scorecards	FWHA, 2012 (a), (b)
CEEQUAL	Institution of Civil Engineers (UK)	Planning/Design Constr./Maint.	9 categories	Applicable to a wide range of project types	Simpson et al. 2014
STARTS	N. American Sustain. Transp. Council	Planning/Design Constr./Maint.	6 categories 29 credits	transportation and land use strategies	STC 2012

5.2. Selected Sustainability Rating Systems

Based on an extensive literature review, the following five rating systems have been most widely used by state DOT's, which are summarized in Table 5-2 with respect to launch date, features and users. The selected sustainability rating systems are discussed below.

Table 5-2. Comparison of Five Sustainability Rating Systems.

Envision	Launch date	2012
	Features	Checklist (a Yes/No questionnaire used as a self-assessment), and a rating system (free self-assessment or fee-based third party evaluation)
	Users	City of Los Angeles, California State Department of Water Resources, Port Metro Vancouver
GreenLITES	Launch date	2008
	Features	Excel-based scorecard; related tools available for operations certification, regional agency project solicitation and regional pilot sustainability assessment.
	Users	New York State and Colorado DOTs
Greenroads	Launch date	2010
	Features	Subscription-based scorecard that is subjected to a third-party rating; projects must be registered and submitted for review.
	Users	Alaska, California and Oregon state DOTs; cities of San Francisco and San Jose, CA; Las Vegas, NV; and Seattle, Bellingham and Tacoma, WA
I-LAST	Launch date	2011
	Features	Self-assessment scorecard/checklist uses a point system, with scoring intended to be relatively simple and require minimal time and effort. No level of certification award.
	Users	Illinois DOT, Illinois Tollway
INVEST	Launch date	2012
	Features	Standard and custom scorecards; web-based tool prompts users to respond to questions to generate a score.
	Users	State DOTs including Arizona, California, Delaware, Kentucky, Massachusetts, Montana, New Hampshire, Ohio, Pennsylvania, Utah, Texas and Washington

5.2.1. INVEST

As discussed earlier, seventy-one agencies (15 state DOTs, 25 MPOs. 23 Federal Land Units, 7 other transportation agencies, and 1 foreign government) adopted INVEST for their projects and practices. Overall, 2,025 users registered for the INVEST, and 2,400 projects and programs have been evaluated. It is interesting to note that there is very little adoption of INVEST by DOTs in the Midwest (FHWA 2012 c). Among them, activities by the most active seven state DOTs, several counties, and MPOs are summarized in Table 5-3 with respect to 1) modules used, 2) criteria used, 3) implemented program/project, and 4) key outcomes (FHWA 2012c).

Table 5-3. Most Active Users of FHWA's INVEST Sustainability Rating System.

Agency / Location	Modules Used	Criteria Used	Implemented Program/Project	Key Outcomes
Arizona DOT	Development, O&M	Freight Mobility, Waste Management, Earthwork Balance	O&M, Construction Perf. measures, Roundabouts	Integration into Decisions, Improve waste stream
California DOT, and Counties	Planning, O&M Development	Air Quality, Energy & Fuels, Resiliency, Sustainability Plan, Recycle and Reuse	Route 198, Route 46, Fresno Panoche Overlay, Grind Overlay, US-101 Corridor	Most useful at the program level, Identify sustainability tools for prioritizing projects
Delaware DOT	O&M	Sustainability Plan, Recycle & Reuse, Environmental Commitments Tracking System	Pavement & Rehabilitation Program, Pavement Preservation	sustainability efforts, System Planning and Project Development modules
Pennsylvania DOT	Development, O& M	Sustainability Plan, Recycle & Reuse, Environmental Commitments Tracking System	Laurell Valley Transportation Project	New programs and initiatives, focus on metrics and tracking sustainability
Texas DOT	Development, O&M	Lifecycle Cost Analyses, Freight Mobility, Reduced Energy & Emissions in Pavement Materials	Harbor Bridge replacement, Alameda II Project	sustainability practices. Incentives for bidders to achieve sustainability
Utah DOT	O&M	Bridge Management System, Sustainability Plan	Developed maintenance program	LIDAR Data savings, Improved air quality
Washington DOT	Planning, Development	Integrated Planning: Land Use & Economic Development	SR 520 Bridge, SR 516 Corridor, SR 167 to SR 169	Action Plan for integrating sustainability improvements
Des Moines MPO			Surface Transportation Block Grant Program (STBGP)	Created their own evaluation criteria

5.2.2. Building Environmentally and Economically Sustainable Transportation-Infrastructure-Highways (BE2ST-in-Highways)

The University of Wisconsin has developed a sustainability rating system called "Building Environmentally and Economically Sustainable Transportation-Infrastructure-Highways (BE^{2}ST-in-Highways)" with six target values illustrated along with rating results of an example highway project in Figure 5-1 (Lee et al. 2010). This rating system was developed for selecting pavement rehabilitation options utilizing several public domain software packages such as PaLATE (Pavement Life-cycle Assessment Tool for Environmental and Economic Effects), ME-PDG (Mechanistic-Empirical Pavement Design Guide), TNM (Traffic Noise Model) software, LCCA (Life-Cycle Cost Analysis) software.

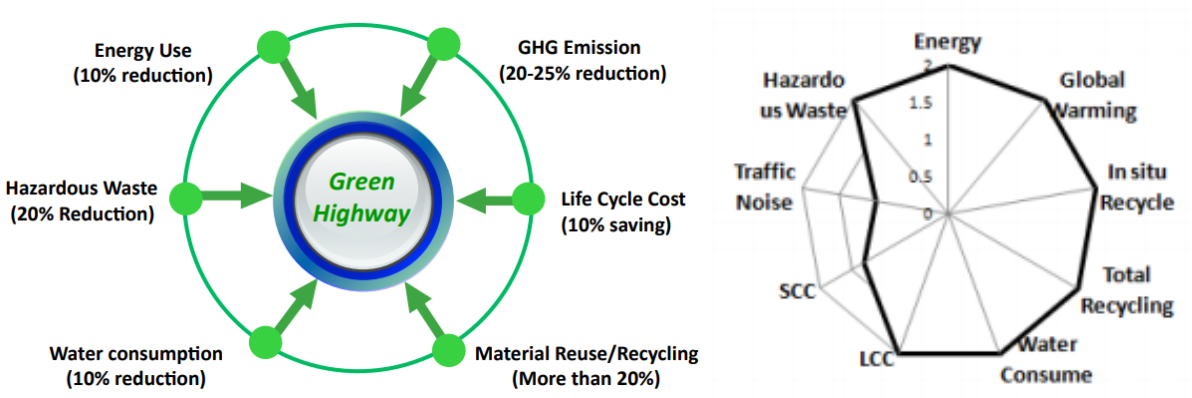


Figure 5-1. Criteria of BE2ST-in-Highways and Example Evaluation Results.

5.3. Sustainability Rating Systems Adopted by State DOT's and Cities

To identify the sustainability rating system adopted by each state DOT, we have visited all fifty state DOTs, sustainability rating systems, and some cities. Based on the website search, we identified the following state DOT's and cities, which adopted various sustainability rating systems for their projects.

5.3.1 New York City (Envision, Sofia et al, 2020)

Project: Pershing Square
Initially NYC closed the street segment to vehicular traffic with paint, epoxied gravel, flexible bollards, and large planters. Now, this repurposed area is a permanent Plaza for general pedestrian and bicycle use.

Project: Henwood Place Step Street
This NYC capital project reconstructed the vertical street to create safer travel conditions and reduce long-term maintenance burdens. NYO reconfigured the staircases and landings, increasing its visibility as a step street and improving the user experience. The conceptual reconfiguration of the project also included new design elements such as ramps and adding street trees.

5.3.2. Colorado DOT (GreenLITES and GreenRoads)

Project: 14th Street Market to Colfax
Sustainability features focused on improvements to active modes of transportation, with significant enhancements to the pedestrian environment as well as bicycle access. The project also emphasized responsible sourcing and disposal of construction materials. Both "GreenLITES" and "Greenroads" were found to be excellent examples of rating systems for construction projects by Colorado DOT (Colorado DOT 2020).

5.3.3. New York State DOT (Envision)

Project: NY Route 353 - Centre Street
NY State DOT performed a bridge replacement and approach work with new traffic signals. The new bridge includes wide shoulders for multi-purpose uses and sidewalks on both sides. A new fishing platform was located near the south abutment and a control levee was reestablished. It is envisioned that this work helped boost this economically depressed area. It helped restore an important transport link and incorporated environmentally sustainably practices such as a creation of new wildlife habitat, a reuse of materials, a multi-modal design and a creation of a new recreational facility through a fishing platform.

5.3.4. Washington State Cities and Counties (GreenRoads)

Project: Wapato Lake Drive project, City of Tacoma, WA
This project included the removal and replacement of an existing roadway with permeable pavement, which was built to create a more environmentally friendly pedestrian link to Wapato Lake Park. The project included non-invasive and native planting, LED lighting

with non-light polluting fixtures, as well as runoff flow control and runoff quality treatment.

Project: City of Ocean Shores, WA
This project was performed to restore a tsunami evacuation route that has been closed since 2006 due to the bridge being structurally deficient. The original timber frame bridge also carried several utilities across the canal, which were hung underneath the new bridge. The new bridge consisted of a 148-foot single span with 6 precast pre-stressed and pre-cambered concrete girders and a cast-in-place concrete deck supported by spread footings with ground improvements. The project provided new pedestrian and bicycle access and restored habitat in the canal by removing the wooden structure.

Project: King County, WA
This project included a replacement of an existing 80-year old bascule bridge with a new bascule bridge crossing the Duwamish waterway in Seattle, Washington. The existing bridge was built on hazardous and contaminated soil, requiring the treatment and disposal of all excavated materials. The scope of the project included the construction of a new bascule bridge, approach structures, realignment of local city streets, drainage conveyance systems, landscaping, and several improvements to the neighborhood's pedestrian and bicycle facilities.

5.3.5. Washington State DOT (INVEST)

Project: SR 516 — SR 167 in Kent to SR 169 in Maple Valley, SR 520 Multi-modal Corridor, US 2 Everett Port
These projects represented a variety of contexts, including the type of highway and surrounding land use, different commute patterns and availability of transit, and varying scope, schedule, budget, and stakeholder participation levels. One of the benefits of integrating INVEST into WSDOT's updated planning guidelines was to help planners view their work through a sustainability lens built upon a well-developed and nationally vetted framework.

5.3.6. Arizona DOT (INVEST)

ADOT used the INVEST Operations and Maintenance (OM) module in 2015 and 2016 to assess both internal operations, specifically the Facilities Management and Equipment Services Divisions, and infrastructure, operations, and maintenance areas using the 14 OM module sustainability criteria. The INVEST scoring process helped ADOT identify gaps in current OM sustainability practices that present opportunities for potential improvement. As a result, ADOT developed eight internal recommendations, six maintenance recommendations, and eight operations recommendations to improve the current OM practices.

5.3.7. Utah DOT (INVEST)

UDOT initially used INVEST in the winter of 2011-2012 to develop specific recommendations for sustainability improvements to its OM Program. UDOT then performed a new self-evaluation in the summer of 2014 to measure progress and identify

room for improvement. UDOT found that it had made progress in a number of areas. While UDOT's most recent INVEST evaluation revealed that the sustainability of the agency's OM program is strong and improving, striving for even further improvement, UDOT developed six additional recommendations for future action.

5.3.8. Delaware DOT (INVEST)

By using INVEST, DelDOT was able to measure the sustainability achievement of its Pavement and Rehabilitation Program and identify areas for improvement across many aspects of project delivery.

5.3.9. Texas DOT (INVEST)

TxDOT used INVEST on the $750 million Harbor Bridge Replacement Project in Corpus Christi, which is the longest cable-stayed bridge in the United States. TxDOT applied INVEST to the procurement phase of the project to ensure that sustainability principles are considered during its project development.

5.3.10. Illinois State Counties (I-LAST)

Project: I-55 at Arsenal Road, Will County

The project included interchange reconstruction and relocation traffic maintenance during construction, frontage road construction and interchange embankment placement, traffic maintenance during construction, roadway connections and existing interchange demolition, and widening of the northern road.

Project: I-57 at I-294 Interchange, South Cook County

Thirty-five proposals were considered before the final configuration was developed by I-LAST. There was considerable coordination among many agencies, organization and consultants to achieve improved access to area businesses and residents with minimal disruption to the environment.

Project: I-290 from Thorndale to I-90/94 and I-355 from Army Trail Road to I-290, Cook and DuPage Counties

This project involved the milling and resurfacing of 27 miles of I-290, and innovation for blue tooth technology to provide traffic information, sediment traps for stormwater treatment, and use of reflective signs to eliminate sign lighting were considered as key components.

5.3.11. Massachusetts DOT (Envision)

Massachusetts DOT required projects to track sustainability through the GreenDOT program, which covers strategic planning to construction and system operations of projects. The "Envision" rating system was used for the $800M Green Line extension project in Boston (Lazzara and Hemzacek 2015).

5.3.12. Oregon DOT (GreenRoads)

The "Greenroads" rating system was used for a pilot study of $16M US 97 project by Oregon DOT (Scarsella 2010).

5.3.13. Des Moines MPO and IEDA, Iowa (INVEST)

In Iowa, significant efforts have been made to integrate social, economic, and natural resource needs while creating a community forum for discussing and sharing ideas for a more sustainable tomorrow for Greater Des Moines (Des Moines 2013). We noticed that there was one user of INVEST in Iowa, Des Moines MPO, who used the INVEST in the update of its long-range plan in 2014. When we contacted Des Moines MPO, they indicated that, they added three sustainability criteria from INVEST for their Surface Transportation Block Grant (STBG) evaluation score (maximum of 100 pts) such as increasing the number of street planting (5 pts), increasing using permeable paving and other green streets techniques (5 pts), and decreasing energy consumption (5 pts) under a sustainability category of "Improve the Region's Environmental Health" (DMAMPO 2019).

The Iowa Economic Development Authority (IEDA) developed Iowa Green Streets Criteria to encourage sustainable community practices of: 1) integrative design, 2) location + neighborhood fabric, 3) site improvements, 4) water conservation, 5) energy efficiency, 6) materials, 7) healthy living environment, and 8) operations, maintenance, and occupant engagement (IEDA 2020).

5.4. Desired Capabilities for Sustainability Rating Systems

To identify the desired characteristics of a sustainability rating system, as shown in the leftmost column in Table 5-4, 15 desired capabilities of an ideal sustainability rating system were selected. Capabilities desired by each state DOT were then identified through the Analytic Hierarchy Process (AHP) process (Simpson et al. 2014). During the AHP process, each state DOT engineer was asked to compare the importance of criteria, two at a time, through pair-wise comparisons. AHP algorithm converted pair-wise comparison results into scores, which were computed for each of the 16 desired capabilities identified. Based on this AHP analysis results, "employ self-assessment" was selected as the most desired capability, followed by "offer a checklist customized to particular types of projects," "evaluate project during the design phase," and "offer performance measures towards achieving credits."

The most suitable sustainability rating system was then identified that has the capabilities each state DOT desires. Based on the AHP analysis results, it was determined that "INVEST" was the most suitable for Colorado DOT and Wyoming DOT, and "GreenLITES" was for South Dakota DOT. No suitable system was found for Utah DOT.

5.5. Desired Capabilities for Iowa DOT

To identify the most desired capabilities for Iowa DOT, we utilized the same survey data from Simpson et al. (2014). As shown in Table 5-5, we assigned "1" to each capability if it is desired by a state DOT and "0" if not desired by a state DOT. The values assigned to each capability by four state DOTs are summed, and a total score is recorded on the rightmost column. As can be

seen from Table 5-5, all four state DOTs selected the following capabilities as the most desired: 1) employ self-assessment, 2) evaluate project during the conceptual phase, 3) evaluate project during the design phase, 4) allocate weights to criteria, 5) offer a checklist customized to particular types of project, 6) award points for innovation, and 7) offer prescriptive measures towards achieving credits. These seven key capabilities were considered for developing a sustainability rating system for Iowa DOT.

5.6. Development of SCORN for Iowa DOT

Based on the evaluation of the existing sustainability assessment tools, the first shelf-ready idea was a development of a flexible "Sustainability Co-Operative Rating Number (SCORN)" using metrics similar to the ones identified by Iowa DOT's sustainability working group in consideration of their impacts on the sustainability attributes. The SCORN was designed as a objective and measurable rating system for Iowa DOT in consideration of the contribution of each sustainable practice towards achieving sustainability goals. The SCORN was developed as an agency-wide system, not a system for a narrowly defined single area such as construction, that would fit to Iowa's geographical and climatic needs. SCORN was developed as an on-line system, which can be accessed from:
SCORN Web Application: https://dev.d2rafxgglufnsm.amplifyapp.com

with a computer code available from:
SCORN GIT Repository: https://github.com/jeongbeom98/SCORN_WebApp.git

The SCORN user's guide is provided in Appendix B.

Table 5-4. Capabilities of Ten Sustainability Rating Systems Desired by Four State DOT's.

CAPABILITIES OF TRANSPORTATION SUSTAINABILITY RATING SYSTEMS (TRSRSs)	BEST-in-highways	Envision	GreenLITES	Greenroads	I-LAST	INVEST	Green Guide for Roads	GreenPave	STARS	CEEQUAL
Ability to assign a score or an award	☑	☑	☑	☑	☑	☑	☑	☑	x	☑
Ability to employ self-assessment	x	☑	☑	x	☑	☑	☑	☑	☑	☑
Ability to evaluate project during conceptual stage	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Ability to evaluate project during design phase	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Ability to evaluate project during construction phase	x	☑	☑	☑	☑	☑	x	☑	☑	☑
Ability to evaluate project during operations and maintenance phase	x	☑	☑	☑	x	☑	x	☑	☑	☑
Ability to allocate weights to criteria	☑	x	☑	x	x	x	x	x	x	x
Ability to choose only relevant criteria to project	x	☑	☑	☑	☑	☑	☑	☑	☑	☑
Ability to offer a checklist customized to particular types of projects	x	x	x	x	x	☑	x	x	x	x
Ability to award points for innovation	x	x	☑	☑	☑	x	x	☑	☑	x
Ability to offer prescriptive measures towards achieving credits	☑	x	☑	☑	☑	☑	☑	☑	x	x
Ability to offer performance measures towards achieving credits	x	☑	x	x	x	x	x	x	☑	☑
Ability to compare different project options side by side	☑	x	x	x	x	x	x	x	x	x
Ability to offer an award for the deisgner, client and contractor	x	x	x	x	x	x	x	x	x	☑
Alignment with State DOT's preffered distribution of credits	x	x	x	x	x	x	x	☑	x	x

(a) Colorado DOT

CAPABILITIES OF TRANSPORTATION SUSTAINABILITY RATING SYSTEMS (TRSRSs)	BEST-in-highways	Envision	GreenLITES	Greenroads	I-LAST	INVEST	Green Guide for Roads	GreenPave	STARS	CEEQUAL
Ability to assign a score or an award	x	☑	☑	x	☑	☑	x	x	☑	x
Ability to employ self-assessment	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Ability to evaluate project during conceptual stage	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Ability to evaluate project during design phase	x	☑	☑	☑	x	☑	x	☑	☑	☑
Ability to evaluate project during construction phase	☑	x	☑	x	x	x	x	x	x	x
Ability to evaluate project during operations and maintenance phase	x	☑	☑	☑	☑	☑	☑	☑	☑	☑
Ability to allocate weights to criteria	x	x	x	x	x	☑	x	x	x	x
Ability to choose only relevant criteria to project	x	x	☑	☑	☑	x	x	☑	☑	x
Ability to offer a checklist customized to particular types of projects	☑	x	☑	☑	☑	☑	☑	☑	x	x
Ability to award points for Innovation	x	☑	x	x	x	x	x	x	☑	☑
Ability to offer prescriptive measures towards achieving credits	☑	x	x	x	x	x	x	x	x	x
Ability to offer performance measures towards achieving credits	x	x	x	x	x	x	x	x	x	☑
Ability to compare different project options side by side	x	x	x	x	x	x	x	☑	x	x
Ability to offer an award for the deisgner, client and contractor	☑	☑	☑	☑	☑	☑	☑	x	☑	☑
Alignment with State DOT's preffered distribution of credits	☑	☑	x	☑	x	x	☑	☑	x	☑

(b) Utah DOT

CAPABILITIES OF TRANSPORTATION SUSTAINABILITY RATING SYSTEMS (TRSRSs)	BEST-in-highways	Envision	GreenLITES	Greenroads	I-LAST	INVEST	Green Guide for Roads	GreenPave	STARS	CEEQUAL
Ability to employ self-assessment	x	☑	☑	x	☑	☑	x	x	☑	x
Ability to evaluate project during conceptual stage	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Ability to evaluate project during design phase	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Ability to allocate weights to criteria	☑	x	☑	x	x	x	x	x	x	x
Ability to choose only relevant criteria to project	x	☑	☑	☑	☑	☑	☑	☑	☑	☑
Ability to offer a checklist customized to particular types of projects	x	x	x	x	x	☑	x	x	x	x
Ability to award points for Innovation	x	x	☑	☑	☑	x	x	☑	☑	x
Ability to offer prescriptive measures towards achieving credits	☑	x	☑	☑	☑	☑	☑	☑	x	x
Ability to offer performance measures towards achieving credits	x	☑	x	x	x	x	x	x	☑	☑
Ability to compare different project options side by side	☑	x	x	x	x	x	x	x	x	x
Ability to offer an award for the designer, client and contractor	x	x	x	x	x	x	x	x	x	☑
Alignment with State DOT's preffered distribution of credits	x	x	x	x	x	☑	x	x	x	x

(c) South Dakota DOT

CAPABILITIES OF TRANSPORTATION SUSTAINABILITY RATING SYSTEMS (TRSRSs)	BEST-in-highways	Envision	GreenLITES	Greenroads	I-LAST	INVEST	Green Guide for Roads	GreenPave	STARS	CEEQUAL
Ability to employ self-assessment	x	☑	☑	x	☑	☑	x	x	☑	x
Ability to evaluate project during conceptual stage	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Ability to evaluate project during design phase	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑
Ability to evaluate project during operation and maintenance phase	x	☑	☑	☑	x	☑	x	☑	☑	☑
Ability to allocate weights to criteria	☑	x	☑	x	x	x	x	x	x	x
Ability to choose only relevant criteria to project	x	☑	☑	☑	☑	☑	☑	☑	☑	☑
Ability to offer a checklist customized to particular types of projects	x	x	x	x	x	☑	x	x	x	x
Ability to award points for Innovation	x	x	☑	☑	☑	x	x	☑	☑	x
Ability to offer prescriptive measures towards achieving credits	☑	x	☑	☑	☑	☑	☑	☑	x	x
Ability to offer performance measures towards achieving credits	x	☑	x	x	x	x	x	x	☑	☑
Ability to compare different project options side by side	☑	x	x	x	x	x	x	x	x	x
Ability to offer an award for the designer, client and contractor	x	x	x	x	x	x	x	x	x	☑
Alignment with State DOT's preferred distribution of credits	x	x	x	x	x	☑	x	x	x	x

(d) Wyoming DOT

Table 5-5. Capabilities of Sustainability Rating System Commonly Desired by Four states.

Sustainability Rating System with Ability to:	Colorado DOT	South Dakota DOT	Wyoming DOT	Utah DOT	Total Score
1. Employ self-assessment	1	1	1	1	**4**
2. Evaluate project during conceptual stage	1	1	1	1	**4**
3. Evaluate project during design phase	1	1	1	1	**4**
4. Allocate weights to criteria	1	1	1	1	**4**
5. Offer a checklist customized to particular types of projects	1	1	1	1	**4**
6. Award points for Innovation	1	1	1	1	**4**
7. Offer prescriptive measures towards achieving credits	1	1	1	1	**4**
8. Evaluate project during operations and maintenance phase	0	1	1	1	**3**
9. Offer performance measures towards achieving credits	1	1	1	0	**3**
10. Align with State DOT's preferred distribution of credits	0	1	1	1	**3**
11. Choose only relevant criteria to project	1	1	1	0	**3**
12. Evaluate project during construction phase	1	0	0	1	**2**
13. Assign a score or an award	1	0	0	1	**2**
14. Offer an award for the designer, client and contractor	0	1	0	1	**2**
15. Compare different project options side by side	0	0	0	0	**0**

6. SUSTAINABILITY GOALS AND TASKS FOR IOWA DOT

Iowa DOT is to develop a comprehensive internal sustainability plan that includes goals, performance metrics, quantifiable targets, strategies, and actions designed to help meet the overall plan objectives. As an example, FHWA provides components of a comprehensive sustainability plan in Table 6-1 which shows examples of each of these components.

Table 6-1. Components of a comprehensive sustainability plan (FHWA INVEST 3.1).

Component	Example
A goal is the area that needs to be improved.	A transportation agency wants to reduce its environmental footprint.
A performance metric will be used to evaluate the progress being made towards the goal area.	To measure its performance, the agency will track its energy consumption.
A target uses the selected performance metric and identifies specific objectives to be achieved in the future.	The target is to reduce the agency's annual energy consumption by 20% below current levels 2 years from now. (The baseline is how much energy the agency currently consumes per year.)
Strategies are categories of actions used to achieve the target.	The agency will use three main strategies to reach the target: (1) consume less electricity, (2) consume less gasoline and diesel fuel, and (3) consume less natural gas.
Actions are specific things that can be done to implement the strategies.	To implement the strategy of consuming less electricity the agency will: (1) replace incandescent light bulbs with compact fluorescents, (2) replace broken office equipment with energy efficient models, and (3) install occupancy sensors in the lighting system.

For example, common performance metrics for internal sustainability plans should include:

- Annual electricity, natural gas, gasoline, and diesel fuel consumption
- Annual renewable energy consumption
- Agency fleet fuel efficiency
- Agency fleet annual vehicle miles traveled
- Annual tons of solid waste produced
- Annual recycling rate
- Annual reams of paper consumed
- Annual water consumption
- Stormwater infiltrations rates at agency-owned facilities
- Percent of procured items that are sustainably produced, contain recycled materials, produced locally, etc.
- Percent of building inventory meeting green or sustainable building criteria

To help develop goals and tasks for Iowa's sustainability implementation plan, we evaluated the goals and tasks for sustainability in core operation developed by US DOT. The 2016 strategic sustainability performance plan by US DOT is summarized in Table 6-2. with respect to 10 sustainability goals along with sustainability evaluation measures and lessons learned from the implementation of each goal (US DOT 2016).

https://www.transportation.gov/sites/dot.gov/files/2016%20DOT%20SSPP%20Final_Complete_Sept_2016.pdf

Table 6-2. USDOT's Sustainability Goals, Evaluation Measures and Lessons Learned.

Sustainability Goals	Sustainability Evaluation Measures	Lessons Learned
Greenhouse gas emissions reduction	Annual GHG inventory	Telework and virtual meetings were most effective
Sustainable buildings	Compliance Tracking System/ ENERGY STAR® Portfolio Manager	Watch hidden administrative costs
Increasing use of renewable energy	Percentage of renewable energy used	Evaluate suitability and eligibility for each renewable energy generation
Water use efficiency	Quarterly water efficiency reporting	Available water conservation measures were not financially feasible
Fleet management	Monthly reports that display missed opportunities for alternative fuel use	Track low mileage vehicles, alternative fuel use and fleet fuel consumption
Sustainable acquisition	Sample at least five percent of all contracts on a quarterly basis	Use federal strategic sourcing initiatives, i.e. DOT Blanket Purchase Agreements
Pollution prevention & waste reduction	Quarterly waste diversion and recycling reporting	Share internal sustainability scorecard and waste report with senior leadership
Energy performance contracts	Effectiveness of PBCs for achieving energy and water savings	Bundling multiple locations under one Perf. Bas. Cont. (PBC) creates add. risks
Electronic stewardship	percentage of electronics purchased that are EPEAT or ENERGY STAR®	Install power management settings for equipment such as printers and copiers
Climate change resiliency	Audit of mission-critical internal assets vulnerable to climate change	Maintain continuity of operation due to its broad consequences for DOT mission

Priority actions towards sustainability goals are summarized in the 2022 Sustainability Plan by USDOT metrics (USDOT 2022) as shown below:

https://www.transportation.gov/sites/dot.gov/files/2022-12/DOT-2022-Sustainability-Plan_Final.pdf

100% Carbon Pollution-Free Electricity (CFE)

- Quantify emissions from purchased electricity by e-GRID region to prioritize locations for CFE purchase and onsite installation.
- Prioritize locations for CFE purchases based on CFE offerings from the local utility.
- Participate in General Services Administration (GSA) area-wide contracts or power purchase agreements to transition to at least 30 percent CFE by end of 2023.
- Utilize an existing energy performance contract or other mechanism to perform a feasibility study to develop new onsite CFE generation and energy storage in 2022.

100% Zero Emission Vehicle (ZEV) Fleet by 2035

- Procure 242 EVSE charging ports to install by end of 2022 and ready field locations for Electric Vehicles (EVs).
- Convert 31 percent of new light duty vehicle acquisitions to ZEVs in FY 2023 with a goal to convert 40 percent of new light duty vehicles in FY 2024.
- Develop a strategic EV transformation plan using iterative multi-year planning to reflect the latest key information regarding mission requirements, vehicle model availability, and relevant costs.

Net-Zero Emissions Buildings, Campuses, and Installations

- Design and Construct for Net-Zero Emissions
- Increasing Energy Efficiency
- Increasing Water Efficiency

Reducing Waste and Pollution

- Divert waste from landfills by entering recycling contracts at some of the largest facilities and leverage telework opportunities to reduce waste generation at facilities.
- Reduce and/or divert construction and demolition waste material and reuse existing building materials, to decrease need for carbon-intensive manufacturing and transport of new building materials.
- Increase diversion of organic waste through composting, when cost effective.

Sustainable Procurement

- Initiate a Low Carbon Procurement Pilot program to increase the acquisition of goods with environmental product declarations (EPDs) to support GHG reduction goals.
- Update acquisition management system and guidance documents in FY 2023 to include the latest resiliency clauses, as well as sustainability and environmental justice requirements and provide training to relevant personnel.
- Complete a per- and polyfluoroalkyl substance (PFAS) product inventory in 2022 to establish a baseline and develop strategies to phase out the purchase of PFAS-containing products and identify replacements.
- Increase acquisition of products and services that meet all federal requirements and designations, including EPA Energy Star-certified, DOE Federal Energy Management Program (FEMP)-designated, WaterSense-certified, Safer Choice labeled, Significant New Alternative Policy (SNAP) substances, and products made with post-consumer waste products.

Sustainability-Focused Federal Workforce

- Integrate standard language for use in performance plans for staff engaged in climate change activities across the Department.
- Work with the NOAA to develop climate education materials and training for all DOT employees and for DOT stakeholders.
- Update four sustainability-focused and three environmental management-focused training courses on the FAA electronic learning management system.

- Hire new staff members with subject matter expertise in clean energy, ZEVs, zero emission frontline workforce needs, environmental policy, and climate resiliency and sustainability, and provide related training opportunities for current staff.

Incorporating Environmental Justice

- The DOT Equity Task Force has established a workstream dedicated to delivering 40 percent of the overall benefits of Department-wide investments to disadvantaged communities in alignment with the Justice40 initiative.
- The Federal Transit Administration is currently developing an Environmental Justice Standard Operating Procedure (SOP) for staff who manage the environmental review process. The SOP is expected to be completed in FY 2023.
- The Pipeline and Hazardous Materials Safety Administration (PHMSA) is updating its existing Environmental Justice policy from 2012 to align with current goals and priorities, with target completion in FY 2023.

Accelerating Progress through Partnerships

- Partner with utility companies to complete multiple audits in 2022 and pursue UESC projects that include onsite renewable energy where feasible.
- Complete implementation of awarded UESC contracts to improve energy and water efficiency across DOT facilities.
- Launch and complete climate challenges across all DOT modes to develop public-private partnerships that accelerate progress towards net-zero transportation emissions.

6.1. Survey Results of Sustainability Goals and Tasks from Iowa DOT Employees

The survey forms on sustainability goals and tasks were completed by 8 employees of Iowa DOT and the results are summarized below.

Q#1. What do you think our department's sustainability goals should be (i.e., increase sustainable construction practices)? Please list them.

- Reduce non-productive vehicle idling.
- Elevate priority of pavement/bridge maintenance practices that extend structure life (get out of the trend of deferred maintenance)
- Maintenance-friendly design on new construction - design that avoids winter issues, shoulder maintenance, mowing, etc. or otherwise cuts the amount of work needed to operate and maintain it.
- Increase sustainable construction practices.
- Increase support for transit or carpooling or trails- whatever we can do to get people out of cars. utilize solar power either at our buildings or by allowing panels in our ROW as appropriate.
- Prioritize the buildout of charging stations along the most-used routes like we are doing with NEVI but even more of that, not just along interstates.
- Having more of our fleet using electric or hybrid or low-emission vehicles.
- Start requiring smog tests on vehicles, similar to other states like California, to make sure there aren't cars on the road that are gross polluters.

- Recycling of waste at central complex.
- Increase consideration of sustainable pavements.
- Promote sustainable design methods in DOT facilities and rest areas, especially with Central Office remodeling.
- expand roadside vegetation program to consider sustainability and water quality.
- increase natural and permanent snow fence for reduced snow plowing.
- apply solar power to permanent snow fence.
- reduce mowing with native plantings.
- place solar panels at DOT shops.
- Identify early resiliency target projects and specific measures to implement on a project-by-project basis.
- expand our sustainability goals; we do not have a legislative mandate, however, we also don't have anything that prohibits us from taking important steps forward.
- Create an official sustainability planning document.

Q#2. What tasks and work efforts should be identified to achieve each sustainability goal that you listed in Question #1 (i.e., making it easy to build test sections for sustainable construction practice)?

- seek multi-level management support and 'common goal'.
- make sure supervisors know how to get an idle time report from Fleetio and what 'reasonable' looks like. Make sure it is treated with some consistency, while accommodating any actual (explainable) differences.
- investigate or request alternative funding mechanisms when normal sources tighten.
- Be willing to ask and make a case for additional funding if needed.
- Make better use of CRP and PROTECT funds- use them for innovative sustainable projects or transit needs/projects, not just throw it on projects we are already doing.
- Provide assistance (whether it is financial or design or planning) to anyone serious about building charging stations and solar panels in our ROW.
- Education and awareness of recycling of waste at DOT.
- Incentivize sustainable pavements - I'm not sure what we do in this already.
- grants for solar power?
- more funding for ROW purchases for permanent snow fence, or use more excess ROW for such. Allow more excess ROW for solar arrays, such as Marquette did for their wastewater plant energy.
- pursue more renewable energy options to offset utility costs.
- reduce our GHG emissions.
- Establish Iowa DOT pillars of sustainability. Identify goals and actions to achieve goals.

Q#3. What kinds of metrics could or does the Iowa DOT use to evaluate the progress in achieving sustainability (i.e., reduction in GHG emission)?

- Fleetio idle time info
- long term maintenance or reconstruction costs- lower costs overall in the long run.
- track a decrease in gas/electric consumption if we used more solar power.
- metrics to track projects that increase resiliency in flood-prone areas.

- calculate the GHG emissions of our fleet and track, over time, how new equipment purchases are reducing the emissions.
- amount of kilowatts derived from solar power
- There is no better metric than cost savings.
- Track GHG emissions.
- Identify any current sustainable practices and compare them to previous practices.

Q#4. What are the most successful sustainable practices that our department has implemented (i.e., recycling asphalt pavements)? Please list sustainability practices that were implemented successfully.

- The NEVI plan is still being implemented but I think that will be a good one.
- Adding resilient features/infrastructure after flood damage in SW Iowa.
- Even all the e-construction and e-ticketing and removing all the paper products we used to go through before is a great accomplishment.
- Living Roadway Trust - roadside vegetation and native plantings.
- butterfly habitat in the I-35 corridor, but I hope they aren't getting killed by vehicles! extend butterfly habitat in more excess ROW and other ROW
- Recycling concrete pavements and crushing pavement for use as drainable backfill.
- Solar energy capture in the ROW (US 18 near Marquette)

Q#5. Are you aware of any important lessons learned from implementing these sustainability practices in the past?
- No- they are all in areas I don't really work in.
- Try to incorporate old items as much as possible instead of throwing away.
- Using crushed concrete pavement as drainable backfill.

Q#6. How can we incorporate sustainability strategies into core DOT activities (administrative, planning, design, construction, operational, and maintenance activities)?
- Collect examples of the smaller things that lead to sustainability that anyone in any position can do and explain how it helps and encourage people to consider it in their decisions.
- Administration could work on where we are sending the CRP and PROTECT funds as well as the fleet and solar panel issues.
- Motor vehicles could work on the smog thing.
- Planning should have a responsibility to plan for charging station infrastructure and where resilient improvement could be made.
- Construction should be working on new methods that are going to be more sustainable whether that is during the construction process or the life of the infrastructure.
- DOT should make sustainability and carbon reduction part of the conversation. It is rarely a topic in Iowa DOT that is discussed or included in decision-making.
- solar arrays on DOT buildings and grounds
- provide an incentive to contractors to recycle old materials instead of throwing away.
- Every sustainability strategy should come with an action plan that spans at least 3 years. We should be able to have metrics for each of those years and an actual plan on how to

utilize the strategy. There should be an accountability piece, an actual follow-up, to review our processes/strategies before the sustainability strategy kicks in and after.
- Sustainability should be a part of all discussions around facilities management.
- formal planning document on Iowa DOT and Sustainability. Then work on achievable and easily trackable activities (design, construction).

Q#7. Are you aware of any incentives by our department for implementing sustainable practices in developing or constructing projects (i.e., a sustainability block grant for sustainable practices)?
- The MPOs get Carbon Reduction funding.
- There is NEVI funding available for charging station infrastructure.
- the Volkswagen settlement money went to sustainability but I'm not sure on that.
- I am not aware of any incentives.

Q#8. Does Iowa DOT leadership encourage sustainability practices and how can leadership further encourage sustainability into Iowa DOT practices (i.e., executive order to implement sustainable practices)?
- Yes. My suggestions are more gentle changes in priority rather than monumental undertakings. Prioritizing the long run. Willingness to invest in or plead a case for something that will pay off later. Cross-departmental partnerships -- transportation design that preserves housing value/community health/accessibility/natural resources/economic development.
- I don't feel like they do much. If something specific comes up where we have to or it makes sense, then they do. But it feels much more reactionary than having a vision to be sustainable and executing that. Like even with the resiliency and sustainability groups- it is made up of people who do other things and squeeze this in when they can. If it was truly important, they would fund at least one position to head up all the resiliency and sustainability efforts.
- Have sustainability be part of the DOT Business Plan goals and objectives. This would elevate sustainability to be more visible and prioritize consideration of sustainable practices.
- Leadership supports it but I think it's still a new program.
- I think DOT leadership is open to ideas in any area of operations to improve overall mission including sustainability and resiliency.
- I think they encourage it but there is very little if any follow-through to actually see the ideas through unless there's a rush/push to complete something quickly. I think leadership values quick wins over actual sustainability generally.
- I would say that Iowa DOT leadership has been neutral to slightly in favor regarding sustainability practices.
- Leadership does not necessarily encourage nor discourage sustainable practices. I think in order to make progress in sustainability efforts at the Iowa DOT, we need official goals (with a timeline) to promote action and implementation.

6.2. Sustainability Goals for Iowa DOT

Before developing sustainability goals for Iowa DOT, the size and scope of its operations should be compiled and used as baseline to evaluate the effectiveness of sustainability efforts in the future.

- Number of Employees:
- Amount of Total Budget ($Million):
- Amount of Contracts Awarded ($Million) in Construction/Maintenance and Non-Construction/Maintenance:
- Amount of GHG Emissions from facilities (Metric Tons of Carbon Dioxide Equivalent):
- Amount of Sustainable Products and Services ($Million):
- Number of Buildings and Building Gross Square Feet (GSF):
- Energy Consumption per square feet (kBtu/SF):
- Water Consumption (Gallon Million):
- Number of Iowa DOT facility locations in Iowa:
- Number of Fleet Vehicles Managed:
- Amount of Fleet Fossil Fuel Use (Gallon Million):
- Amount of GHG Emissions from fleet vehicles (Metric Tons of Carbon Dioxide Equivalent):
- Lane-Miles of Roads Managed (concrete, asphalt, gravel):
- Number and Lane-Miles of Bridges Managed:
- Miles of bike lanes
- Amount of GHG Emissions from construction and maintenance (Metric Tons of Carbon Dioxide Equivalent):
- Number and locations of Lighting Fixtures:
- Miles and locations of Noise walls:
- Number and locations of rest areas:
- Number and locations of weigh stations:
- Acres of Roadside Land Managed:

We then evaluated the goals and tasks of sustainability developed by Minnesota. The 2021 Sustainability Report by Minnesota DOT lists metrics in 5 focus areas (Minnesota DOT 2021): https://www.dot.state.mn.us/sustainability/sustainability-reporting.html

1) Facilities (GHG Emission, Energy Intensity, Renewable energy, Water consumption, Solid waste recycling),
2) Fleet (GHG emission, Fossil fuel use, and Electric vehicles),
3) Highway operations (LED roadway lighting, Salt use, and Snow fences),
4) Roadside vegetation (Native seeding and Native planting), and
5) Construction (Construction GHG and Sustainable Pavement).

To ensure successful implementation of beneficial sustainability practices in Iowa, in consideration of USDOT and other state DOTs' practices, the following sustainability goals and tasks for five target areas of facilities, fleet, construction, maintenance/operations and employees are provided.

Goal #1: **Facilities:** Achieve X% reduction in GHG emissions by 2030.
Tasks:

- Collect data and develop best practices in areas that influence GHG emission reductions.
- Assess Iowa DOT's carbon footprint from internal operations and measure progress on a yearly basis.
- Use ENERGY STAR Portfolio Manager to consistently track GHG emission reductions from facility energy use and conservation activities.

Goal #2: **Facilities:** Achieve X% reduction in **wastes** through recycling and reuse by 2030.
Tasks:

- Recycle all possible paper, cardboard, metals, glass and plastics.
- Provide convenient and easily identifiable recycling options at rest areas.
- Perform recycling and waste audits.

Goal #3: **Facilities:** Achieve X% reduction in **water** use by 2030.
Tasks:

- Undertake rainwater harvesting pilot projects.
- Use drought tolerant plants in roadside landscaping areas.
- Use low-flow fixtures.
- Perform a leak assessment.

Goal #4: **Facilities:** Achieve X% reduction in **energy** use by 2030.
Tasks:

- Use low-energy light fixtures in the building.
- Changing roadway lighting to LED or Solar.
- Perform an energy audit.

Goal #5: **Fleet:** Achieve X% reduction in **emissions** from vehicles by 2030.
Tasks:

- Incorporate alternative fuel vehicles such as electric, hybrid, and biofuel technology, and alternative fuel infrastructure into other fleet vehicles and equipment.
- Gasoline used by the fleet vehicles should be E-85 equivalent.
- Diesel used by the fleet vehicles should be B-20 equivalent (Research project focused on B-XX fuels including pilots and a number of other aspects for varying vehicles.) https://ideas.iowadot.gov/subdomain/ideas-main/end/node/3080?qmzn=iKFrYf#Active
- Give incentives for fuel conservation at the crew manager or individual driver level.
- Purchase all new vehicles to be alternative fuel vehicles.

Goal #6: **Construction:** Achieve X% increase in sustainable construction practices by 2030.
Tasks:

- Following Iowa DOT's sustainable bridge design guide, the sustainable road design guide should be developed, i.e., "Construction minimizes disturbing greenfield, wetland or farmland."
- Change specifications to encourage more sustainable practices.
- Develop a more flexible procedure to create test sections to evaluate new sustainable practices.

- Create a sustainability block grant where sustainable practices will be reviewed favorably in the application review process.
- Provide incentives for implementing sustainable practices.
- Build sustainable pavements such as warm mix asphalt, cold in-place recycling, high RAP mix, recycled concrete as subbase materials, waste plastics in asphalt pavement, high friction surface treatment (on curve sections), and quiet pavements such as longitudinal tining and grinding texture for next generation concrete.
- Use less salt and increase organic deicer using soybean and corn (Ravi Yellavajjala at Arizona State University). https://publications.iowa.gov/33802/
  Concentration Preserving Deicing Solutions for Higher Ice Melting
  https://ideas.iowadot.gov/subdomain/ideas-main/end/node/3522?qmzn=iKFrYf
- Build bicycle lanes and sidewalks.
- Build HOV lanes.
- Build truck only lanes.

Goal #7: **Maintenance and Operations:** Increase X% increase in sustainable maintenance and operation practices by 2030.
Tasks:

- Increase public transportation subsidies.
- Optimize traffic signal timing.
- Implement E-Ticketing and Automatic Flagger
- Roadside native seeds and planting
- Build corn stalk/tree as noise walls
- Build corn stalk/trees as snow fences
- Purchase sustainable products

Goal #8: **Employees:** Develop Sustainability-Focused Workforce
Tasks:

- Integrate standard language for use in performance plans for staff engaged in sustainability activities across Iowa DOT.
- Develop sustainability education materials and training for all Iowa DOT employees and for Iowa DOT stakeholders.
- Provide sustainability training opportunities for new and current staff members.

7. DEVELOPMENT OF "DOSPIR" SUSTAINABILIY PRACTICE DATABASE

Over the past decades, numerous test sections applying sustainable practices have been built throughout Iowa and their performance evaluation reports have been published. However, because the performance evaluation results of these test sections have not been stored in an on-line computer database, they could not be easily searched by future users of the same sustainable practices. Therefore, Database Of Sustainable Practices with Implementation Records (DOSPIR) was developed to include sustainable practices along with their field performances.

7.1. Example Sustainable Practices Implemented in Iowa

Selected sustainable practices are discussed below.

7.1.1. Integrated roadside vegetation management (IRVM)

Integrated Roadside Vegetation Management (IRVM) is an approach to right-of-way maintenance that combines an array of management techniques with sound ecological principles to establish and maintain safe, healthy, and functional roadsides. The IRVM's benefits include judicious use of herbicides, spot mowing, prescribed burning, mechanical tree and brush removal, and the prevention and treatment of disturbances to existing vegetation. IRVM's long-term objective is to reduce roadside maintenance by creating stands of durable, long-lived, native plants with specific goals and basic tenets as shown below:

Goals

- Maintain a safe and effective road system.
- Provide responsible and sustainable vegetation management.
- Make the most of Iowa's immense, 700,000-acre, roadside resource.

Basic tenets

- Prevent soil erosion.
- Control undesirable species in roadsides.
- Do not rely exclusively on herbicides.
- Plant the best-adapted vegetations.

As shown in Figure 7-1, Iowa IRVM historical planning map is available from Arc GIS online archive where each point contains acres, planted year, and length.

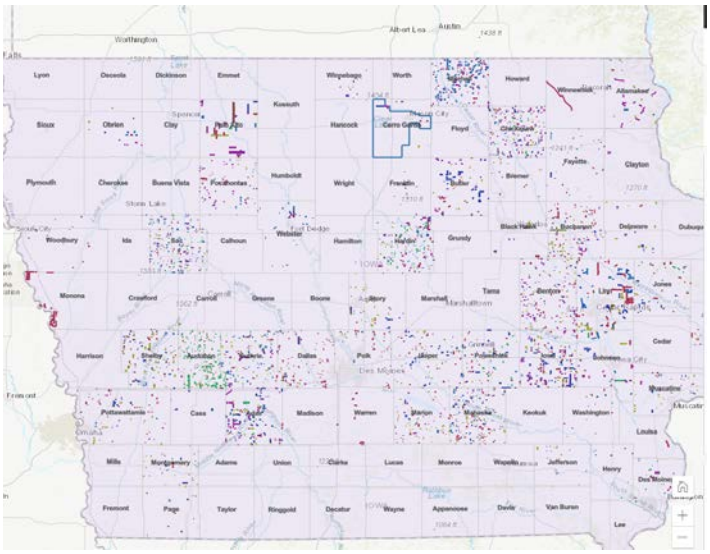


Figure 7-1. IRVM Historical planning Map.

7.1.2. Roundabout

Roundabouts eliminate the stop-and-go traffic associated with stop signs or traffic signal-controlled intersections, which results in savings in gasoline costs. Roundabouts also provide an opportunity to landscape the center island, providing green space within the intersection. Roundabouts have been used in Iowa to reduce crashes, traffic delays, fuel consumption, air pollution, and construction and maintenance costs. The Iowa DOT has started using roundabouts in certain situations to enhance safety and reduce delays encountered by the motoring public. Since 2000, 61 roundabouts were built, and 2 more projects were planned in Iowa. (https://iowadot.gov/traffic/roundabouts/Roundabouts-in-IA). The Highway Data Loss Institute (HDLI) of the Insurance Institute for Highway Safety (IIHS) reported the benefits of roundabouts, which are summarized below:

- Studies of intersections in the United States converted from traffic signals or stop signs to roundabouts have found reductions in injury crashes of 72-80 percent and reductions in all crashes of 35-47 percent (*Retting et al., 2001; Eisenman et al., 2004*; *Rodegerdts et al., 2007*)
- A study of 19 higher-speed rural intersections (speed limits of 40 mph or higher) that originally had stop signs on the minor approaches and were converted to roundabouts found a 62 percent reduction in all crashes and an 85 percent reduction in injury crashes (*Isebrands & Hallmark, 2012*).
- Studies of intersections in Europe and Australia that were converted to roundabouts have reported 25-87 percent reductions in injury crashes and 36-61 percent reductions in all crashes (*Rodegerdts et al., 2010*).
- Based on the results of a 2004 study (*Eisenman et al., 2004*), it's estimated that the conversion of 10 percent of the signalized intersections in the United States to roundabouts would have prevented approximately 51,000 crashes in 2018, including 231 fatal crashes and about 34,000 crashes involving injuries.

It was reported that the safety of two-lane roundabouts improved over time as drivers became more familiar with them (Hu & Cicchino, 2019). Based on the study performed on roundabouts built in Washington state between 2009 and 2015, crashes at two-lane roundabouts decreased by an average of 9 percent a year, and severe accidents decreased by nearly one-third annually. Studies in Europe indicate that, on average, converting conventional intersections to roundabouts can reduce pedestrian crashes by about 75 percent (Brilon et al., 1993; Schoon & van Minnen, 1994). Single-lane roundabouts lowered pedestrian crash rates than comparable intersections with traffic signals (Brude & Larsson, 2000).

7.1.3. LED Roadway Luminaries

LED lights are adopted more frequently to replace the existing conventional lighting system. As an example, the specification that applies to luminaires for new installations or replacements at signalized highway intersections within the City of Council Bluffs is presented in Table 7-1.

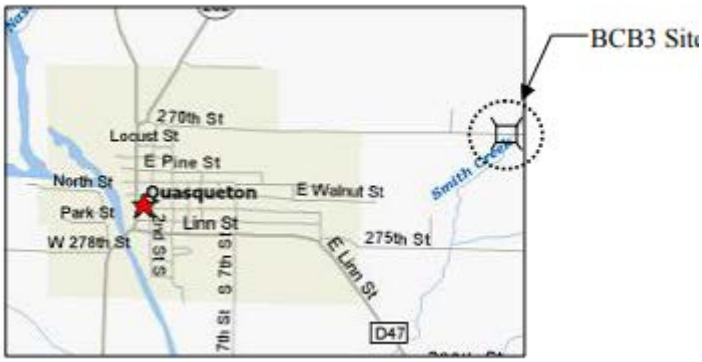
Table 7-1. Luminaire Designation: 250W HPS Equivalent LED.

PERFORMANCE CRITERIA LED LUMINAIRE					
INPUT POWER	Maximum nominal luminaire input power				108 W
VOLTAGE	Nominal luminaire input voltage (or range as applicable)				120 V
LUMEN MAINT.	Minimum % of initial output at 36,000 hours operation				90%
WARRANTY	Minimum luminaire warranty				10 years
NOMINAL CCT	Rated correlated color temperature				4000 ± 350 K
BUG RATING	Maximum nominal backlight-uplight-glare ratings				B2-U0-G2
DOWNWARD OUTPUT	Minimum *maintained* luminaire output below horizontal				10,800 lm
FINISH	Luminaire housing finish color				Gray
WEIGHT	Maximum luminaire weight				30 lb
LIGHT DISTRIBUTION	Distribution Type and Range				TYPE III Medium
MOUNTING	Mtg. method	☐ Post-top	☑ Side-arm	☐ Trun./yoke	☐ Swivel-tenon
	Tenon nominal pipe size (NPS)				2 inches
VIBRATION	ANSI C136.31	☑ Level 1 (normal)	☐ Level 2 (bridge/overpass)		
THERMAL ENVIRONMENT	Typical minimum ambient temperature during operation				-20 °C
	Typical maximum ambient temperature during operation				40 °C
ELECTRICAL IMMUNITY	ANSI C136.2 Comb. Wave Test Level	☑ Basic (6kV / 3kA)	☐ Enhanced (10kV / 5kA)		☐ Elevated (20kV / 10kA)
CONTROL INTERFACE	☐ None	☐ ANSI C136.10, 3-pin	☑ ANSI C136.41, 5-pin		☐ ANSI C136.41, 7-pin
LED DRIVER	☐ Not dimmable	☑ Dimmable, 0-10V (IEC 60929)	☐ Dimmable, DALI (IEC 62386)		

7.1.4. Railcar bridge

The old railcars have been used for several bridges in Iowa. A railcar bridge was installed at the intersection of 270th Avenue and Rainbow Road in Delaware County, which crosses Elk Creek approximately three miles northeast of Greeley, Iowa. The general location of the bridge is identified with a dashed rectangle and labeled Detail A in Figure 7-2(a), and the approximate location of the bridge is identified with a dashed circle. In the fall of 2004, as shown in Figure 7-2(b), the third railcar bridge, spanned 66 ft - 2 in. and a deck width of 26 ft - 5 1/2 in, was constructed on 270th St in Buchannan County that crosses Smith Creek 1.5 miles east of Quasqueton, Iowa.

(a) Railcar Bridge in Delaware County



(b) Third Railcar Bridge in Buchanan County

Figure 7-2. Locations of Railcar Bridges.

7.2. Development of "DOSPIR" Sustainability Practice Database

As discussed earlier, because the construction and performance evaluation results of these test sections of sustainable practices have not been stored in an online computer database, they could not be easily searched by future users of the same sustainable practices. Zhao et al. (19) proposed that the pavement management system (PMS) should incorporate sustainability principles and methods for assessing the environmental and economic impacts of using sustainable practices. While PMS is a comprehensive software tool that is effective for the overall maintenance and management of road infrastructure, its uniformly segmented database with no consideration of specific test sections makes it challenging to locate test sections constructed with sustainable practices.

Therefore, DOSPIR was developed to include implementation records of sustainable practices along with their field performances. By providing a centralized platform for a transportation sustainability-focused database, DOSPIR would enable researchers to conduct comparative analyses across various geographical locations and over an extended timeframe. DOSPIR would significantly enhance the ability to monitor, assess, and predict the long-term sustainability impacts of transportation projects.

DOSPIR was developed using the programming language Python on the ArcGIS Pro platform. ArcGIS Pro was used to store construction and performance monitoring data and

spatially join various datasets containing locations of test sections, performance data, and crash data. Python was used to develop a versatile and powerful data structure for handling and analyzing georeferenced data. This step also involved refining the data by eliminating records with missing values and outlier data reduction and adding analyzed data. Such data processing and analysis steps are crucial for a comparative analysis of the impacts of implemented sustainable practices.

Python's data visualization tools were used to plot bar charts based on the spatially joined GIS database. To update them, users can download the latest locations of sustainable practices and performance/crash data files and run a DOSPIR with a new set of data files. By running DOSPIR again with new datasets, the data sets will be automatically spatially joined, and visual representations will be updated with new sets of data files. Further, DOSPIR's online accessibility and spatial analysis functions would facilitate the ongoing data updates.

On-line version of DOSPIR can be accessed from:
https://dev.dgybd4eur8aqw.amplifyapp.com

DOSPIR computer codes can be obtained from:
https://github.com/jeongbeom98/DOSPIR_WebApp.git

Currently, as shown in Figure 7-3, a prototype DOSPIR includes four sustainable practices of asphalt pavement recycling, high-friction surface treatments, Ultra High-Performance Concrete (UHPC) bridges, and roundabouts, which are discussed below. Please see the DOSPIR user's guide in Appendix C for step-by-step instructions on how to access a database of sustainable practices and analyze the crash data before and after the construction of any roundabout in Iowa.

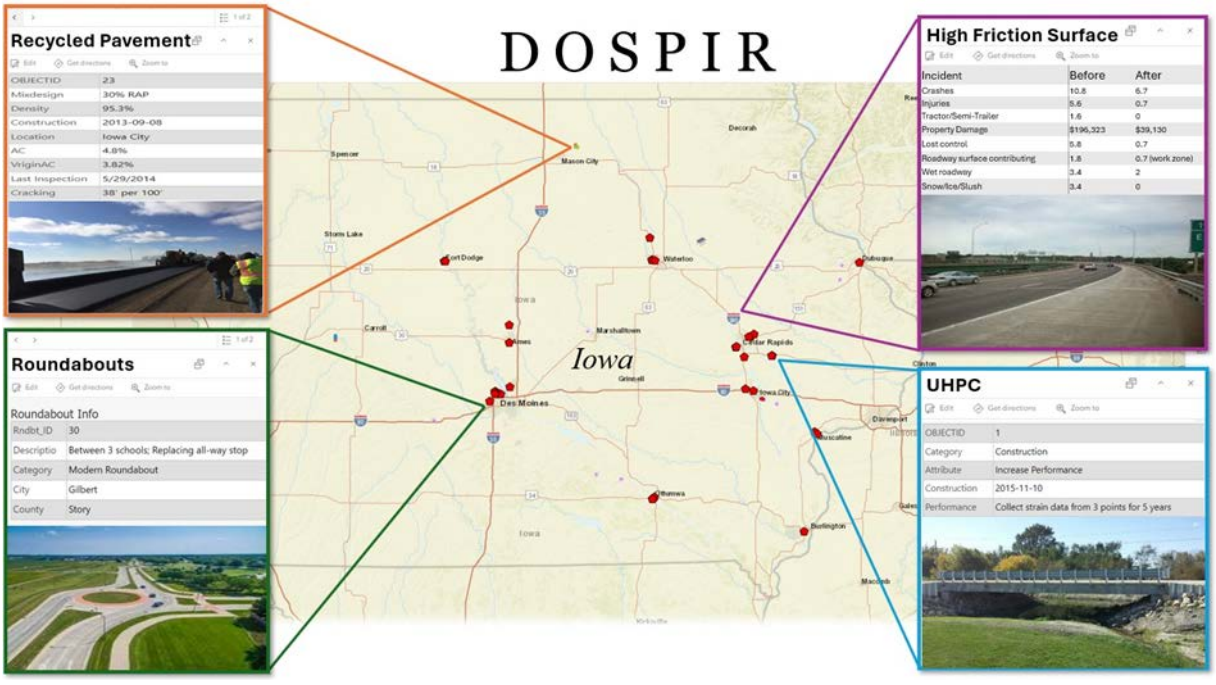


Figure 7-3. Screenshot of DOSPIR on ArcGIS Pro.

7.2.1. Field Conditions of High RAP Test Sections with Different Rejuvenators

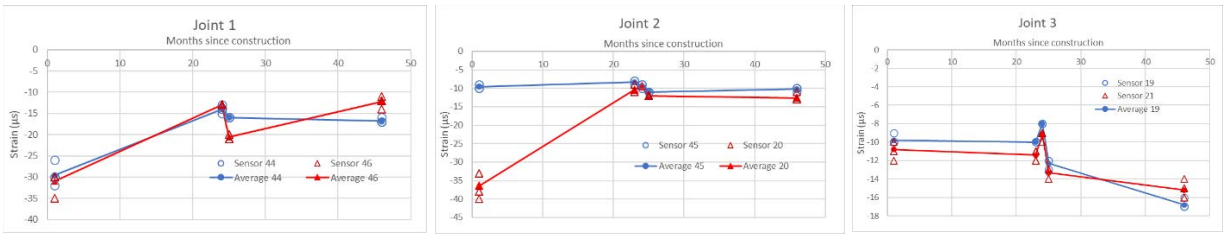
Several high RAP test sections with two different rejuvenators for asphalt mixtures with three different RAP contents have been constructed in Cerro Gordo County in Iowa. As illustrated in the upper-left corner of Figure 7-3, if a user clicks on this test section, DOSPIR will provide information about construction materials, asphalt mat densities, and cracking survey data of three different RAP contents with three different dosages of INVIGOR8 or TUFFTREK rejuvenators (Moon et al. 2022). As can be seen from the upper left corner of Figure 7-3, the field asphalt mat density of a test section of 34% RAP mix with PG58-28S and 3% TUFFTREK constructed on 3 August 2020 was 93.7%.

7.2.2. Characteristics and Performance of High Friction Surface Treatments

During the past decade, high friction surface treatments (HFST) have been applied in nine sections in Iowa. As shown in the upper-right corner of Figure 7-3, each HFST section contains the number of lanes, lane width, applied length, area, AADT, curve length, curve radius, runout length, surface type, and materials. DOSPIR can provide accidents before and after HFST applications, which can be used to determine the effectiveness of HFST if the location of each HFST section is provided.

7.2.3. Strain Database of a Bridge Built using Ultra High Performance Concrete

Recently, a new bridge was constructed using ultra-high-performance concrete (UHPC) in Buchanan County, Iowa (Kim 2021). If a user clicks on the menu item of UHPC in the lower-right corner of Figure 7-3, DOSPIR provides strain data from gauges installed on both sides of three joints over the past five years, along with a picture of a UHPC bridge. As can be seen from plots in Figure 7-4, strain data on the left in blue color and right in red color of each three joints, it can be observed that strain values from both sides of all three joints were not only very small but also very close each other during 47 months since construction, which indicates an excellent joint performance.



(a) Strains at Joint #1 (b) Strains at Joint #2 (c) Joint #3

Figure 7-4. Strain Values from Joints Monitored over 47 Months since Constriction.

7.2.4. Accidents Before and After Construction of Roundabouts

Over the past decade, a total of 110 roundabouts have been constructed in Iowa. As shown in Figure 7-5, a user can draw a circle with a radius of 250ft around the center of a roundabout and collect accident data before and after the construction of the roundabout. As can be seen from Figure 7-6, DOSPIR can then plot an average number of crashes, average damage level, average

severity level, and average monetary value before and after the construction of the roundabout. This is a useful tool to evaluate the effectiveness of a roundabout in reducing the number and severity of traffic accidents.

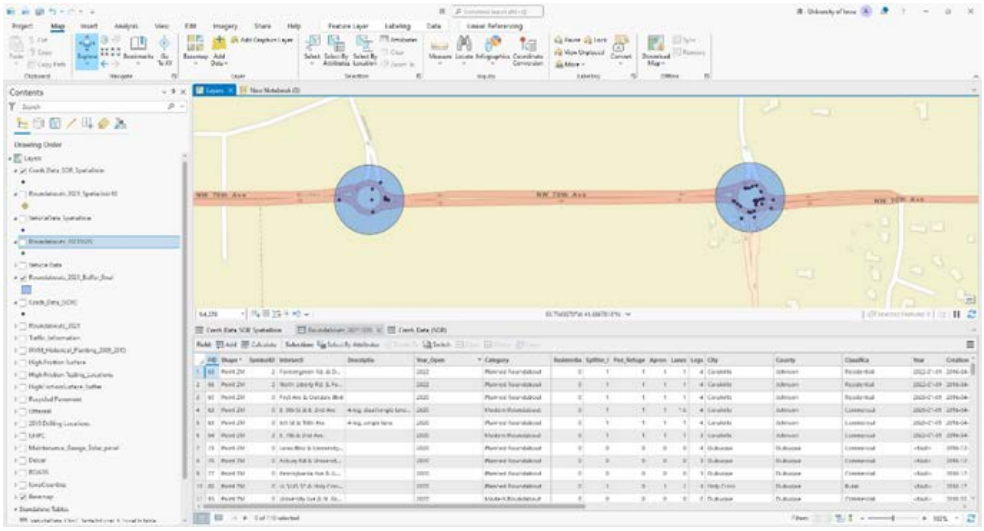


Figure 7-5. Screenshot of DOSPIR's Spatially Joined Roundabout and Accident Data.

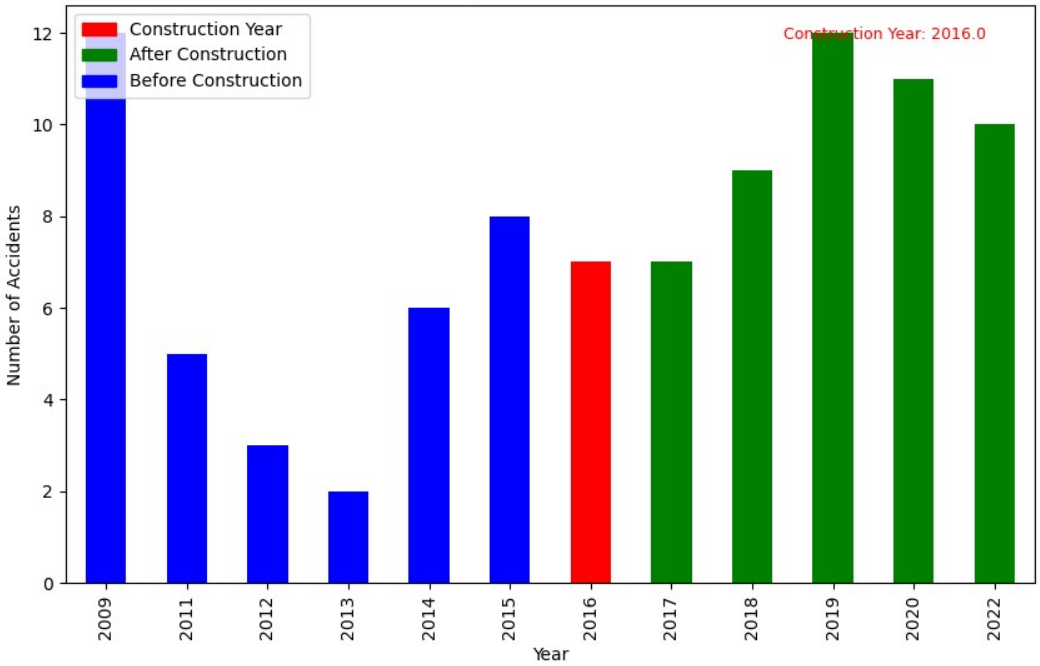


Figure 7-6. Number of Traffic Accidents per Year Before and After a New Roundabout.

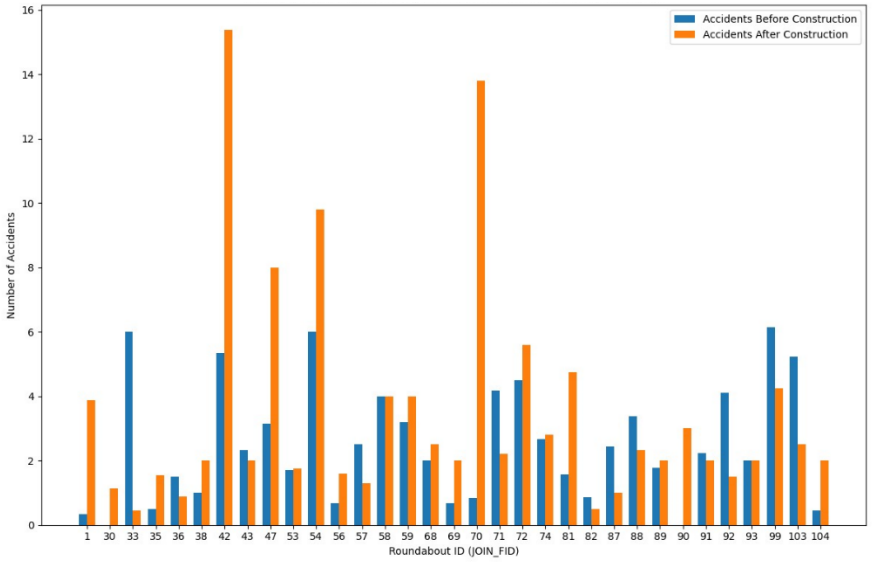
7.3. Spatial and Temporal Analyses of Crashes Near Roundabouts

This section discusses the effectiveness of newly constructed roundabouts through both spatial and temporal analyses of traffic crash data near roundabouts using DOSPIR, developed using Python programming language on the ArcGIS Pro platform. ArcGIS Pro was used to spatially join datasets containing information about roundabouts and traffic incidents, which merged crash data based on geographical coordinates, ensuring that each traffic incident is georeferenced to its nearest roundabout within a 250 ft radius. Subsequently, the amalgamated data was converted into a Pandas DataFrame in Python, which provides a versatile and powerful data structure for handling and analyzing georeferenced crash data.

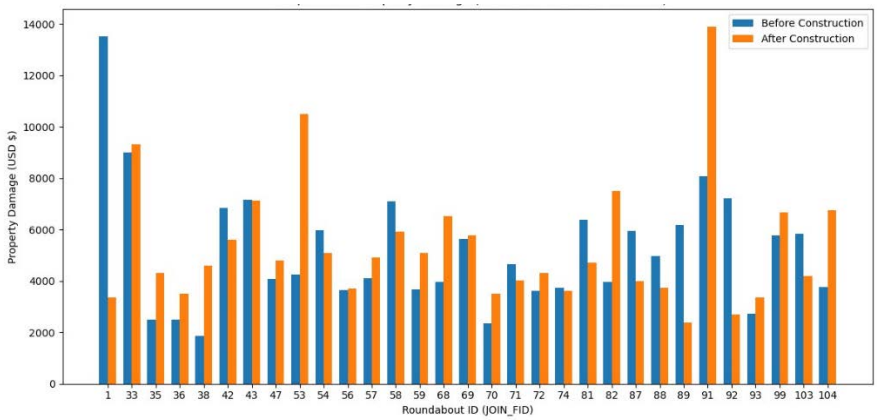
First, locations and times of crashes near newly constructed roundabouts in Iowa were analyzed using a geoprocessing function called "Spatial Join," where the roundabouts and vehicle data layers are combined based on shared geographic locations. To automate ArcGIS Pro's "Spatial Join" function and crash analysis before and after the construction of roundabouts, a computer program was developed using Python in Jupyter Notebook's environment, which is particularly suited to the iterative nature of spatial analysis.

Spatially joined vehicle and roundabout data were saved as a datatype of Pandas DataFrame, which was then used to store and manipulate data. The spatially joined data were further processed to remove missing or null values with NaN in the 'Year_Open' field and 77 in the 'Damage' field, which reduced the number of roundabouts from 110 to 69. To ensure the validity of the analysis results, we only included datasets with at least two years of crash data in datasets before and after roundabout construction. As a result, the number of roundabouts was further reduced from 69 to 33.

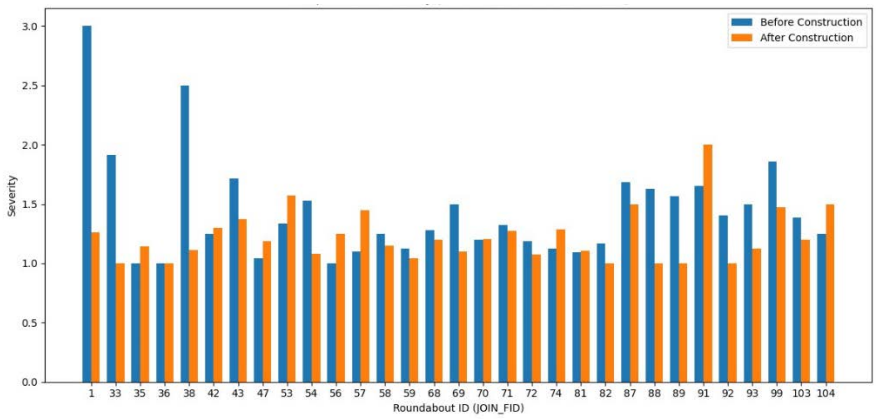
To determine the impact of a new roundabout on traffic accidents, the spatially joined data were then divided into two categories: 'before' and 'after' its construction. To further evaluate the effectiveness of roundabouts, as shown in Figure 7-7, the number of crashes, average damages in dollar amount, and the average severities from 1 (property damage only), 2 (possible/unknown injury), 3 (minor injury) 4 (major injury) to 5 (fatality), are plotted for each of 33 roundabouts side by side. On average, after the construction of 33 roundabouts, the number of crashes has increased from 2.4 to 3.5 crashes per year. It is contrary to the belief that roundabouts would decrease the number of crashes. However, the property damage and severity of crashes have decreased from 1.44 to 1.24 and $5,886 to $5,267 per crash, respectively, which confirms that roundabouts decreased property damage amounts and crash severities.



(a) Number of Crashes



(b) Property Damages



(c) Severity of Traffic Crashes

Figure 7-7. Crash Data Before and After New Roundabout.

8. SUMMARY AND CONCLUSIONS

The transportation sector contributes a significant amount of GHG emissions and, therefore, sustainable practices that reduce the negative environmental impacts of its decisions and operations need to be promoted. Sustainable transportation practices can yield 1) cost savings, 2) increased resource efficiency, 3) reduced environmental impacts, and 4) increased service life. Recent sustainability initiatives emphasize environmental stewardship and ecological preservation at national and local levels.

Sustainability is a concept that has been introduced previously in the design and construction of transportation projects. For example, the need to incorporate recycled materials and locally available materials in pavements has long been emphasized from both economic and environmental viewpoints. The need to incorporate sustainability principles and practices is increasing due to both environmental and economic reasons. It is critical to identify and operationalize sustainability strategies into core administrative, planning, design, construction, operational, and maintenance activities for the transportation infrastructure systems using a comprehensive systems approach and the integration of sustainability in decision-making processes.

Because Iowa DOT is building, operating, and maintaining its transportation infrastructure systems with constrained budgets, there is a critical need to maximize service and performance quality while controlling costs and environmental impact by incorporating sustainability principles and practices in their everyday operations. Recently, to effectively coordinate sustainability efforts within Iowa DOT, the sustainability working group was established.

The primary goal of this study is to develop an implementation plan for achieving more sustainable transportation infrastructure systems for Iowa DOT. This research developed a methodology for identifying the best sustainable practices for implementation in transportation infrastructure practices in Iowa by developing a shelf-ready idea based on identified target areas to be put into practice through small-scale pilot projects.

This research emphasizes the critical importance of integrating sustainability principles into the transportation infrastructure, which not only addresses environmental concerns but also offers economic benefits and enhanced efficiency. By conducting comprehensive surveys from 50 state DOTs and analyzing sustainable practices across various states, we have identified core strategies and approaches that significantly contribute to the development of more sustainable transportation infrastructures. This report presents efforts to identify sustainability goals and practices through surveying 50 state Departments of Transportation (DOTs).

Developing a systemic methodology to find the most appropriate sustainable practices for Iowa's transportation system while improving environmental conditions and reducing the life-cycle cost is one of the most important achievements sought in this study. This report presents a comprehensive study on integrating sustainability in Iowa's transportation infrastructure by developing a database of sustainable practices with implementation records (DOSPIR), which can serve as a central repository of construction, materials, and performance data of sustainable practices, allowing transportation engineers to access past performance data and identify the most appropriate sustainable practices.

As part of this study, the sustainability co-operative rating number (SCORN) was developed to help transportation engineers identify the most appropriate sustainable practices by measuring

the outcome of each sustainable practice with the multiple criteria of cost, performance, and environment. The SCORN was specifically designed for Iowa DOT with relevant sustainability criteria with numerically oriented rating numbers.

Our findings highlight the diverse range of sustainable practices currently in use, such as recycling asphalt pavements, high friction surface treatments, and employing roundabouts for more efficient traffic operations while reducing the severity of traffic accidents. These practices not only promote traffic safety and environmental stewardship but also optimize resource efficiency and cost-effectiveness.

Furthermore, our study reveals that the adoption of sustainable practices in transportation infrastructure is not merely a technical challenge but also requires a change in decision-making processes. Engaging with communities, stakeholders, and incorporating sustainability into strategic planning are essential steps towards achieving this transformation.

In conclusion, the pursuit of sustainable transportation infrastructures is a multifaceted endeavor that necessitates a systemic approach, integrating technical, economic, and environmental perspectives. The insights gained from this study provide a roadmap for Iowa DOT and local public agencies to effectively implement sustainable practices. As the transportation sector continues to evolve, embracing sustainability will be crucial in ensuring that it contributes positively to our environment and society.

9. FUTURE STUDIES

1. Prototype SCORN on a small scale should be expanded to include and refine rating criteria after adjusting their relative weights based on normalized performance metrics so that the effect of meeting or not meeting sustainability targets could be appropriately quantifiable. Therefore, the prototype SCORN should be upgraded to allow users to obtain measurable outputs, such as how much sustainability impacts can be achieved in a measurable unit, i.e., a percent reduction in energy use by adopting more sustainable practices.

2. To become more effective, the prototype DOSPIR should be expanded to incorporate more sustainable practices with historical data and their GIS locations.

3. Both SCORN and DOSPIR should be made available for all employees and stakeholders of Iowa DOT and local publica agencies where they can give feedback for further improvements.

4. It is recommended that the research team would interview the top management of Iowa DOT and local public agencies to assess their perception and support for sustainability efforts with encouragement to provide incentives for sustainable practices and possibly creating a separate sustainability office that can lead and oversee sustainability efforts by encouraging more sustainable practices, including the enhancement and implementation efforts of SCORN and DOSPIR.

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APPENDIX A. AASHTO SWG SURVEY ANALYSIS

The Appendix #1 below contains all information presented during the TAC meeting on March 27th including analysis of the AASHTO SWG working group survey. In consideration of AASHTO survey results, the Iowa survey was prepared and sent out for more targeted feedback directed at states which provided the most responses to the AASHTO survey.

Sustainability Survey Statement by AASHTO:

"In 2016, after adopting a new committee structure, AASHTO created the Committee on Environment & Sustainability (CES). This change reflected the growing importance and consideration of sustainability among AASHTO members. In 2020, CES established the Sustainability Working Group to begin integrating "sustainability" — which includes efforts to address climate change; reduce energy use, water use, and CO_2 emissions; and increase resilience — into the work of CES and other relevant AASHTO committees. To inform these efforts, the Working Group is conducting a survey of AASHTO members to better understand how state DOTs are managing their operations, programming, and other work related to sustainability. This survey will help the Working Group determine professional development opportunities, useful resources and tools for members, and possible partnerships both within and beyond AASHTO."

Executive Summary:

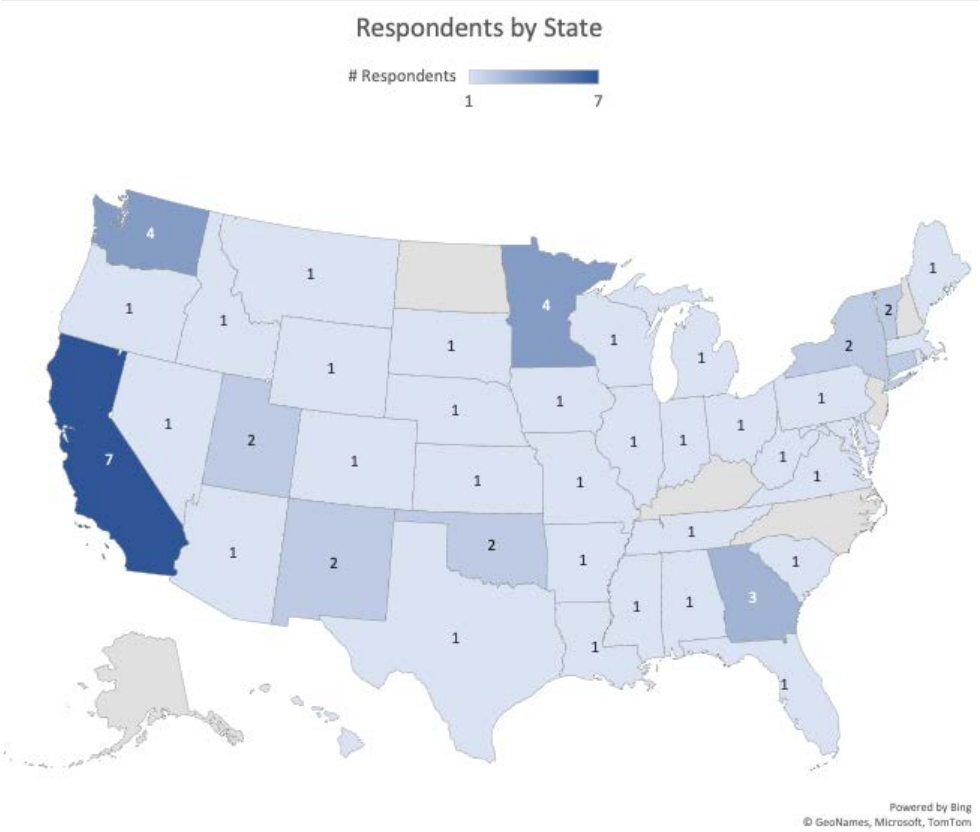
This survey consisted of 22 questions, a combination of open-ended questions and multiple choices. This survey was sent to AASHTO CES, which has over 118 members from 50 states and Washington D.C. As of today, AASHTO received responses from 44 states, where some states included multiple responses across departments. Particularly, surrounding states of Minnesota and Wisconsin have existing policies and planning operations to pursue the integration of sustainability in their transportation infrastructure networks. Our research team summarized the AASHTO survey results.

Number	Question
1	Please provide your contact information below. (Name, Agency or Organization, State, Email Address)
2	Has your state DOT adopted a definition of "sustainability"?
3	Using the space below, please provide your state DOT's adopted or in-process definition of "sustainability."
4	Using the space below, please list any topics or activities that you believe should fall under the Working Group's definition of "sustainability."
5	Does your state DOT have a standalone sustainability office or department?
6	Which of the following best describes your state DOT's staffing (including consultants, contractors, or other external staff) as it relates to sustainability?

7	Roughly how many full-time equivalent (FTE) employees (including consultants, contractors, or other external staff) does your state DOT dedicate to working on sustainability? Please express your answer as a number (0.5, 1, 1.25, etc.).
8	Using the space below, please list the office(s) or department(s) in which these staff sit.
9	Does your state DOT have a directive or requirement to address sustainability?
10	Which of the following best describes your state DOT's sustainability directive or requirement?
11	Using the space below, please briefly describe the nature of your state DOT's sustainability directive or requirement.
12	Has your state DOT implemented any formal programs related to sustainability?
13	Using the space below, please describe the formal program(s) that your state DOT has implemented or is in the process of implementing.
14	Which of the following activities is your state DOT currently conducting related to sustainability? Select all answers that apply.
15	Which of the following activities does your state DOT plan to conduct within the next 3-5 years related to sustainability? Select all answers that apply.
16	Using the space below, please describe any performance measures being used to track the progress of these activities and/or your state DOT's progress towards meeting its goals related to sustainability.
17	How does your state DOT provide funding for its programs and/or activities related to sustainability? Select all answers that apply.
18	From where do you receive this funding?
19	Using the space below, please list any resources or tools that your state DOT has found helpful to conducting work related to sustainability (e.g., Invest, Envision, and/or Greenroads).
20	Please indicate the level of support your state DOT's work related to sustainability has from each of the groups below.
21	What messaging has your state DOT utilized to obtain support from agency leadership, other offices within the agency, and/or community stakeholders? Select all answers that apply.
22	Using the space below, please list any desired resources, tools, technical assistance, or other support your state DOT needs to advance its work related to sustainability.

COMPLETE LIST OF SURVEY RESPONSES

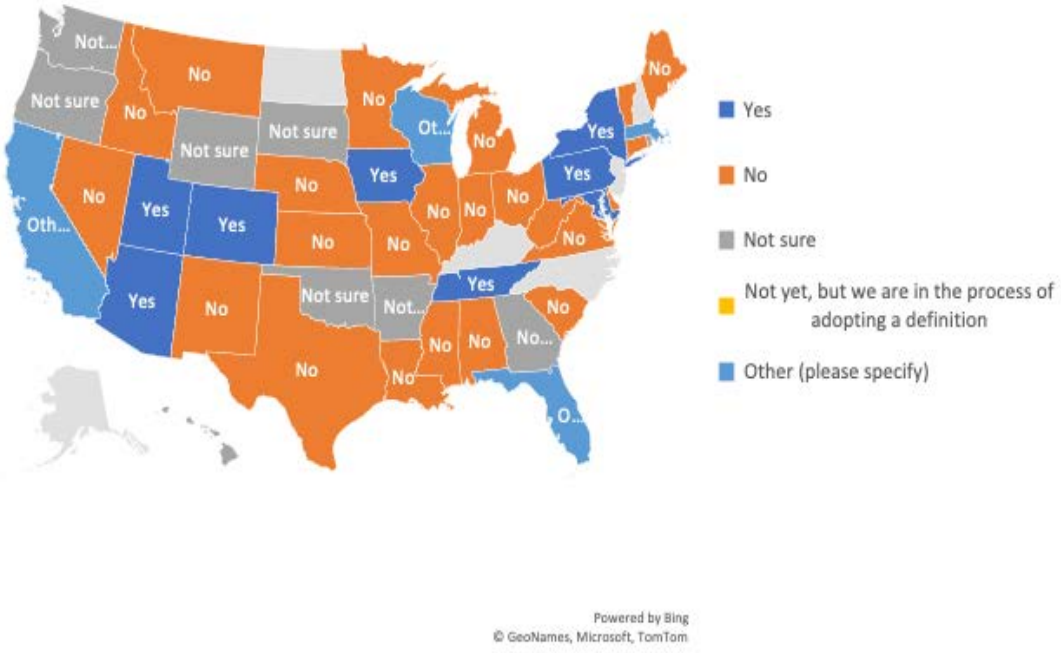
AASHTO Survey Respondents Map across the United States:



Total of 44 responses where 1 response per state has been selected for analyzing.

1 reply	2 replies	3 replies	4 replies	5 replies	6 replies	7 replies
35 states	6 states	1 state	2 states	0 states	0 states	1 state

Question #2: Has your state DOT adopted a definition of "sustainability"?



Has your state DOT adopted a definition of "sustainability"?				
Yes	**No**	**Not sure**	**Not yet**	**Other**
18	**27**	**14**	**1**	**4**
		California		
5	0	1	0	1
		Connecticut		
0	2	0	0	0
		Georgia		
0	2	1	0	0
		Minnesota		
3	1	0	0	0
		New Mexico		
0	1	1	0	0
		New York		
1	0	0	1	0
		Oklahoma		
0	1	1	0	0
		Utah		
1	0	1	0	0
		Vermont		
0	1	1	0	0

Washington				
2	1	1	0	0
Wyoming				
0	1	1	0	0

Has your state DOT adopted a definition of "sustainability"?		
State	**Respondent ID**	**Response**
WisDOT - DTSD - BTS - Environmental Services	12353423744	No official definition yet in WisDOT. However, WI does have Governor Evers Executive Orders: EO 38 (Aug 16, 2019) – Relating to Clean Energy in WI and EO 52 (Oct 17, 2019) – Relating to Creation of Task Force on Climate Change. The WI Dept of Administration (DOA) created an Office of Sustainability and Clean Energy as a result of EO 38 and the UW Nelson Institute/WI DNR supports Executive Orders 38 & 52. See links below: https://evers.wi.gov/Documents/EO%20038%20Clean%20Energy.pdf https://evers.wi.gov/Documents/EO/EO052-ClimateChange.pdf https://doa.wi.gov/Pages/AboutDOA/OSCE.aspx https://wicci.wisc.edu/ - Wisconsin Initiative on Climate Change Impacts (WICCI)
Caltrans - California Dept of Transportation	12359628762 CA	Not so much a definition- but strategic direction "make long lasting, smart mobility decision that improve the environment, support a vibrant economy, and build communities, not sprawl." Other (please specify) Not so much a definition- but strategic direction "ma lasting, smart mobility decision that improve the envir support a vibrant economy, and build communities, not
MassDOT (Massachusetts)	12336537334	MassDOT does not have a formal definition of sustainability that applies to all contexts but the issue areas that are commonly associated with the terms “sustainable” or “sustainability” include GHG emission reduction, climate resiliency, air quality, public health, active transportation, and transit.
Florida DOT	12465787716	While we have not "adopted" a definition, we have a working definition that we are using for our purposes: the ability to meet the needs of the present without compromising the ability of future generations to meet their own needs.

Question #3: Using the space below, please provide your state DOT's adopted or in-process definition of "sustainability."

Using the space below, please provide your state DOT's adopted or in-process definition of "sustainability."		
State	**Respondent ID**	**Response**
MD	12421964669	MDOT Supporting Policy Document 606.4 contains a vision for a "sustainable and multimodal transportation system." Within the Vision Statement, MDOT defines sustainability and supports the definition with a sustainability commitment and goal framework. We sent a copy 606.4 to AASHTO via email.
CO	12414436614	2.1 DEFINITION The most commonly recognized and accepted definitions of sustainability are from: - A White House Council on Environmental Quality Report from 1981 which stated "If economic development is to be successful over the long term, it must proceed in a way that protects the natural resource base...", - The Brundtland Commission of the United Nations in 1987 which stated "development which meets the needs of current generations without compromising the ability of future generations to meet their own needs.", and - The Environmental Protection Agency which explains the concept as "Sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations.". The model and goal of sustainability considers three primary principles: Social, Environmental, and Economic. These principles are evaluated based on the impacts each has on the other with regards to the present and the future.
KS	12413883873	
IL	12413363496	
GA	12408421730	
	12405790884	
	12402223626	
ME	12399546015	
OR	12398522918	
AL	12398447021	
WY	12392148345	
ID	12387018122	
MS	12386161393	
MO	12386055023	
DE	12385993640	
RI	12385984299	
		See link: https://www.dot.ny.gov/programs/greenlites/sustainability A sustainable society manages resources in a way that fulfills the social (community), economic and environmental needs of the present without compromising the needs and opportunities of future generations. A

NY	12385702344	transportation system which supports a sustainable society is one that: Allows individual and societal transportation needs to be met in a manner consistent with human and ecosystem health with equity within and between generations. Is safe, affordable, accessible, operates efficiently, offers choice of transport mode, and supports a vibrant economy. Protects and preserves the environment by limiting transportation emissions and wastes, minimizes the consumption of resources and enhances the existing environment as practicable.
	12374143355	A sustainable society manages resources in a way that fulfills the social (community), economic and environmental needs of the present without compromising the needs and opportunities of future generations. A transportation system which supports a sustainable society is one that: 1. Allows individual and societal transportation needs to be met in a manner consistent with human and ecosystem health with equity within and between generations. 2.Is safe, affordable, accessible, operates efficiently, offers choice of transport mode, and supports a vibrant economy. 3.Protects and preserves the environment by limiting transportation emissions and wastes, minimizes the consumption of resources and enhances the existing environment as practicable.
SD	12383693448	
MT	12383360782	
CT	12382471505	
	12374273231	
MI	12373346114	
IN	12373151332	
TX	12372862762	
AZ	12372826753	Strategically invest resources that recognize the importance of delivering transportation solutions in a more sustainable manner to achieve the State's economic, social, environmental, and intergenerational needs.
WV	12372798674	
LA	12372745768	
IA	12372584304	The system is available and in good condition, meeting the needs of today and in the future.
VA	12372224174	
VT	12362768279	
	12337072319	
NM	12355780857	
	12355711369	
WA	12353673175	Sustainability is a value. Be resource stewards by supporting economic, environmental and community needs. See https://wsdot.wa.gov/about/secretary/strategic-plan/
	12353381334	
	12341044991	I can no longer find it.
	12375931148	

WI	12353423744	There is no singular adopted definition yet by the Department, but there are some broad definitions or descriptions of "sustainability" or sustainability related topics in most of WisDOT's Long-Range Plans for multimodal areas (note -elements of sustainability are embodied in some of the routine NEPA process and/or other Federal Regulations for project development too): https://wisconsindot.gov/Pages/projects/data-plan/plan-res/default.aspx For example: a broad definition is found in the Wisconsin State Rail Plan 2030: https://wisconsindot.gov/Documents/projects/multimodal/rail/plan-chap8.pdf Per Wisconsin Rail Plan 2030 (Chapter 8: Livable and Sustainable Communities, page 8-2): sustainability is defined as supporting growth in a way that does not negatively impact the natural or social environment. Sustainable development supports policies that integrate environmental, economic and social values in decision making. Previously, WisDOT's continued commitment to maintaining and enhancing community livability and sustainability is demonstrated in Connections 2030, the State's long-range multimodal transportation plan. Connections 2030 defined the State's transportation vision as: "...an integrated multimodal transportation system that maximizes the safe and efficient movement of people and products throughout the state, enhancing economic productivity and the quality of Wisconsin's communities while minimizing impacts to the natural environment." While focused at the statewide level, Connections 2030 includes several transportation policies that further define the department's commitment to the continued enhancement of the communities and the transportation system. These policies include: Ensuring system connectivity; Planning and developing a multimodal system; Continuing community sensitive solutions efforts to better integrate transportation projects into communities; Balancing transportation needs with environmental considerations. Similar definitions are expected to be incorporated into the WisDOT Connect 2050 Plan (in-progress): https://connect2050.wisconsindot.gov/ and the 2050 Rail Plan (in-progress): https://wisconsindot.gov/Pages/projects/multimodal/railplan/default.aspx
OK	12346488578	
	12343303953	
SC	12346025628	
NE	12343626137	
OH	12343527019	
CA	12340881716	Make long-lasting, smart mobility decisions that improve the environment, support a vibrant economy, and build communities, not sprawl.
	12340794191	Make long-lasting, smart mobility decisions that improve the environment, support a vibrant economy, and build communities, not sprawl.
	12339908587	Make long-lasting, smart mobility decisions that improve the environment, support a vibrant economy, and build communities, not sprawl.

	12337612173	
	12337443587	“Sustainability” as defined by the Roadmap includes taking action across five target areas: energy efficiency, water conservation, zero-emission vehicles, green operations, and adapting to the anticipated impacts from climate change.
	12359628762	make long lasting, smart mobility decision that improve the environment, support a vibrant economy, and build communities, not sprawl."
	12337666575	Make long-lasting, smart mobility decisions that improve the environment, support a vibrant economy, and build communities, not sprawl.
PA	12338840160	Invest taxpayer money into smart, environmentally sustainable transportation infrastructure in which community benefits and impacts are sought before dollars are allocated.
TN	12338106458	Sustainability is defined as the capacity to endure and for sustainable strategies to be cost-effective. Sustainable transportation involves providing accessibility and mobility in the most efficient and safe manner while being a good steward of public funds and environmental resources. [Green Generates Green, 2018]
HI	12337302726	
MN	12337083267	Sustainability is often referred to as the intersection of economy, environment, and society, which directly aligns with the MnDOT Vision of a multimodal transportation system that maximizes the health of people, the environment and our economy.
	12336865901	This is not exact wording, but our approach incorporates reducing carbon pollution from the transportation sector, increasing operational efficiencies that support Executive Orders (fuel consumption and energy use), improving resilience of the transportation system to climate change and promoting public health in transportation decision making.
	12336427295	
	12355731550	
MA	12336537334	See previous answer
FL	12465787716	A working definition that we are using: the ability to meet the needs of the present without compromising the ability of future generations to meet their own needs.
AR	12453275040	
NV	12413455610	
UT	12453265632	
	12453024447	In developing a Vision Statement for Transportation System in Utah, sustainability was a key component taken into consideration. Working with other stakeholders involved with the Utah Transportation system, a Vision Statement of “Quality of Life” was decided upon. The vision, Quality of Life included four areas, known as the Quality-of-Life

		Framework. These included Good Health, Strong Economy, Better Mobility and Connected Communities.

Question #4. Using the space below, please list any topics or activities that you believe should fall under the Working Group's definition of "sustainability."

Using the space below, please list any topics or activities that you believe should fall under the Working Group's definition of "sustainability."		
State	**Respondent ID**	**Response**
MD	12421964669	See: MDOT Supporting Policy Document 606.4
CO	12414436614	Especially with the increasing focus on GHG tracking and reductions, sustainability activities should be broken by “internal and external" agency actions/impacts. What can the agency complete itself to reduce its impact, and what can the agency complete to reduce external impacts from the public.
KS	12413883873	resilience, adaptation, preservation
IL	12413363496	Meeting the needs of the present without compromising the ability of future generations to meet their own needs
GA	12408421730	none
	12405790884	Using & maintaining existing assets; ensuring assets can withstand extreme weather events
	12402223626	resiliency natural environment human environment climate change
ME	12399546015	energy efficiency, cost-savings, adaptation, advancements, resilience, emissions savings
OR	12398522918	construction materials and best practices; environmental product declarations and lifecycle analysis (more transparency);
AL	12398447021	I think an aspect of risk tolerance needs to be considered when defining sustainability. While a triple bottom line approach sounds fine on the surface, it is easy to over emphasize the more intangible aspects such as societal and environmental. When in fact, these are the more resilient aspects and have proven to be constantly evolving.
WY	12392148345	environmental resources
ID	12387018122	
MS	12386161393	Meeting the needs of the present without compromising the future generations - economy, social, & environment, etc.
MO	12386055023	Soil erosion control for project construction.
DE	12385993640	ensuring long-lasting infrastructure and systems
RI	12385984299	cultural resources
NY	12385702344	NYSDOT's sustainability mission is to fully integrate sustainability into its decisions and practices in planning, designing, constructing, maintaining and operating New York State’s transportation system. Therefore, literally, all activities are

		part of this mission. With the recently passed NYS Climate Leadership and Community Protection Act, reducing greenhouse gas emissions from the transportation sector will be a new focus area. NYSDOT has developed a sustainability program called GreenLITES, which uses checklists for projects, planning, maintenance and operations to instill sustainability approaches across its activities as well as local projects. Link: https://www.dot.ny.gov/programs/greenlites
	12374143355	▪Develop, advocate and advance Department sustainability goals, objectives and strategies through interaction with Main Office and Regional employees, program areas, workgroups and external stakeholders. ▪Incorporate sustainability concepts into the Department's procedures, investments, policies, manuals, specifications, programs, projects and practices. ▪Use the Sustainability Steering Committee as a feedback loop so that constructive participation is vetted through Executive Management. ▪Develop and use sustainability measures and indicators to better manage NYSDOTs internal resources and programs. ▪Facilitate partnerships through sharing of ideas and best practices. ▪Evaluate the costs and benefits (societal, environmental, and economic) of transportation investments over life cycles as well as fiscal cycles.
SD	12383693448	
MT	12383360782	
CT	12382471505	-climate change mitigation -extreme weather resiliency -alternative fuels (EVs, etc.) -renewable energy -energy efficiency -waste and materials management -congestion mitigation and air quality -low impact development -context-sensitive solutions -road safety -public health -active transportation -ride-sharing -public transportation -parking management -complete streets -smart growth -transit-oriented development and other sustainable land use typologies -life cycle cost analysis -benefit-cost analysis
	12374273231	solar and renewable energy use electric vehicle charging /green corridors low/no emissions strategies smart material usage storm resilience planning around critical community needs prioritizing projects with resilience as a factor
MI	12373346114	Recycling pavement and roadway materials Suitability of other recycled materials for roadways
IN	12373151332	roadside management, fuel usage, energy usage, salt/chloride usage for winter operations, recycling, taxation/deposits on disposable materials (i.e., combating littering).
TX	12372862762	Recycling, energy conservation, renewable energy, water conservation, transportation system resilience, sustainable building materials and sources, increasing fleet fuel efficiency,

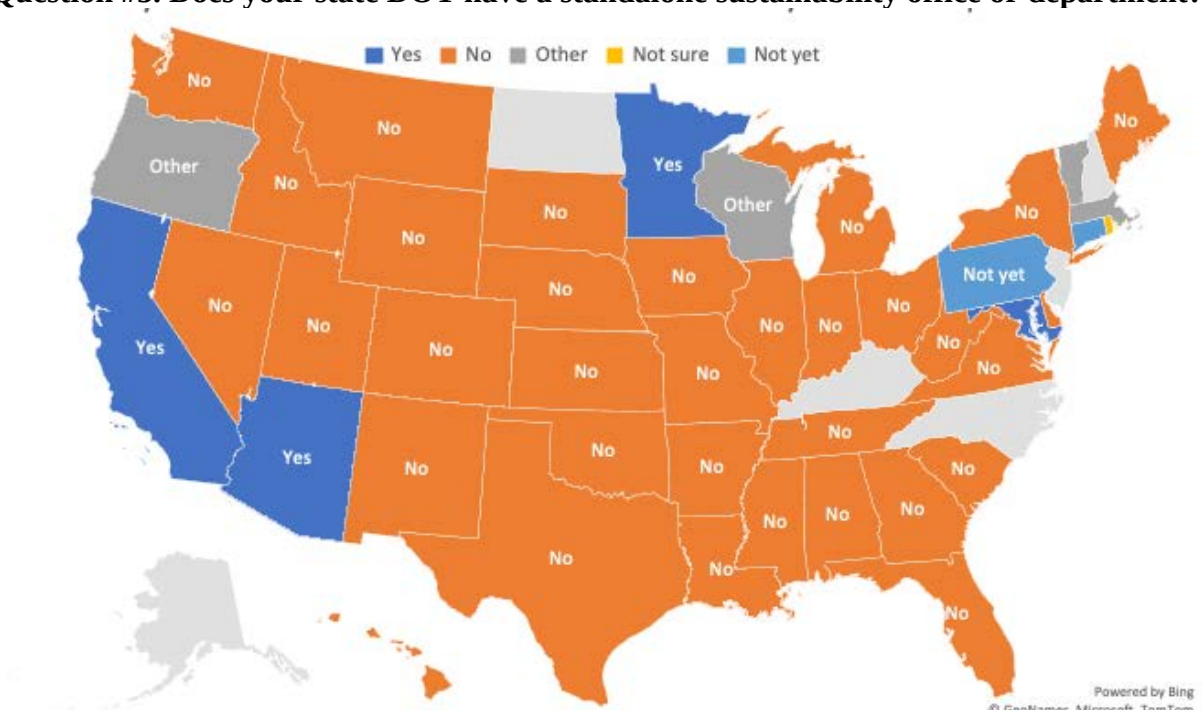
		reducing air emissions, pavement preservation, encouraging land use and transit-oriented development, congestion mitigation, system safety, system connectivity,
AZ	12372826753	Agency core administrative, planning, design, construction, operations, and maintenance activities. Along with transportation specific GHGe, renewable energy, and sustainability policy and legislative needs.
WV	12372798674	
LA	12372745768	sustain a safe and reliable multimodal transportation and infrastructure system
IA	12372584304	Facilities (decrease energy use, deduce waste, conserve water), Fleet (decrease GHG, reduce mileage, electrification), Roadside Management (plant native species, increase snow fences, reduce herbicide), Construction (incorporate recycled materials, porous pavement, fast track concrete overlay), Operations (salt with beet juice, convert to LED bulbs, efficient roundabouts), Resiliency (mitigate flood, manage assets, emergency response), Purchasing (buy sustainable products, consider LCC, employ ProdSI), Planning (transportation and land use, context sensitive solutions, plan HOV lanes), and Indirect Infrastructure (ROW Energy Capture, EV Corridors, Alternative Fuel Charger).
VA	12372224174	resilient infrastructure
VT	12362768279	GHG emissions, wildlife movement, habitat integrity and connectivity, scenery, smart growth (integrated and coordinated planning at the state, county (or region), and local levels, with baseline planning, zoning, and enforcement required everywhere.
	12337072319	GHG emissions, wildlife movement, habitat integrity and connectivity, scenery, smart growth (integrated and coordinated planning at the state, county (or region), and local levels, with baseline planning, zoning, and enforcement required everywhere.
NM	12355780857	Reduction of GHG emissions by reducing VMT; designing and building infrastructure that is resilient and uses sustainable materials
	12355711369	Roadside vegetation management, traffic/infrastructure planning, project design, fleet/vehicles/buildings and grounds.
WA	12353673175	Reducing pollution; increasing energy and resource efficiency; enhanced resilience to disruptions (natural disasters, climate change, pandemics, operational threats)
	12353381334	Any items dealing with the intersection of the environment, economy, and equity when it comes to decision making.
	12341044991	Addressing climate change, taking care of the environment, addressing equity, responsibly investing the public's investments in our infrastructure.
	12375931148	lifecycle cost.
WI	12353423744	WisDOT MAPPS (Mobility, Accountability, Preservation, Safety, and Service) Metric: Preservation – Material Recycling

		(including participation in WDNR NR-538 beneficial reuse of high-volume industrial byproduct in embankments or construction fill and/or construction specifications for pavements and geotechnical fill): https://wisconsindot.gov/Pages/about-wisdot/performance/mapss/goalpreservation.aspx https://dnr.wisconsin.gov/topic/Waste/Beneficial.html Road Salt Storage and Use Reduction (protection of groundwater resources): see description and links in the WI Groundwater Coordinating Council Annual Report to the Legislature (WisDOT is a member) and subsequent WisDOT Link: https://dnr.wi.gov/topic/groundwater/documents/GCC/AgencyActivities/DOTactivities.pdf https://wisconsindot.gov/Pages/doing-bus/local-gov/hwy-mnt/winter-maintenance/rd-slt-strg.aspx Congestion Mitigation and Air Quality Improvement program https://wisconsindot.gov/Pages/doing-bus/local-gov/astnce-pgms/aid/cmaq.aspx Vehicle Emission Requirements and Testing (Federal Clean Air Act): https://wisconsindot.gov/Pages/dmv/vehicles/rnew-plts/emissiontest.aspx Variety of likely others topics or activities include: Climate change in general and greenhouse gas emission reduction/quantification; multimodal transportation; EV corridors; resiliency (structural & nature based); water use; sustainable procurement; density-focused development; next-gen biofuels; green infrastructure and nature-based resiliency (e.g., wetland restoration focused on flood attenuation and groundwater recharge, native prairie or other ROW vegetation with a focus on stormwater management/erosion control/groundwater recharge); asset management of infrastructure; environmental justice including multimodal pedestrian safety and mobility; pollinator corridors; connected and automated vehicle (CAV) technology; beneficial use of dredge sediment (BUDS); and restricted beneficial use of built environment low level contaminated soil in Transportation ROW (and/or with connected brownfield redevelopment).
OK	12346488578	R/W land use Transit options
	12343303953	Construction, Planning, Maintenance
SC	12346025628	Any activities related to developing and maintaining our state's road network that promote/protect the natural environment in the long term.
NE	12343626137	recycled material uses in new highway construction, "green" infrastructure to support changing transportation patterns and technology, clean air, hazard (flood/storm damage) mitigation/planning.
OH	12343527019	

CA	12340881716	Advance zero emissions vehicles; reduce VMT; champion bike, walking and transit; prepare for climate change and adaptation; race and equity.
	12340794191	Preservation of existing natural environment whenever possible.
	12339908587	
	12337612173	
	12337443587	climate change, emissions/air quality, energy efficiency, active transportation/multi-modal, sea level rise, materials conservation
	12359628762	
	12337666575	Reduce VMT Reduce unfunded liabilities including maintenance A network approach to transportation Bike-able and walk-able communities, safe routes
PA	12338840160	construction, design, maintenance, fleet,
TN	12338106458	Use of recycled materials in construction, retrofitting fleets to reduce vehicle emissions, investing in multi modal infrastructure to provide more transportation options to the public, or other sustainable practices that feasible, cost-effective and provide long-term value in Tennessee.
HI	12337302726	Climate Adaptation Resilience Environmental Mitigation
MN	12337083267	
	12336865901	GHG reduction, equity, public health, system-wide and operationally
	12336427295	
	12355731550	I think the sustainability "doughnut" is the best I've seen. https://www.kateraworth.com/doughnut/ https://en.wikipedia.org/wiki/Doughnut_(economic_model)
MA	12336537334	The working group should consider what impacts or end points it wants to be included within scope. A broader definition that includes financial and social aspects of sustainability could result in overlaps with existing efforts. If the focus is just on environmental sustainability, then I would focus on GHG emissions, criteria pollutant emissions/air quality, climate resiliency/vulnerability, water quality and noise impacts and on the equity, implications associated with these issues. A broader definition of sustainability would probably need to include factors that include accessibility, safety/crash risk, affordability, fiscal sustainability of DOTs, public health impacts associated with active transportation or lack thereof, economic tradeoffs between use of capital for transportation vs other societal processes, and the intersection between housing needs and the transportation system.

FL	12465787716	Managing resources efficiently, identifying ways to reduce any negative impacts of transportation on the environment (both natural and human), using recycled materials and products.
AR	12453275040	
UT	12453265632	
	12453024447	1. Good Health - encompasses the health of individuals and communities, recognizing the role of active transportation in mental and physical health as well as environmental conditions contributing to health such as air quality and water quality. 2. Strong Economy - recognizes the vital role of transportation in business and commerce. 3. Better Mobility - addresses traditional transportation objectives to move people and reduce delay. 4. Connected Communities - points to the intersection of transportation and land use as well as the need for intermodal connections between walking, biking, transit and vehicle travel.
NV	12413455610	Environment

Question #5. Does your state DOT have a standalone sustainability office or department?

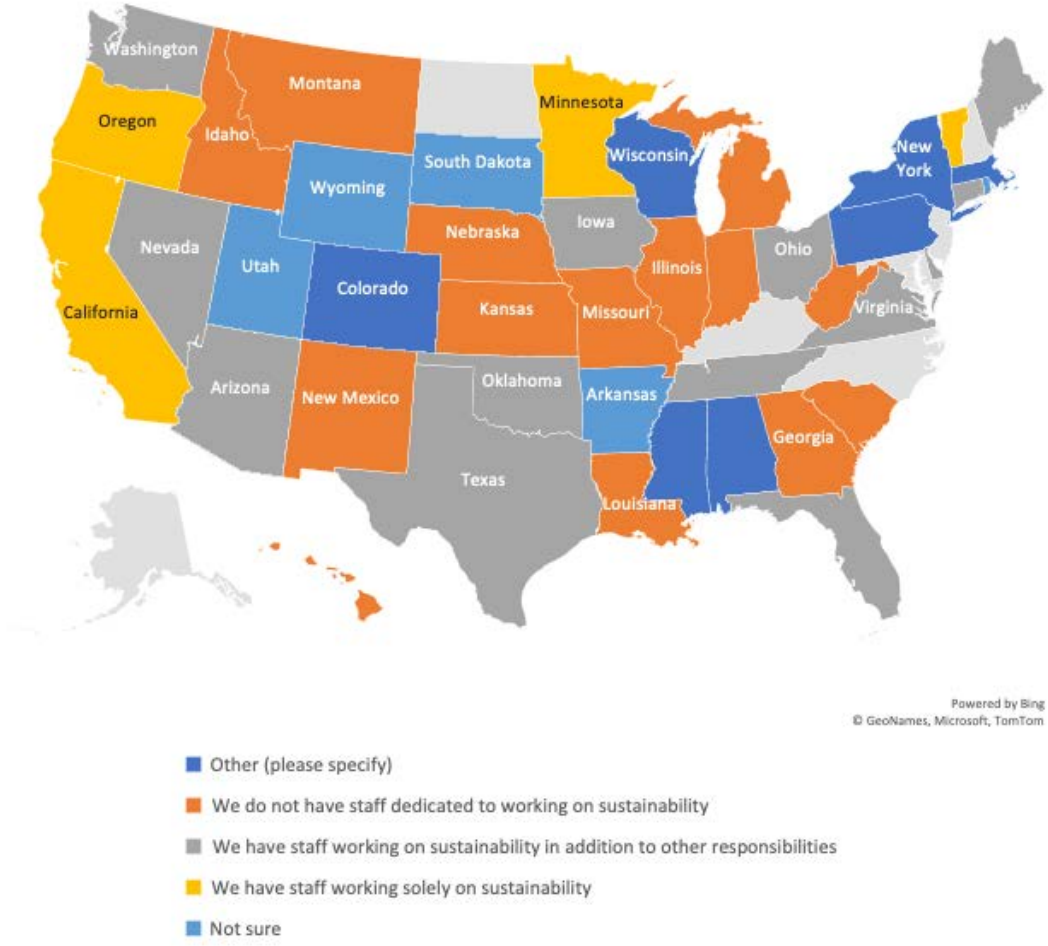


Does your state DOT have a standalone sustainability office or department?			
State	**Respondent ID**	**Response**	**Other (please specify)**
MD	12421964669	Yes	
CO	12414436614	No	
KS	12413883873	No	

IL	12413363496	No	
GA	12408421730	No	
	12405790884	No	
	12402223626	No	
ME	12399546015	No	
OR	12398522918	Other	Climate Office, which incorporates sustainability with climate mitigation and adaptation.
AL	12398447021	No	
WY	12392148345	No	
ID	12387018122	No	
MS	12386161393	No	
MO	12386055023	No	
DE	12385993640	No	
RI	12385984299	Not sure	
NY	12385702344	No	
	12374143355	Other	We have individuals within several offices that have a substantial focus on issues of sustainability
SD	12383693448	No	
MT	12383360782	No	
CT	12382471505	Other	Not yet, but we are in the process of creating a standalone sustainability office or department
	12374273231	Other	Not yet, but we are in the process of creating a standalone sustainability office or department
MI	12373346114	No	
IN	12373151332	No	
TX	12372862762	No	
AZ	12372826753	Yes	
WV	12372798674	No	
LA	12372745768	No	
IA	12372584304	No	
VA	12372224174	No	
VT	12362768279	Other	We have an Environmental Policy Manager (me), but the position is understaffed and not adequately integrated into the agency.
	12337072319	No	
NM	12355780857	No	
	12355711369	No	
WA	12353673175	Other	No. Sustainability is woven throughout the agency via strategic plan and Sec. Millar's Executive Order
	12353381334	No	
	12341044991	Yes	
	12375931148	No	
WI	12353423744	Other	No standalone sustainability office. Some sustainability themes are sprinkled throughout the organization (Divisions and Bureaus) and in some

			staff descriptions and activities. Some examples include: Planning Group (sustainability); Project Development Group(flood resiliency); Structures Group (flood resiliency); Environmental Group (nature-based resiliency w/stormwater management, ecological/wetland restoration, NEPA, environmental justice); DMV (emissions testing); Materials Group (beneficial use of high-volume industrial by-product including pavement construction specifications among others & and beneficial use of dredge sediment); Multimodal Planning & Project Groups (Rails/Harbors/Transit/Airports/Highways); and Agency Asset Management Group (transportation system health, investment $, and performance longevity): https://wisconsindot.gov/Documents/projects/multimodal/tamp.pdf
OK	12346488578	No	
	12343303953	No	
SC	12346025628	No	
NE	12343626137	No	
OH	12343527019	No	
CA	12340881716	Yes	
	12340794191	Yes	
	12339908587	Yes	
	12337612173	Not sure	
	12337443587	Yes	
	12359628762	Yes	
	12337666575	Yes	
PA	12338840160	Not yet	
TN	12338106458	No	
HI	12337302726	No	
MN	12337083267	Yes	
	12336865901	Yes	
	12336427295	Yes	
	12355731550	Yes	
MA	12336537334	Other	We have staff working on sustainable transportation/sustainability/sustainable mobility issues, but they are not concentrated in one branch or division of the agency.
FL	12465787716	No	
AR	12453275040	No	
UT	12453024447	No	
	12453265632	No	
NV	12413455610	No	

Question #6. Which of the following best describes your state DOT's staffing (including consultants, contractors, or other external staff) as it relates to sustainability?



Note: Iowa has staff working on sustainability in addition to other responsibilities

Which of the following best describes your state DOT's staffing (including consultants, contractors, or other external staff) as it relates to sustainability?			
State	**Respondent ID**	**Response**	**Other (please specify)**
MD	12421964669	We have staff working solely on sustainability	
CO	12414436614	Other (please specify)	We have recently hired a full-time employee focused on GHG & Climate, not Sustainability as a whole. If you include the new GHG FTE CDOT is at ~1.5.
KS	12413883873	We do not have staff dedicated to working on sustainability	
IL	12413363496	We do not have staff dedicated to working on sustainability	
GA	12408421730	We do not have staff dedicated to working on sustainability	

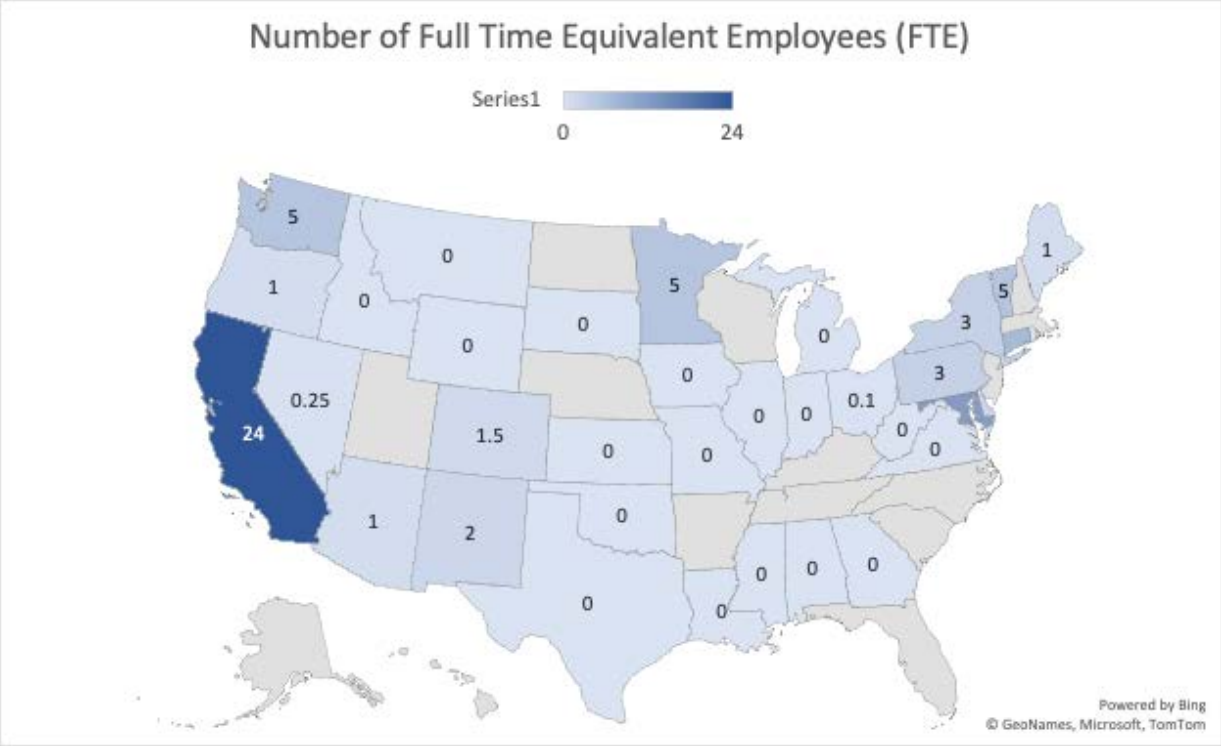
	12405790884	We do not have staff dedicated to working on sustainability	
	12402223626	We do not have staff dedicated to working on sustainability	
ME	12399546015	We have staff working on sustainability in addition to other responsibilities	
OR	12398522918	We have staff working solely on sustainability	
AL	12398447021	Other (please specify)	We have considerable staff working toward sustainability but have not rebranded under a sustainability label.
WY	12392148345	Not sure	
ID	12387018122	We do not have staff dedicated to working on sustainability	
MS	12386161393	Other (please specify)	Our current staff tries to incorporate sustainability within our normal practices.
MO	12386055023	We do not have staff dedicated to working on sustainability	
DE	12385993640	We have staff working on sustainability in addition to other responsibilities	
RI	12385984299	Not sure	
SD	12383693448	Not sure	
MT	12383360782	We do not have staff dedicated to working on sustainability	
CT	12382471505	We have staff working on sustainability in addition to other responsibilities	
	12374273231	We have staff working on sustainability in addition to other responsibilities	
NY	12385702344	Other (please specify)	Sustainability is the responsibility shared across Department activities.
	12374143355	We have staff working on sustainability in addition to other responsibilities	
MI	12373346114	We do not have staff dedicated to working on sustainability	
IN	12373151332	We do not have staff dedicated to working on sustainability	
TX	12372862762	We have staff working on sustainability in addition to other responsibilities	
AZ	12372826753	We have staff working on sustainability in addition to other responsibilities	

WV	12372798674	We do not have staff dedicated to working on sustainability	
LA	12372745768	We do not have staff dedicated to working on sustainability	
IA	12372584304	We have staff working on sustainability in addition to other responsibilities	
VA	12372224174	We have staff working on sustainability in addition to other responsibilities	
VT	12362768279	We have staff working solely on sustainability	
NM	12355780857	We do not have staff dedicated to working on sustainability	
	12355711369	We have staff working on sustainability in addition to other responsibilities	
WI	12353423744	Other (please specify)	WisDOT does not have staff dedicated to working on sustainability, but there are elements of sustainability ethics/applications in some programs or projects via internal DOT staff or external consultants.
OK	12346488578	We have staff working on sustainability in addition to other responsibilities	
SC	12346025628	We do not have staff dedicated to working on sustainability	
NE	12343626137	We do not have staff dedicated to working on sustainability	
OH	12343527019	We have staff working on sustainability in addition to other responsibilities	
OK	12343303953	We do not have staff dedicated to working on sustainability	
CA	12359628762	We have staff working solely on sustainability	
	12340881716	We have staff working solely on sustainability	
	12340794191	We have staff working solely on sustainability	
	12339908587	We have staff working solely on sustainability	
	12337666575	We have staff working on sustainability in addition to other responsibilities	
	12337612173	We have staff working solely on sustainability	
	12337443587	We have staff working solely on sustainability	

HI	12337302726	We do not have staff dedicated to working on sustainability	
PA	12338840160	Other (please specify)	Different sections on different activities, i.e., converting bus stations to CNG as a multimodal project.
TN	12338106458	We have staff working on sustainability in addition to other responsibilities	
VT	12337072319	We have staff working on sustainability in addition to other responsibilities	
MA	12336537334	Other (please specify)	We have staff working solely on sustainability if we define the term broadly
FL	12465787716	We have staff working on sustainability in addition to other responsibilities	
AR	12453275040	Not Sure	
UT	12453265632	Not Sure	
	12453024447		Everyone involved has a piece of the Vision Quality of Life. Sustainability was a key component considered when developing the Vision for Utah's transportation system. This vision not only includes UDOT, but other stakeholders as well such as MPO's, Cities and Rural systems.
NV	12413455610	We have staff working on sustainability in addition to other responsibilities	
MN	12355731550	We have staff working solely on sustainability	
	12355731550	We have staff working solely on sustainability	
	12336865901	We have staff working solely on sustainability	
	12337083267	We have staff working solely on sustainability	
WA	12341044991	We have staff working on sustainability in addition to other responsibilities	
	12353381334	We have staff working on sustainability in addition to other responsibilities	
	12353673175	We have staff working on sustainability in addition to other responsibilities	

	12375931148	We have staff working on sustainability in addition to other responsibilities	

Question #7. Roughly how many full-time equivalent (FTE) employees (including consultants, contractors, or other external staff) does your state DOT dedicate to working on sustainability? Please express your answer as a number (0.5, 1, 1.25, etc.).



Iowa does not have any FTE employees related to sustainability.

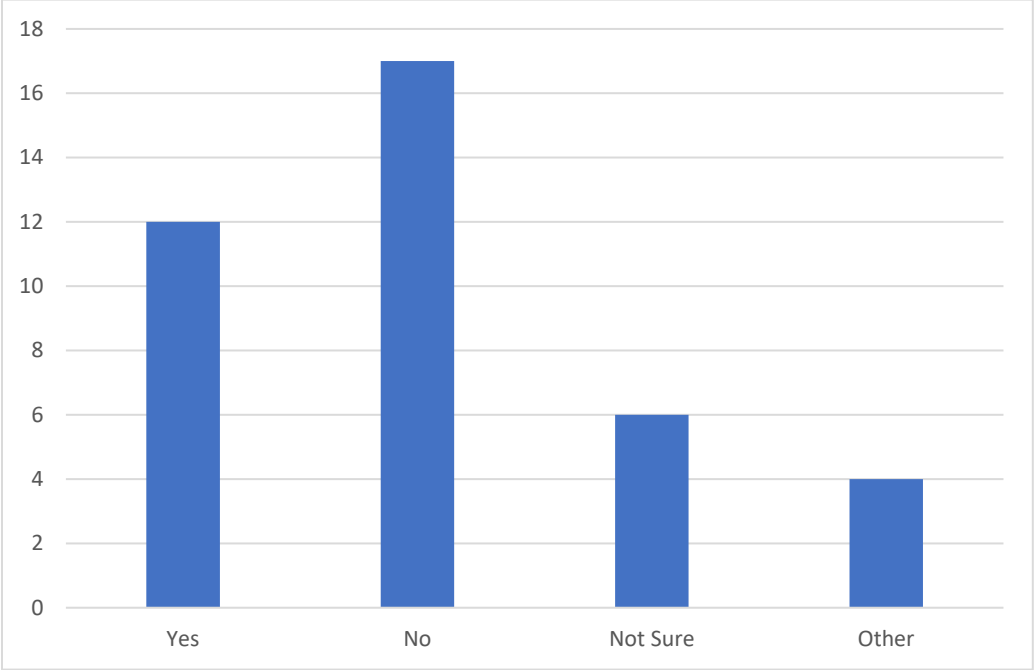
Roughly how many full-time equivalent (FTE) employees (including consultants, contractors, or other external staff) does your state DOT dedicate to working on sustainability? Please express your answer as a number (0.5, 1, 1.25, etc.).			
State	**Respondent ID**	**Number of FTE**	**Using the space below, please list the office(s) or department(s) in which these staff sit.**
MD	12421964669	12	6.0 FTE: MDOT The Secretary's Office Office of Environment 1.0 FTE: MDOT MTA 1.0 FTE: MDOT MAA 1.0 FTE: MDOT MVA 1.0 FTE: MDOT MPA 1.0 FTE: MDOT SHA 1.0 FTE: MDTA
CO	12414436614	1.5	Division of Transportation Development, Environmental Program Branch
KS	12413883873		
IL	12413363496		
GA	12408421730		
	12405790884		
	12402223626		
ME	12399546015	1	Environmental Office
OR	12398522918	1	Climate Office - 7 staff total working on climate related topics.
AL	12398447021		

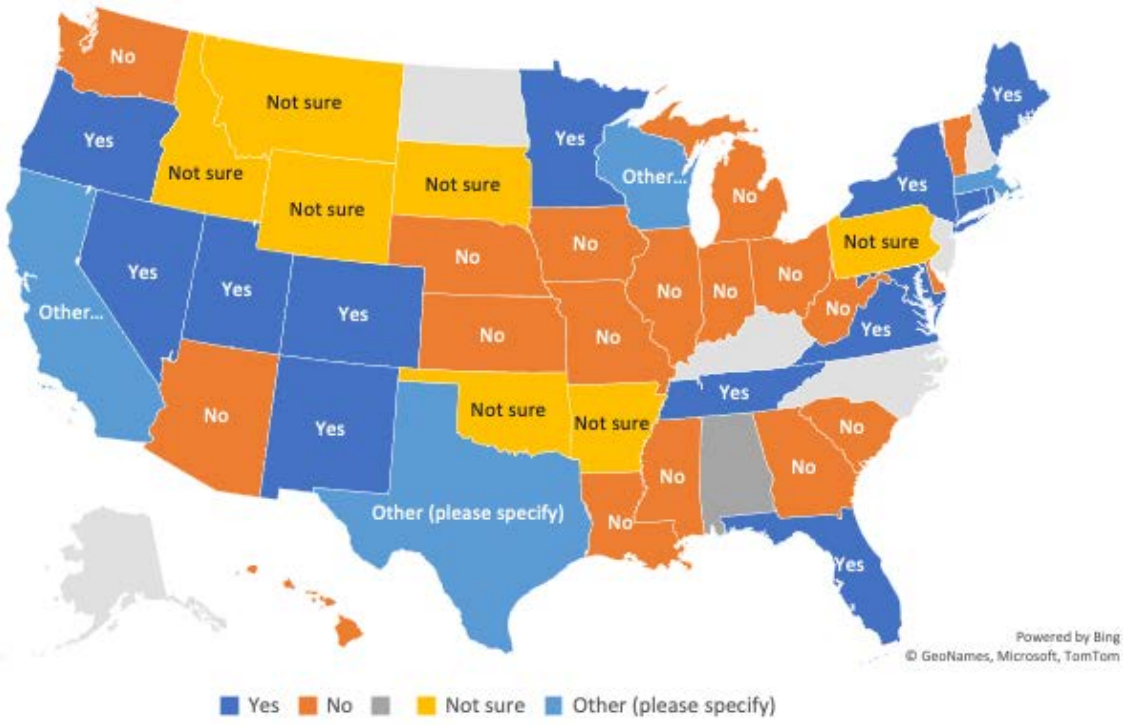
WY	12392148345		
ID	12387018122		
MS	12386161393		Districts & Divisions take sustainability into account during their normal practices.
MO	12386055023		
DE	12385993640	2	ours is across the Department including operations, planning, design, transit, construction
RI	12385984299		
NY	12385702344		NYSDOT has an Asset Management Team that addresses Sustainability. However, the mission of sustainability is shared among a wide spectrum of staff including Headquarters and Regions.
	12374143355	3	Planning, Design, Constructions, Operations
SD	12383693448		
MT	12383360782		
CT	12382471505	7	-Environmental Planning (all units) -Strategic Planning (Policy Unit, Intermodal Planning Unit) -Environmental Compliance -Hydraulics and Drainage -Property & Facilities Services - Facilities Design -Public Transit (Program Management Unit)
	12374273231	1	The new unit will be the Sustainability & Resiliency Unit, in our office of Environmental Planning, in our Bureau of Policy & Planning
MI	12373346114		
IN	12373151332		
TX	12372862762	0	NA
AZ	12372826753	1	Equivalent hours are derived from ENV Planning 75%, Pavement 15%, Project Development 2%, Planning 2%, Operations 6%
WV	12372798674		
LA	12372745768		
IA	12372584304	0	The Iowa DOT Sustainability Working Group currently consists of employees from the Location and Environment Bureau, Systems Planning Bureau, Construction and Materials Bureau, and Iowa DOT District III.
VA	12372224174		
VT	12362768279	5	Policy, Planning, and Research Bureau; Program Development; Maintenance.
NM	12355780857		
	12355711369	2	Planning, Environment, Maintenance, Engineering.
WI	12353423744	0	A variety of staff sprinkled throughout the organization may occasionally participate in a sustainability related theme in their programs or a singular project. See listing: Division of Transportation System Development (DTSD): Bureau of Technical Services (BTS) – Environmental Services and Materials Management Section; Bureau of

			Project Development (BPD); Bureau of Structures (BOS); Bureau of Highway Maintenance (BHM); Bureau of Traffic Operations (BTO); Regional Operations. Division of Transportation Investment Management (DTIM): Bureau of Aeronautics (BOA), Bureau Planning and Economic Development (BPED); Bureau of State Highway Programs (BSHP); Bureau of Transit, Local Roads, Rail Roads and Harbors; Office of Asset & Performance Management. Division of Business Management (DBM): Bureau of Information &Technology Services (BITS); and Bureau of Financial Management (BFM). Department of Motor Vehicles (DMV) – Emissions Inspections Facilities in SE WI non-attainment areas (7 Counties).
OK	12346488578		
SC	12346025628		
NE	12343626137		
OH	12343527019	0.1	Office of Environmental Services, Division of Planning
OK	12343303953		
WA	12375931148	1	Environmental Services, WA State Ferries
	12353673175		All across the agency - sustainability is a value we strive to meet in all business areas
	12341044991	1	Environment, public transportation - these lead our sustainability efforts. Many others are involved in sustainability actions - managing our facilities and fleet for climate reductions, changing our planning practices, improving our equity approaches, etc.
	12353381334	5	Washington State Ferries, WSDOT HQ Environmental Services, WSDOT HQ Facilities
CA	12359628762		We have a dedicated Sustainability office, but there are other staff throughout the department that are working on these topics spread throughout the department. For example- I am located in our Environmental Analysis division focused solely on climate change related topics
	12340881716	1	Primarily in Transportation Planning.
	12340794191	12	Caltrans Directors Office, Sustainability Program
	12339908587		Office of Sustainability
	12337666575		All departments have, at a minimum, a sustainability representative
	12337612173	10	
	12337443587	24	HQ Sustainability Program, District's Division of Sustainability
HI	12337302726		
MN	12337083267	5	Office of Sustainability and Public Health
	12336865901	2	Sustainability and Public Health Division
	12336427295	5	Sustainability and Public Health Division/Office
	12355731550	5	Sustainability and Public Health Division (within DOT)

FL	12465787716		While we have no staff that work solely on sustainability, we have many employees that incorporate sustainability in their day-to-day duties.
AR	12453275040		
UT	12453265632		
	12453024447		All of UDOT
NV	12413455610	.25	Environmental, Traffic Operations
PA	12338840160	3	maintenance, design, planning
TN	12338106458	1	Long Range Planning, Asset Management, Materials and Tests, and Environmental Divisions
MA	12336537334		The Office of the Secretary The Office of Transportation Planning Highway Division – Environmental Services The MBTA – Environmental Affairs The number of FTE would depend on how sustainability was defined. For example, we may have a small amount of FTE working fulltime on resiliency issues, GHG mitigation, air quality, and in-house sustainability issues, but a much larger number working on walking, cycling and transit related tasks because we are a multi-modal transportation agency.
VT	12337072319		Policy and Planning

Question #9. Does your state DOT have a directive or requirement to address sustainability?





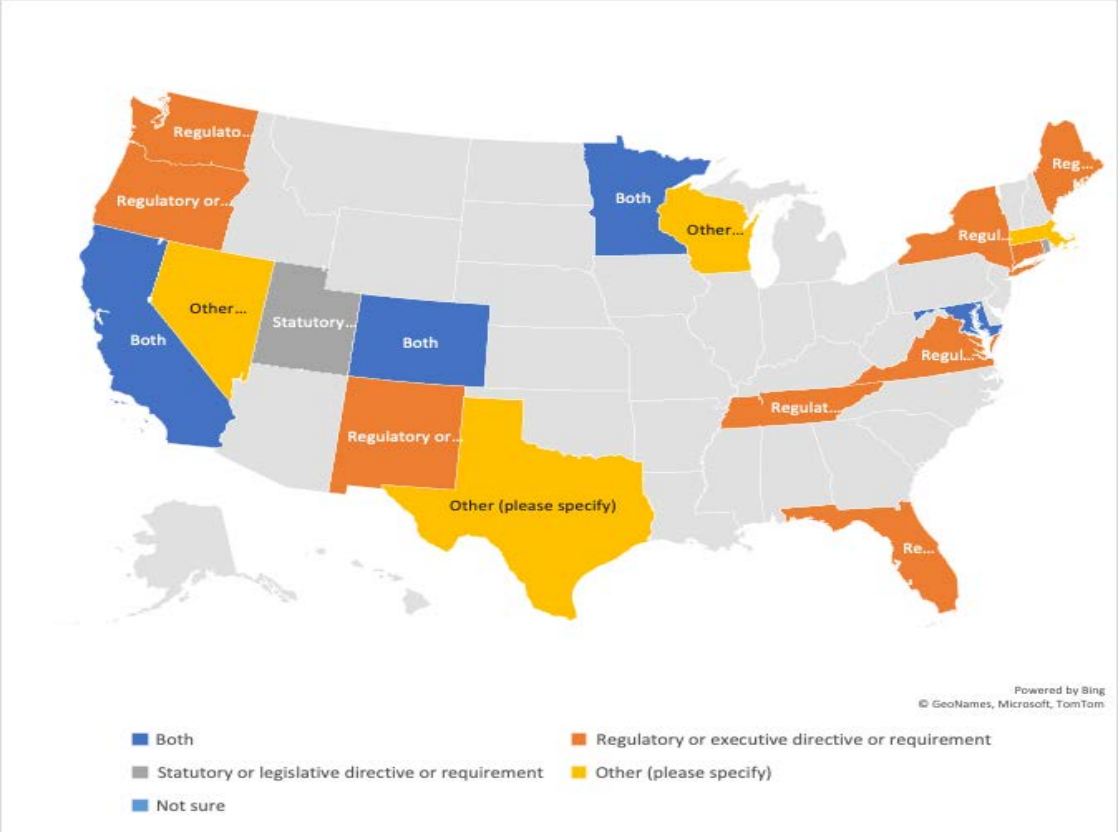
Does your state DOT have a directive or requirement to address sustainability?			
Respondent ID	**State**	**Response**	**Other (please specify)**
12421964669	MD	Yes	

12414436614	CO	Yes	
12413883873	KS	No	
12413363496	IL	No	
12408421730	GA	No	
12405790884	GA	No	
12402223626	GA	No	
12399546015	ME	Yes	
12398522918	OR	Yes	
12398447021	AL		
12392148345	WY	Not sure	
12387018122	ID	Not sure	
12386161393	MS	No	
12386055023	MO	No	
12385993640	DE	No	
12385984299	RI	Yes	
12385702344	NY	Yes	
12383693448	SD	Not sure	
12383360782	MT	Not sure	
12382471505	CT	Yes	
12375931148	WA	No	
12374273231	CT	No	
12374143355	NY	Yes	
12373346114	MI	No	
12373151332	IN	No	
12372862762	TX	Other (please specify)	Although TxDOT does not have a specific directive or requirement related to sustainability TxDOT does include sustainability related concepts within in our official Goals and Objectives statement. These include the following: Foster Stewardship – Ensure efficient use of state resources. • Use fiscal resources responsibly. • Protect our natural resources. • Operate efficiently and manage risk. Optimize System Performance – Develop and operate an integrated transportation system that provides reliable and accessible mobility and enables economic growth. • Mitigate congestion. • Enhance connectivity and mobility. • Improve the reliability of our transportation system. • Facilitate the movement of freight and international trade. • Foster economic competitiveness through infrastructure investments. Preserve our Assets – Deliver preventive maintenance for TxDOT's system and capital assets to protect our investments. • Maintain and preserve system infrastructure to achieve a state of good repair and avoid asset deterioration. • Procure, secure, and maintain equipment, technology, and buildings to achieve a state of good repair and prolong life cycle and utilization. Promote Safety - Champion a culture of safety. • Reduce crashes and fatalities by continuously improving guidelines and innovations along with

			increased targeted awareness and education. • Reduce employee incidents.
12372826753	AZ	No	
12372798674	WV	No	
12372745768	LA	No	
12372584304	IA	No	
12372224174	VA	Yes	
12362768279	VT	No	
12359628762	CA	Other (please specify)	State has legislation for GHG reduction targets and related executive orders
12355780857	NM	Yes	
12355731550	MN	Yes	
12355711369	NM	Yes	
12353673175	WA	Yes	
12353423744	WI	Other (please specify)	No. However, WI does have Governor Evers Executive Orders: EO 38 (Aug 16, 2019) – Relating to Clean Energy in WI and EO 52 (Oct 17, 2019) – Relating to Creation of Task Force o Climate Changes. The WI Dept of Administration (DOA) created an Office of Sustainability and Clean Energy as a result of EO 38. The DOA Office of Sustainability and Clean Energy coordinates with WisDOT among other State & Local Government entities, Native Nations, businesses and other stakeholders. The UW Nelson Institute/WI DNR supports Executive Orders 38 & 52. See links below: https://evers.wi.gov/Documents/EO%20038%20Clean%20Energy.pdf https://evers.wi.gov/Documents/EO/EO052-ClimateChange.pdf https://doa.wi.gov/Pages/AboutDOA/OSCE.aspx https://wicci.wisc.edu/ - Wisconsin Initiative on Climate Change Impacts (WICCI)
12353381334	WA	Yes	
12346488578	OK	Not sure	
12346025628	SC	No	
12343626137	NE	No	
12343527019	OH	No	
12343303953	OK	No	
12341044991	WA	Yes	
12340881716	CA	Yes	
12340794191	CA	Yes	
12339908587	CA	Yes	
12338840160	PA	Not sure	
12338106458	TN	Yes	
12337666575	CA	Yes	
12337612173	CA	Yes	
12337443587	CA	Yes	
12337302726	HI	No	

12337083267	MN	Yes	
12337072319	VT	Not sure	
12336865901	MN	Yes	
12336537334	MA	Other (please specify)	There are a range of requirements on our agency that could be considered related to sustainability. These include regulatory requirements relating to GHGs in transportation planning, regulatory requirements relating to our agency's emissions, and Executive Orders relating to corporate sustainability (e.g. procurement) and climate resiliency and internal goals/strategies that are active or have been completed (e.g. relating to renewable energy production and energy efficiency). These do not necessarily have "sustainability" in their title.
12336427295	MN	Yes	
12465787716	FL	Yes	
12453275040	AR	Not Sure	
12453265632	UT	Yes	
12453024447		Yes	
12413455610	NV	Yes	

Question #10. Which of the following best describes your state DOT's sustainability directive or requirement?



Which of the following best describes your state DOT's sustainability directive or requirement?			
State	**Respondent ID**	**Response**	**Other (please specify)**
MD	12421964669	Both	
CO	12414436614	Both	
KS	12413883873	N/A	
IL	12413363496	N/A	
GA	12408421730	N/A	
	12405790884	N/A	
	12402223626	N/A	
ME	12399546015	Regulatory or executive directive or requirement	
OR	12398522918	Regulatory or executive directive or requirement	
AL	12398447021	N/A	
WY	12392148345	N/A	
ID	12387018122	N/A	
MS	12386161393	N/A	
MO	12386055023	N/A	

DE	12385993640	N/A	
RI	12385984299	Statutory or legislative directive or requirement	
NY	12385702344	Regulatory or executive directive or requirement	
	12374143355	Other (please specify)	Engineering Instructions
SD	12383693448	N/A	
MT	12383360782	N/A	
CT	12382471505	Regulatory or executive directive or requirement	
	12374273231	N/A	
MI	12373346114	N/A	
IN	12373151332	N/A	
TX	12372862762	Other (please specify)	See response to question 8 as it related to TxDOT's goals and objectives statement
AZ	12372826753	N/A	
WV	12372798674	N/A	
LA	12372745768	N/A	
IA	12372584304	N/A	
VA	12372224174	Regulatory or executive directive or requirement	
VT	12362768279		
NM	12355780857	Regulatory or executive directive or requirement	
	12355711369	Other (please specify)	Self-imposed, and in compliance with governor's initiatives
WA	12353381334	Both	WA
	12375931148	N/A	
	12353673175	Regulatory or executive directive or requirement	
	12341044991	Other (please specify)	We have an agency executive order on sustainability. We also have numerous laws in our state requiring action on climate, equity, etc.
WI	12353423744	Other (please specify)	Nonspecific except embedded in some State/Fed Regulations we follow, and some standard practices established long ago (e.g., Pavement Specifications, NR 538 Beneficial Reuse, etc.).
SC	12346025628	N/A	
NE	12343626137	N/A	
OH	12343527019	N/A	
OK	12343303953	N/A	
	12346488578	N/A	
CA	12340881716	Both	

	12340794191	Regulatory or executive directive or requirement	
	12339908587	Not sure	
	12337666575	Statutory or legislative directive or requirement	
	12337612173	Regulatory or executive directive or requirement	
	12359628762	Both	
	12337443587	Both	
HI	12337302726	N/A	
MN	12337083267	Not sure	
	12336865901	Statutory or legislative directive or requirement	
	12336427295	Statutory or legislative directive or requirement	
	12355731550	Both	
FL	12465787716	Regulatory or executive directive or requirement	
AR	12453275040	N/A	
UT	12453265632	N/A	
	12453024447	Statutory or legislative directive or requirement	
NV	12413455610	Other (please specify):	Our Transportation System Management and Operations plan identify fostering sustainability as one of our strategic goals.
PA	12338840160	N/A	
TN	12338106458	Regulatory or executive directive or requirement	
VT	12337072319	VT	12337072319
MA	12336537334	Other (please specify)	Per previous question there is a range of requirements in legislation, regulation, executive orders and directives that could be considered to fall within the umbrella of sustainability.

Question #11. Using the space below, please briefly describe the nature of your state DOT's sustainability directive or requirement.

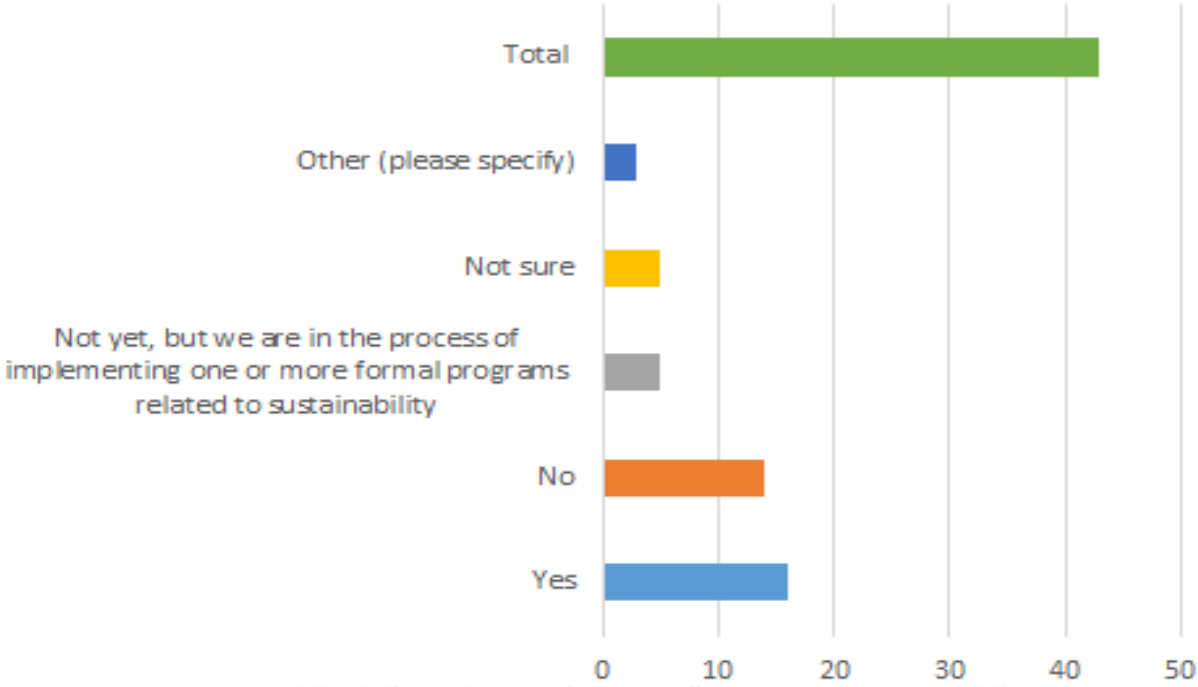
Using the space below, please briefly describe the nature of your state DOT's sustainability directive or requirement.		
State	**Respondent ID**	**Open-Ended Response**
FL	12465787716	We have a policy document from the Secretary on resiliency that strives to maintain our infrastructures sustainability and continued use. We also include goals/strategies in our Florida Transportation Plan that: - Integrate land use and transportation -Develop transportation systems to protect and enhance air quality, water quality and quantity, critical lands, and protect important species habitats.
AR	12453275040	
UT	12453265632	
	12453024447	S.B. 136 directed the Utah Department of Transportation (UDOT) to develop statewide strategic initiatives across all modes of transportation in collaboration with local, regional and statewide partners. Recognizing that Utah's transportation system is owned, maintained and operated by many different entities, UDOT convened a committee of stakeholders at the executive and staff levels in order to develop the statewide vision for transportation. The Stakeholder Committee of executives provided direction for the vision and statewide initiatives. The Technical Committee of staff further developed the statewide initiatives and identified Shared Ideas and Potential Actions for how to achieve the vision. The Stakeholder Committee reviewed goal statements from existing plans and documents in combination with the list of considerations named in S.B. 136, including attention to air quality, return on investment, sustainability and economy.
MD	12421964669	Md. TRANSPORTATION Code Ann. Sec. 2-103.7(c)(2) requires capital funded expansion projects over $5 million to rank the project's impacts on 10 different themes, which include those supporting sustainability. For more information, please view: https://codes.findlaw.com/md/transportation/md-code-transp-sect-2-103-7.html. There is also executive support for implementing a sustainability framework.
CO	12414436614	- Colorado has a Greening of State Government Executive Order that applies to all executive level state agencies. D 2019 016 - Colorado HB 19-1261, Climate Action Plan to Reduce Pollution - The Colorado GHG Pollution Reduction Roadmap is the planning process to achieve goals set in HB 19-1261
KS	12413883873	
NV	12413455610	Develop a sustainable transportation system through sustainable and balanced design, operations, and maintenance.
IL	12413363496	
GA	12408421730	
	12405790884	
	12402223626	

ME	12399546015	Executive Order for State agencies (including DOT) to Lead by Example through energy efficiency, renewable energy, and sustainability measures. DOT is part of the sustainability leadership committee that's developing a baseline of energy use and greenhouse gas emissions for state operations and a plan for meeting the goals.
OR	12398522918	Governor's Executive Orders issued to support and drive specific sustainability strategies within state government operations to addresses the management of internal operations toward sustainability.
AL	12398447021	
WY	12392148345	
ID	12387018122	
MS	12386161393	
MO	12386055023	
DE	12385993640	
RI	12385984299	
SD	12383693448	
MT	12383360782	
CT	12382471505	CSG Section 22a-200a (GHG targets) Governor's Executive Order 1 (state agency lead by example program) Governor's Executive Order 3 (climate change & resiliency) CGS Section 4a-67d (light duty fleet electrification)
	12374273231	
NY	12385702344	All NYSDOT projects (with few exceptions) fill out the GreenLITES checklists, which asks that staff consider sustainable practices in projects, from planning to design and construction as well as maintenance and operations. https://www.dot.ny.gov/programs/greenlites/project-design-cert
	12374143355	We have a "Leeds" type self-certification program known as GreenLITES with a scorecard for sustainability efforts that have been included in project designs that must be submitted with the plans, specifications and estimate for each project. Each is scored and given a rating - certified, silver, gold or the highest, evergreen.
MI	12373346114	
IN	12373151332	
TX	12372862762	See response to questions 8 and 9
AZ	12372826753	
WV	12372798674	
LA	12372745768	
IA	12372584304	
VA	12372224174	
VT	12362768279	
NM	12355780857	Executive Order from the Governor re: climate change
	12355711369	Generally seeking ways to incorporate sustainability into planning, operations and maintenance programs.
WI	12353423744	See #4 and #9 above.
OK	12346488578	

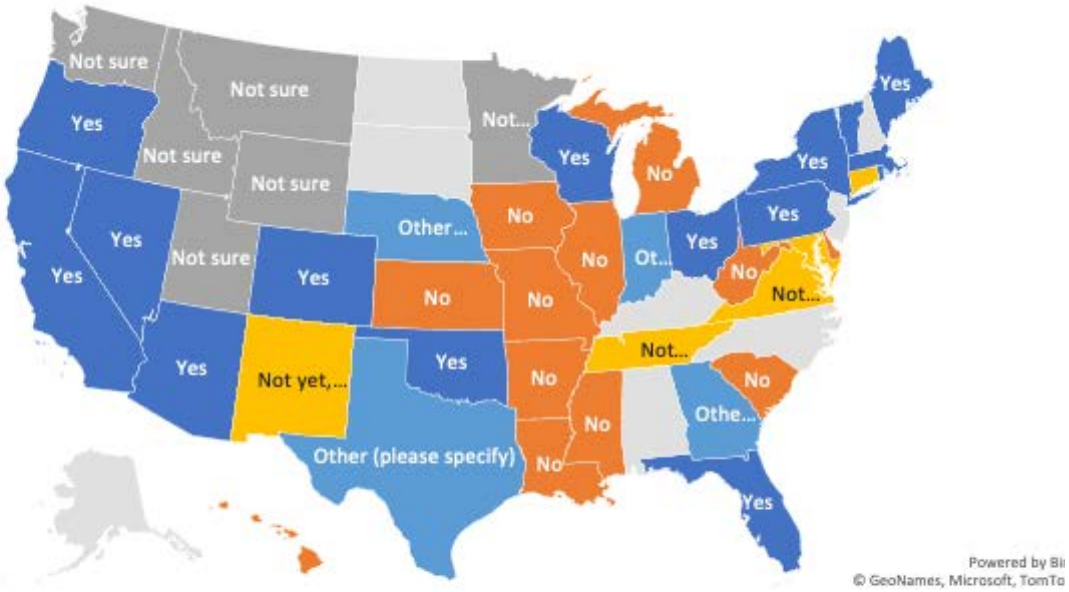
SC	12346025628	
NE	12343626137	
OH	12343527019	
OK	12343303953	
WA	12353381334	We have executive orders from the Governor that include sustainability measures for all state agencies, with special notes for WSDOT. We have legislation that mandates GHG reduction goals for state agencies. We have WSDOT secretary executive orders that made sustainability be incorporated into agency decision making processes.
	12353673175	https://wsdot.wa.gov/sites/default/files/2020/11/05/WSDOT-EO-1113.pdf - Secretary's EO "WSDOT employees are directed to take actions that enhance sustainability through a focus on energy efficiency, pollution reduction, and enhanced resilience."
	12341044991	The sustainability EO focuses on energy efficiency, toxics reduction, and orca whale recovery because these items are not explicitly identified in other agency directives, goals, and strategies.
	12375931148	
CA	12359628762	GHG reduction targets (40% by 2030 and 80% by 2050), multi sector approach, required consideration of life cycle approach
	12340881716	The Sustainability Roadmap 2018-19 is a two-year progress report and action plan for state agencies to implement sustainable practices related to Executive Orders B-16-12, B-18-12, and B-30-15. The Roadmap covers five key sustainability topics that relate to reducing the environmental footprint of our building facilities and day-to-day enterprise operations: Energy conservation Water conservation Green Operations Zero-emission vehicles (focusing on Department fleet and workplace charging for employees) Climate adaptation
	12340794191	Sustainability Roadmap provides guidelines to meet Executive Orders B-16-12, B-18-12, and B-30-15. The Roadmap covers five key sustainability topics that relate to reducing the environmental footprint of our building facilities and day-to-day enterprise operations:
	12339908587	
	12337666575	reduction in energy usage Reduction in VMT ZEV targets Water conservation
	12337612173	It is a part of our Mission Statement and is a Department goal.
	12337443587	At Caltrans, this emphasis on the sustainability of government operations complements the Department's unique mission as the owner/operator of the State Highway System (SHS): "Provide a safe, sustainable, integrated and efficient transportation system to enhance California's economy and livability."
HI	12337302726	
VT	12337072319	
MN	12355731550	State has adopted CO2 targets that apply to all agencies (exec order, etc.), and agency leadership has made it clear it's a priority for staff
	12336865901	The MnDOT vision also supports progress toward the MnDOT originating statute (174.01), specifically related to promoting multimodal, intermodal, HOV and low-emission transportation options and reducing transportation-related GHG. We also work to support the

		Next Generation Energy Act (2007), which established the goal of reducing GHG emissions 15 percent by 2015, 30 percent by 2025, and 80 percent below 2005 levels by 2050 compared to a 2005 baseline.
	12337083267	
	12336427295	Statute 174.01: reduce GHG from transportation. There are also a number of EOs and the agency policy plan that provide direction on sustainability.
PA	12338840160	
TN	12338106458	Sustainability directive referenced in TDOT's 25-Year Long-Range Policy Plan under National Goals and Guiding Principles available on TDOT's website.
MA	12336537334	See previous two answers

Question #12. Has your state DOT implemented any formal programs related to sustainability? (total: total response).



Has your state DOT implemented any formal programs related to sustainability?



Yes

No

Not sure

Not yet, but we are in the process of implementing one or more formal programs related to sustainability

Other (please specify)

Question #13. Using the space below, please describe the formal program(s) that your state DOT has implemented or is in the process of implementing.

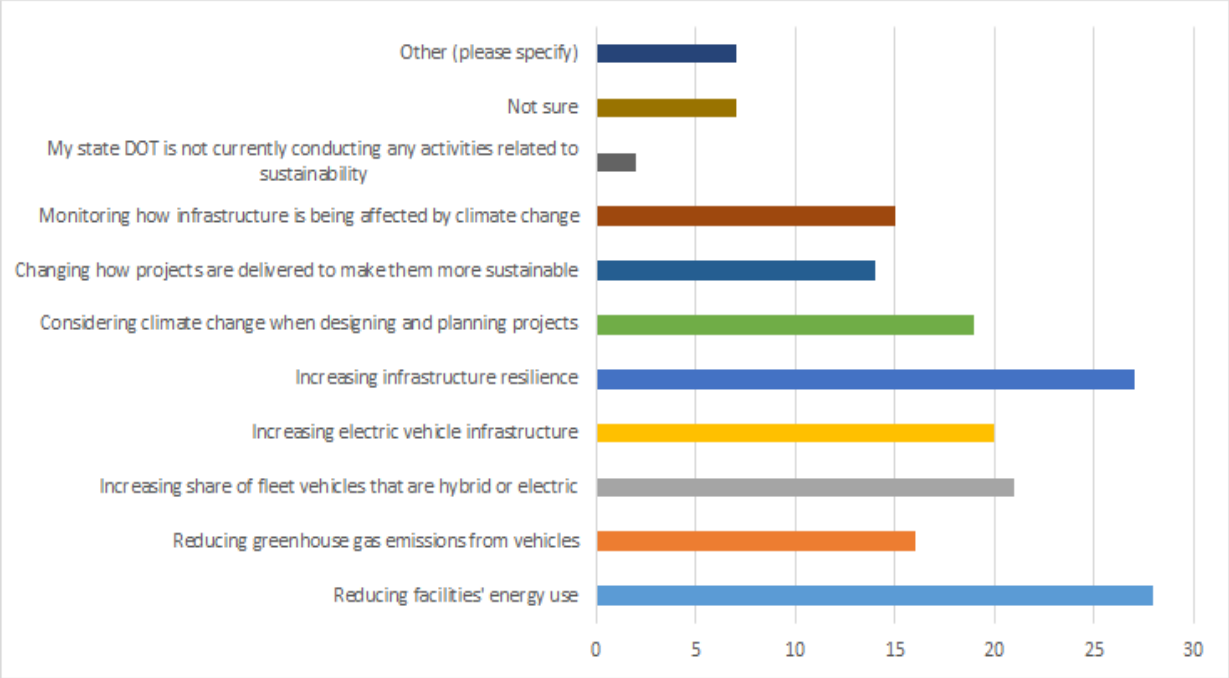
Using the space below, please describe the formal program(s) that your state DOT has implemented or is in the process of implementing.		
State	**Respondent ID**	**Response**
MD	12421964669	
CO	12414436614	CDOT has a Sustainability Program Manager that works throughout the agency towards the Greening Government E.O. goals and CDOT recently hired a full time GHG/Climate Action Specialist.
KS	12413883873	
IL	12413363496	
GA	12408421730	
	12405790884	
	12402223626	
ME	12399546015	Maine DOT has implemented weatherization techniques, LED lights, and installed heat pumps in facilities to save energy. We have an electric vehicle and have installed chargers at all regional offices. We are currently developing a vulnerability assessment that will rank the vulnerability of transportation assets to sea level rise and increased precip. This includes recording maintenance issues. With this information we will be able to increase resilience of our infrastructure.
OR	12398522918	Energy / fuel use; material resource flows (waste / paper use); environmental stewardship (site landscaping / hazardous materials); workforce diversity.
AL	12398447021	
WY	12392148345	
ID	12387018122	
MS	12386161393	
MO	12386055023	
DE	12385993640	
RI	12385984299	Electric trolley pilot program
NY	12385702344	GreenLITES. https://www.dot.ny.gov/programs/greenlites
	12374143355	See answer to #12 - GreenLites self-Certification program awards points for sustainable Design practices in the categories of Sustainable Sites, Water Quality, Materials and Resources, Energy and Atmosphere and Innovation/Unlisted (the latter meaning new proposals not yet anticipated in the scorecard). There is also an Operations certification program: The program encourages Transportation Maintenance, Fleet Administration, Traffic, Safety & Mobility, and Modal Safety and Security to advance "Triple Bottom Line The preceding document link requires Adobe Reader" (AASHTO, Center for Environmental Excellence The preceding external link opens a new browser window) sustainability principals in all aspects of our work.
SD	12383693448	
MT	12383360782	

CT	12382471505	Formal Program: Community Connectivity Program (road safety audits and grants) Not formal programs, but progress towards becoming: - formally inventorying agency's sustainable practices - light and heavy duty fleet electrification - on-site solar energy generation - vulnerability assessments - transit-oriented development - active transportation planning
	12374273231	
MI	12373346114	
IN	12373151332	https://www.epa.gov/sites/production/files/2016-01/documents/13101.pdf
TX	12372862762	
AZ	12372826753	https://azdot.gov/node/5561
WV	12372798674	
LA	12372745768	
IA	12372584304	
VA	12372224174	
VT	12362768279	Vehicle electrification, bike/ped, public transit, wildlife movement, solar net metering, biomass heating.
	12337072319	
NM	12355780857	Adopting Complete Streets policy/guideline, advancing EV infrastructure and use, remodeling buildings to be more efficient and installation of solar panels, conducting a resiliency study
	12355711369	
WA	12353673175	
	12353381334	Washington State Ferries has a Sustainability Action Plan that is an outgrowth of its Long-Range Plan and sets is goals and results each biennium. Washington State Ferries also has an electrification program to transition the fleet from diesel to hybrid electric.
	12341044991	
	12375931148	
WI	12353423744	See #4 with weblinks above, and additional example descriptions below: Asset management- statewide focus has changed from expanding roadways to maintaining existing structures. Framed as a cost-savings measure, but it has positive environmental effects by not expanding capacity, reducing material use, and remaining on existing footprint. 23 CFR 667 process- required to consider resiliency when rebuilding structures that have been washed out three or more times by flood events. Provides additional funding to more robustly rebuild these structures. Multimodal transportation- • USBR 30 and USBR 230: WI's first nationally designated bike route; 269 miles long; consists of state and county trails, local roads and state and county highways • Bus Rapid Transit (BRT) program: will connect downtown Milwaukee with Wauwatosa and Marquette University; received $41 million in federal funds • Twin Cities-Milwaukee-Chicago Passenger Rail Project (TCMC): received $31.8 million grant that will add an additional daily round trip along an existing Amtrak route • Transportation Alternatives (TAP) Program: awarded more than $14 million to enhance state's intermodal transportation system Road salt- reducing the need for salt by increasing use of liquid brine; e.g. reduced salt by nearly 9 million lbs. in Jefferson County (cost savings of over a half million dollars) Wetland restoration and native

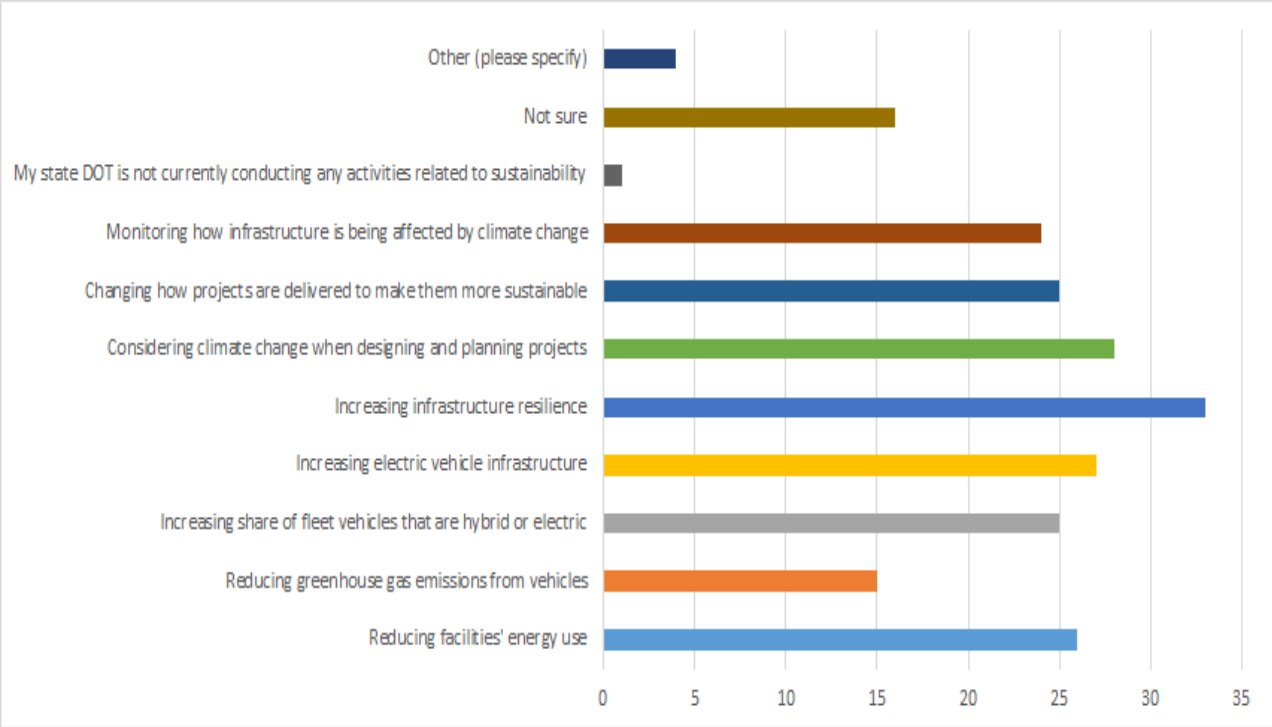
		vegetation improves water quality, provides flood storage/mitigation, provides groundwater infiltration, supports pollinator populations that provide services to farmers • Monarch CCAA, Karner Blue Butterfly, rest area, remnants, wetland sites, native seed mixes, reduced mowing, limited herbicide use • Funding sources: maintenance and project budgets, grants opportunities, Veg Fund (damage claim fund to replace lost trees), public/private partnerships (e.g. Pheasants Forever), dedicated wetland mitigation bank funding.
OK	12346488578	
	12343303953	
SC	12346025628	
NE	12343626137	We have a formal construction materials recycling program that is mostly aimed at reused of paving materials (asphalt millings, crushed concrete for base course material) that is tracked on applicable project plan sheets. Each project cover sheet has a recycle badge and score if applicable.
OH	12343527019	In the early 2010s ODOT investigated and assigned a sustainability lead. This was dissolved after two years
CA	12340881716	
	12340794191	Sustainability Roadmap
	12339908587	Reducing Caltrans' energy usage by 28 percent in 2016 compared to the baseline year — surpassing the 20 percent target required by EO B-18-12 and saving Caltrans approximately $23 million • Reducing facility water use by 38 percent in 2016 compared to 2010; the number is even higher (42 percent) when compared with data from 2013 • Decreasing highway water usage by 67 percent in 2016 compared to 2010 • Surpassing targets for replacing fleet vehicles with zero-emission vehicles under Management Memo 16-07 • Installing LEDs in all Caltrans maintenance stations • Completing construction on Caltrans' first Zero Net Energy pilot building
	12337612173	
	12337443587	
	12359628762	
	12337666575	
PA	12338840160	Pollinator program (formal), repurposing metal bridges, robotic technology in construction, funds for CNG conversion of bus stations...
TN	12338106458	Implementation of sustainability actions identified in Green Generates Green (TDOT, 2018)
HI	12337302726	
MN	12337083267	
	12336865901	Sustainability reporting, Sustainable Transportation Advisory Council, Clean Transportation Pilot
	12336427295	
	12355731550	
AR	12453275040	
UT	12453265632	
	12453024447	
NV	12413455610	TSMO and Environmental review

FL	12465787716	Our aviation office has a guidebook and an annual award for sustainability for airports.
MA	12336537334	MassDOT has a range of programs that target outcomes related to sustainability. Some examples are below: Shared Winter Streets and Spaces Grant Program (active): A program to help municipalities address the particular challenges of winter amid the ongoing public health crisis. Provides cities and towns with grants to improve plazas, sidewalks, curbs, streets, parking areas, and other public spaces in support of public health, safe mobility, and renewed commerce. This builds on an earlier Shared Streets and Spaces program. Complete Streets program (active) - Provides technical assistance and construction funding to eligible municipalities. Eligible municipalities must pass a Complete Streets Policy and develop a Prioritization Plan. Mass RIDES program (completed) – This was an "employer TDM" program that provided employees at member employers with information on commuting options, a guaranteed ride home program, safety item giveaways, and a ride-matching platform. Climate adaptation and vulnerability assessment (active) – Developing a statewide risk assessment for exposure of critical transportation assets flooding and integrating these findings into MassDOT systems and practices. Incorporating GHG impacts into capital planning (active) – Providing technical assistance and guidance to MPOs to ensure that GHG impacts are considered as a criterion in all capital planning and GHG impacts are quantified where practical. Clean Vehicles Program (completed) – A program to subsidize the capital costs of a range of clean vehicle and infrastructure types. Highway Renewable Energy Program (completed) – A program to identify areas of MassDOT right of way suited for development of solar farms and the subsequent development of solar farms in those locations Electric vehicle fast charging infrastructure (active) – Identified locations suited to hosting electric vehicle fast charging infrastructure and funded the construction of these stations. Congestion Mitigation and Air Quality Program (active) – Funding of projects that result in an air quality benefit. These typically include transit service, transit vehicle replacement, walking and cycling infrastructure, bike share, bike parking, and intersection improvements.

Question #14. Which of the following activities is your state DOT *currently conducting related* to sustainability? Select all answers that apply.



Question #15. Which of the following activities does your state DOT *plan to conduct within the next 3-5 years* related to sustainability? Select all answers that apply.



Question #16. Using the space below, please describe any performance measures being used to track the progress of these activities and/or your state DOT's progress towards meeting its goals related to sustainability.

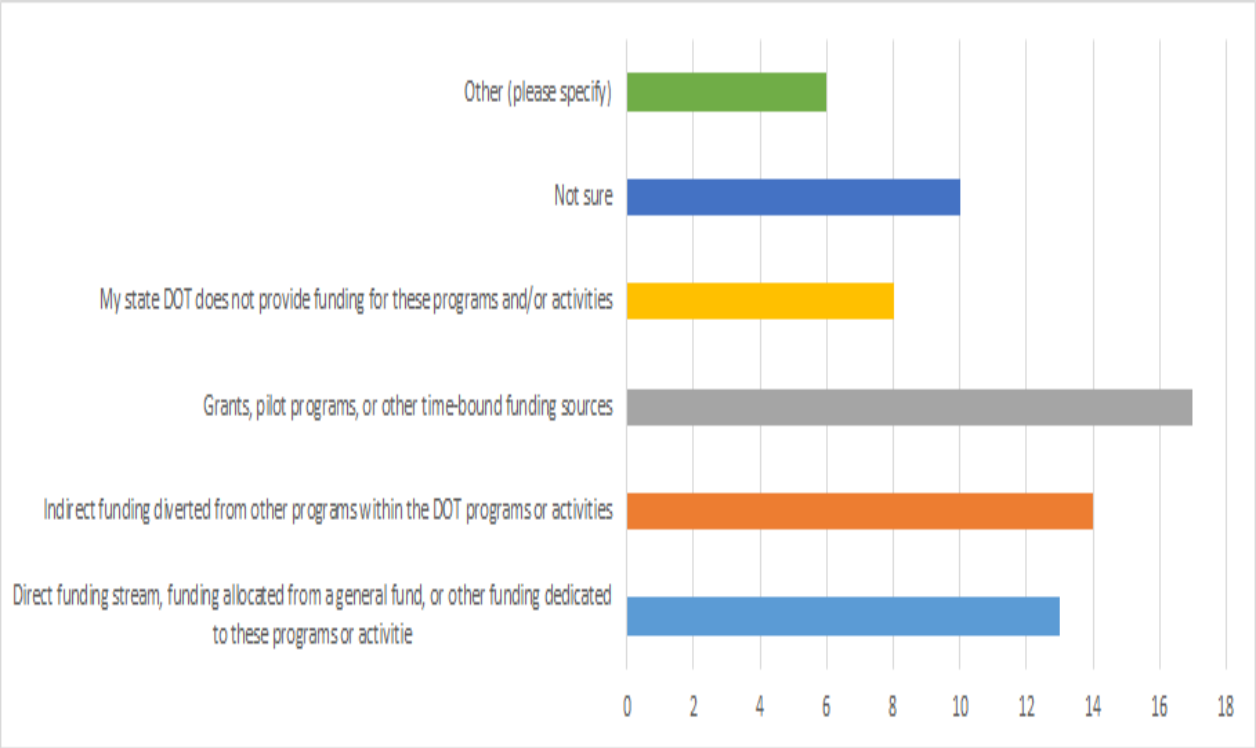
Using the space below, please describe any performance measures being used to track the progress of these activities and/or your state DOT's progress towards meeting its goals related to sustainability.		
State	**Respondent ID**	**Response**
MD	12421964669	Performance measures will be identified in MDOT's 2021 sustainability Report, due out later this year.
CO	12414436614	The Greening Government E.O. mandates all agencies track their energy consumption in a designated database. A Greening Government Leadership Council with reps from each executive agency reports annually in a collective report on progress towards energy, petroleum, and GHG reduction goals.
KS	12413883873	N/A
IL	12413363496	None
GA	12408421730	none that I know of
	12405790884	none that I'm aware of
	12402223626	N/A
ME	12399546015	Moving forward we hope to track green building improvements and infrastructure resilience projects. This is not set up yet.
OR	12398522918	Total greenhouse gas emissions from ODOT's building, energy, and transportation (fuel) sources. Building level energy Use Intensity (EUI) per square foot per year. Total biodiesel and other alternative fuel use as percent of total fuel use. Total number of trucks using anti-idling technology as a percent of total truck fleet. Hybrid, best-in-class high-mileage vehicles, and gasoline vehicles using alternative fuels as percent of all passenger sedans. Percent of employees that participate in the monthly transit pass payroll deduction program. Use of video and web conferencing solutions for meetings. Recycling volumes in major facilities. Amount of "green" office supplies and equipment purchased by ODOT or provided by contractors. And more!
AL	12398447021	
WY	12392148345	n/a
ID	12387018122	none
MS	12386161393	Energy reduction, vehicle fleet reduction, etc.
MO	12386055023	We have A TRACKER meeting once a month to report on activities.
DE	12385993640	n/a
RI	12385984299	
NY	12385702344	Working with the NYS Department of Environmental Conservation and other state agencies to track progress on energy use and sustainable practices at the agency/facility level per the requirements of NYS EO's 166, 4, 88 and 18. Example report: https://ogs.ny.gov/system/files/documents/2020/08/18-19-greenny-progress-report.pdf There are numerous metrics at the agency and facility

		level from tons materials recycled to Kwh energy use reduced to green purchases made and employees using ride shares, public transit or other modes. For the transportation system, NYSDOT monitors State VMT and energy usage, ridership levels, ridesharing as well as congestion along with analysis by other state agencies and authorities (NYSDEC; NYSERDA). VMT and greenhouse gas emissions are part of the monitoring efforts. https://www.nyserda.ny.gov/About/Publications/EA-Reports-and-Studies/Greenhouse-Gas-Inventory Sustainability also includes resiliency such as to the impacts of climate change. NYSDOT's approach is described in its 2019 Transportation Asset Management Plan. https://www.dot.ny.gov/programs/capital-plan/repository/Final%20TAMP%20June%2028%202019.pdf
	12374143355	
SD	12383693448	
MT	12383360782	
CT	12382471505	CTDOT does not currently utilize performance measures directed specifically toward sustainability. However, CTDOT consistently reports on the following performance measures: -Percent of Funds Expended for Bicycle/Pedestrian Access -Rail utilization - Number of rail passengers - Bus utilization - Number of passenger trips
	12374273231	none yet
MI	12373346114	I am not sure - except for the GreenLITES scorecard included with every project that will go out to bid.
IN	12373151332	None
TX	12372862762	N/A
AZ	12372826753	We have no official sustainability related performance measures. However, TxDOT likely has performance measures related to some of the other programs listed in previous questions.
WV	12372798674	5-year partnership with Texas Transportation Institute CARTEEH https://www.carteeh.org/ to develop Sustainable Transportation Program performance measures, metrics, indicators and map Agency activities to the UN Sustainable Development Goals (SDGs)
LA	12372745768	
IA	12372584304	Not developed yet
VA	12372224174	Our department is not currently tracking progress of these metrics at this time.
VT	12362768279	
	12337072319	VTrans has established a goal of providing funding necessary to ensure that a public charging station is located within 30 miles of every address in Vermont and is close to achieving it. New goals for EVSE will be established. We also have EV market penetration targets in our Comprehensive Energy Plan and as part of our membership in the U.S. Climate Alliance. Goals for implementing watershed resiliency tools have also been established.
NM	12355780857	
	12355711369	None at this time

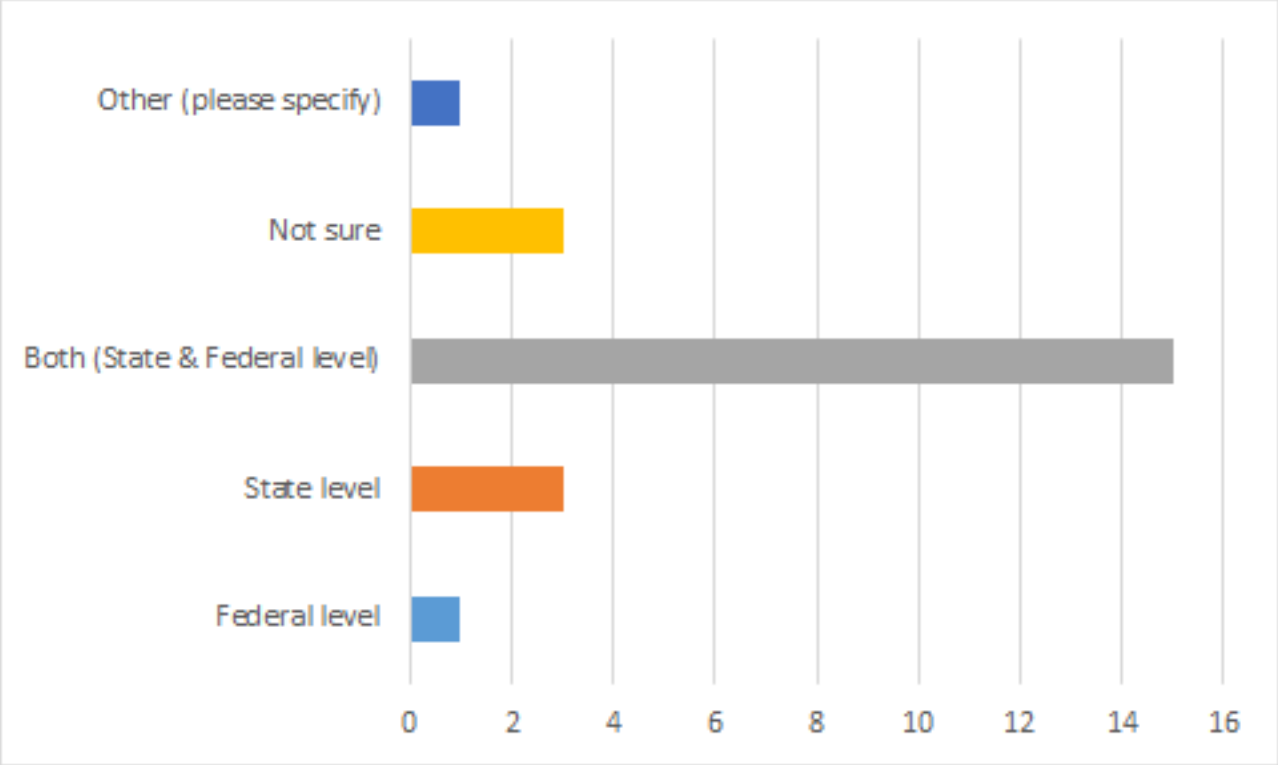
WA	12353673175	Some examples include building energy use, water use, recycling rate, vehicle fuel use, infrastructure condition (culverts, bridges, etc.). Full list of performance measures is in our annual Sustainability Report http://www.dot.state.mn.us/sustainability/sustainability-reporting.html
	12353381334	
	12341044991	
	12375931148	See #4 above.
WI	12353423744	State law has required GHG reduction goals that are tracked within our agency. Washington State Ferries creates a Sustainability Action Plan for each biennium that sets objectives and key results for that two-year cycle. These are monitored and reported out monthly to an internal interdepartmental team, and quarterly to the executive and public.
OK	12346488578	
	12343303953	
SC	12346025628	
NE	12343626137	We have a formal construction materials recycling program that is mostly aimed at reused of paving materials (asphalt millings, crushed concrete for base course material) that is tracked on applicable project plan sheets. Each project cover sheet has a recycle badge and score if applicable.
OH	12343527019	In the early 2010s ODOT investigated and assigned a sustainability lead. This was dissolved after two years
CA	12340881716	
	12340794191	Sustainability Roadmap
	12339908587	Reducing Caltrans' energy usage by 28 percent in 2016 compared to the baseline year — surpassing the 20 percent target required by EO B-18-12 and saving Caltrans approximately $23 million • Reducing facility water use by 38 percent in 2016 compared to 2010; the number is even higher (42 percent) when compared with data from 2013 • Decreasing highway water usage by 67 percent in 2016 compared to 2010 • Surpassing targets for replacing fleet vehicles with zero-emission vehicles under Management Memo 16-07 • Installing LEDs in all Caltrans maintenance stations • Completing construction on Caltrans' first Zero Net Energy pilot building
	12337612173	
	12337443587	
	12359628762	
	12337666575	
PA	12338840160	Pollinator program (formal), repurposing metal bridges, robotic technology in construction, funds for CNG conversion of bus stations...
TN	12338106458	Implementation of sustainability actions identified in Green Generates Green (TDOT, 2018)
HI	12337302726	
MN	12337083267	
	12336865901	Sustainability reporting, Sustainable Transportation Advisory Council, Clean Transportation Pilot

	12336427295	
	12355731550	
AR	12453275040	
UT	12453265632	
	12453024447	
NV	12413455610	Reducing GHG emissions from operations, maintenance and planning. Increase multi-modal travel (% of non-single occupancy vehicles travel in urbanized areas.
FL	12465787716	
MA	12336537334	MassDOT has a range of programs that target outcomes related to sustainability. Some examples are below: Shared Winter Streets and Spaces Grant Program (active): A program to help municipalities address the particular challenges of winter amid the ongoing public health crisis. Provides cities and towns with grants to improve plazas, sidewalks, curbs, streets, parking areas, and other public spaces in support of public health, safe mobility, and renewed commerce. This builds on an earlier Shared Streets and Spaces program. Complete Streets program (active) - Provides technical assistance and construction funding to eligible municipalities. Eligible municipalities must pass a Complete Streets Policy and develop a Prioritization Plan. Mass RIDES program (completed) – This was an "employer TDM" program that provided employees at member employers with information on commuting options, a guaranteed ride home program, safety item giveaways, and a ride-matching platform. Climate adaptation and vulnerability assessment (active) – Developing a statewide risk assessment for exposure of critical transportation assets flooding and integrating these findings into MassDOT systems and practices. Incorporating GHG impacts into capital planning (active) – Providing technical assistance and guidance to MPOs to ensure that GHG impacts are considered as a criterion in all capital planning and GHG impacts are quantified where practical. Clean Vehicles Program (completed) – A program to subsidize the capital costs of a range of clean vehicle and infrastructure types. Highway Renewable Energy Program (completed) – A program to identify areas of MassDOT right of way suited for development of solar farms and the subsequent development of solar farms in those locations Electric vehicle fast charging infrastructure (active) – Identified locations suited to hosting electric vehicle fast charging infrastructure and funded the construction of these stations. Congestion Mitigation and Air Quality Program (active) – Funding of projects that result in an air quality benefit. These typically include transit service, transit vehicle replacement, walking and cycling infrastructure, bike share, bike parking, and intersection improvements.

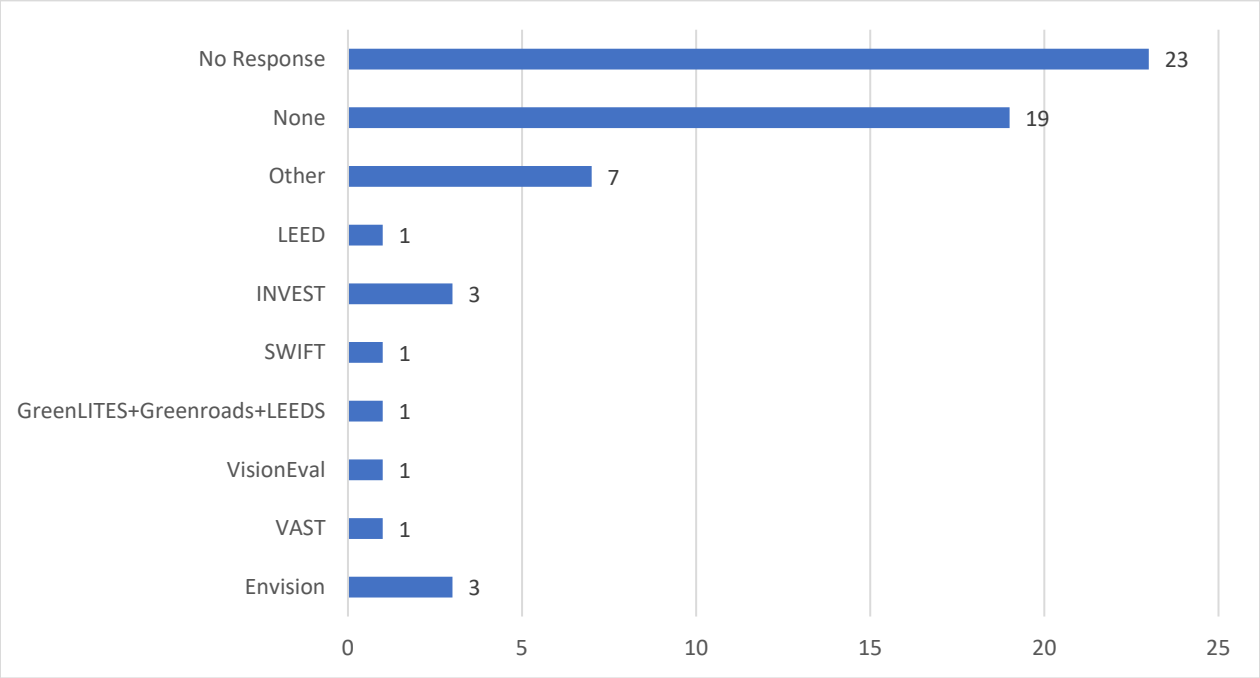
Question #17. How does your state DOT provide funding for its programs and/or activities related to sustainability? Select all answers that apply.



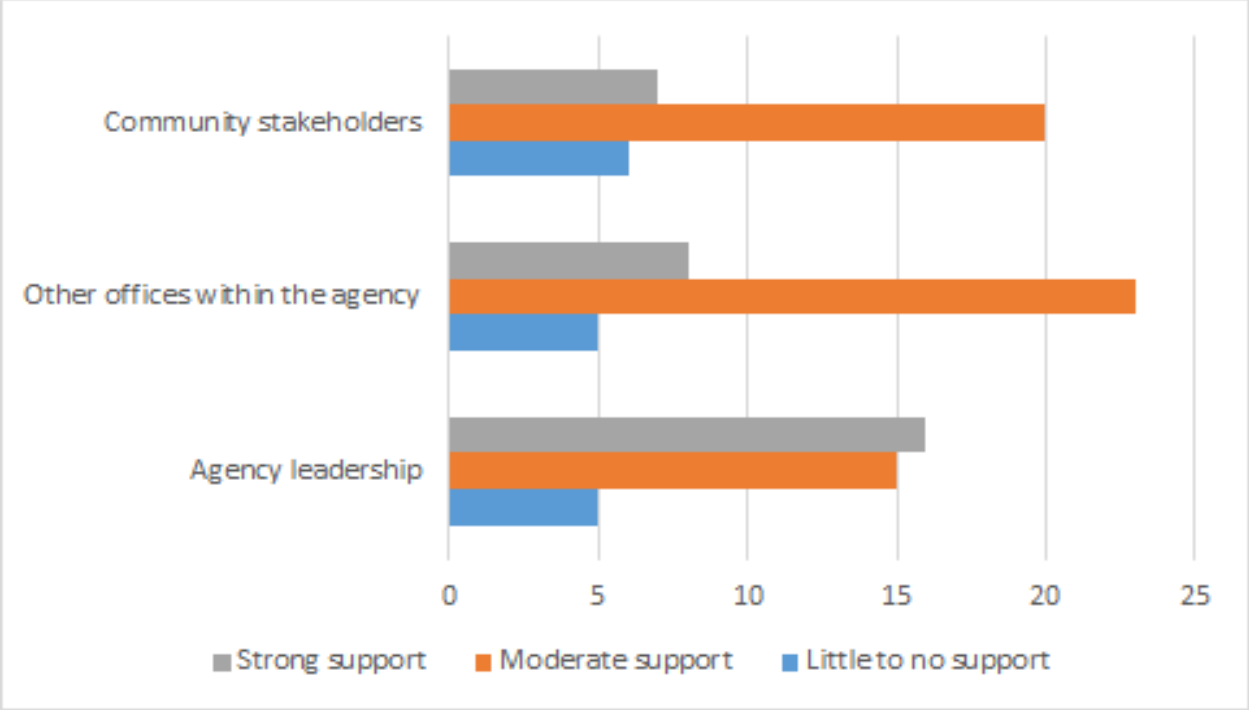
Question #18. From where do you receive this funding?



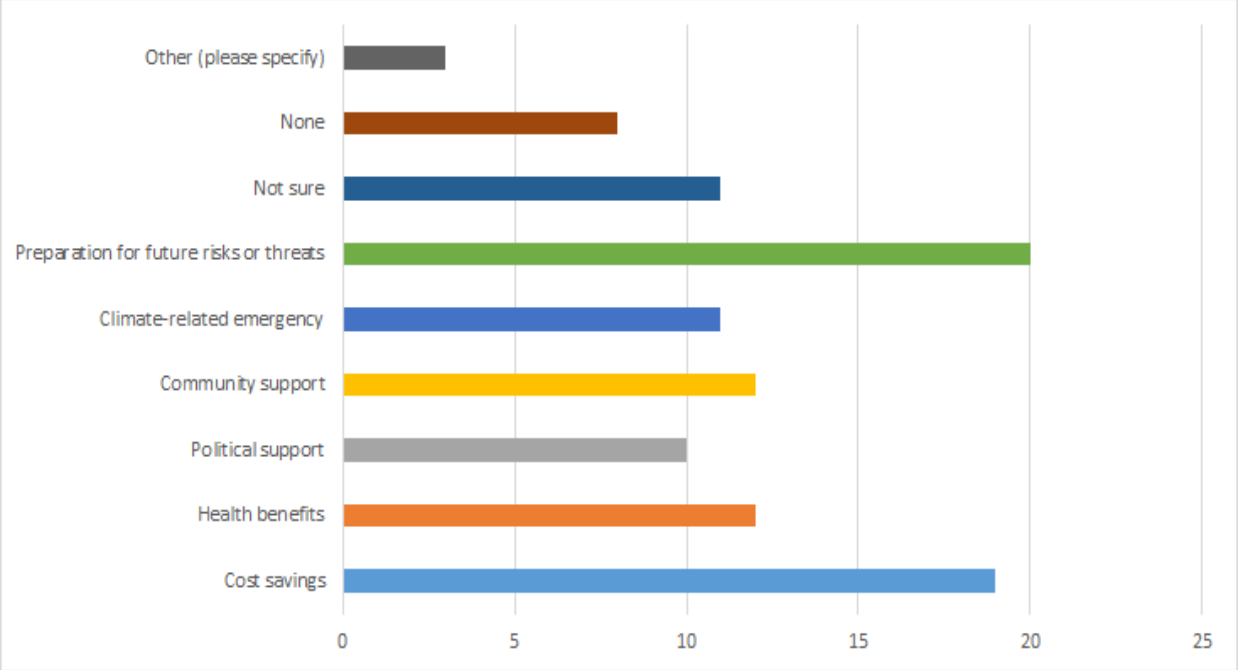
Question #19. Using the space below, please list any resources or tools that your state DOT has found helpful to conducting work related to sustainability (e.g., Invest, Envision, and/or Greenroads).



Question #20. Please indicate the level of support your state DOT's work related to sustainability has from each of the groups below.



Question #21. What messaging has your state DOT utilized to obtain support from agency leadership, other offices within the agency, and/or community stakeholders? Select all answers that apply.



Question #22. Using the space below, please list any desired resources, tools, technical assistance, or other support your state DOT needs to advance its work related to sustainability.

Using the space below, please list any desired resources, tools, technical assistance, or other support your state DOT needs to advance its work related to sustainability.		
State	**Respondent ID**	**Response**
MD	12421964669	Dedicated funding and guidance/tools to evaluate multimodal impacts from varying transportation projects.
CO	12414436614	Funding, sharing of implementation policies (how integrating sustainability into DOT activities), cost effective reduction opportunities/ROI studies and examples.
KS	12413883873	Our agency is focused on delivering a multimodal transportation program that centers on preservation and modernization of the system. Turning our attention towards sustainability related concepts and systems will be incremental.
IL	12413363496	None
GA	12408421730	
	12405790884	none that I'm aware of
	12402223626	tech assistance training
ME	12399546015	Funding opportunities are welcomed. Stakeholder engagement resources. Technical assistance for tracking progress of infrastructure resilience.
OR	12398522918	Network with other DOTs to learn best practices, assistance on GHG inventories and implementation of recommended actions, funding. LCA / LCCA tools to aid material selection.

AL	12398447021	
WY	12392148345	n/a
ID	12387018122	
MS	12386161393	
MO	12386055023	Information provided that gives guidance on what we can do to implement sustainability.
DE	12385993640	n/a
RI	12385984299	Leadership buy-in
NY	12385702344	Development of sustainability metrics at the national level along with easy to implement tools.
	12374143355	Continued awareness, partnership with materials producers, research and testing, collaboration with other agencies and DOTs
SD	12383693448	
MT	12383360782	
CT	12382471505	dedicated staffing, funding for implementation of projects/programs, and in-house expertise or access to outside expertise
	12374273231	we are just getting started and could use any support made available
MI	12373346114	Messaging and clear direction from Federal agencies
IN	12373151332	Like most things, in order for something to be adopted there needs to be a business case.
TX	12372862762	Demonstration or pilot projects in a host agency Workshops or peer exchanges Training (related to DOT operations) Flyers, brochures, or videos for specific target audiences Briefing materials for senior management
AZ	12372826753	Establish a dedicated EDC initiative for sustainability as ADOT submitted for EDC-6 but was not adopted. Establish parameters for Fed-Aid program and specifically FHWA design and construction authorization to include sustainable activities
WV	12372798674	
LA	12372745768	Our Mission: Plan, design, build and sustain a safe and reliable multimodal transportation and infrastructure system that enhances mobility and economic opportunity. At the moment, our sustainability focus is on safe and reliable systems. As this evolves in light of environmental factors, tools and assistance of some kind will likely be needed. Not sure what that will be at this point.
IA	12372584304	We would like to learn more about what other states are doing that don't have a directive to implement sustainability.
VA	12372224174	
VT	12362768279	Coordinated planning is a major missing element. This is a complex political problem that needs higher recognition.
	12337072319	
NM	12355780857	
	12355711369	
WA	12353673175	
	12353381334	Information on how other DOTs are incorporating sustainability in practice. Greater focus on sustainability from federal partners and

		professional organizations. Stronger support from contractor and consultant community. Continued executive focus and orders.
	12341044991	We need more tools and support in using them to increase the sustainability of our project delivery - from identifying actions across the state we should take, to identifying low carbon materials. For example, our planning group is starting to use VisionEval - additional federal support for this tool and input resources would be great. Likewise, around understanding the embodied emissions in construction materials and making better decisions in the materials we use.
	12375931148	
WI	12353423744	Develop a basic communication fact sheet and YouTube on Sustainability applications in the Transportation Sector to share with a variety of Divisions/Bureaus within DOTs. This may help large organizations connect the dots of the sustainable practices throughout the organization and help them with developing a coordinated dashboard or metrics for the sustainability theme. Develop a generic score card template for likely Transportation Sustainability themes to track and measure. Provide an index of the range of sustainability practices applied in the Transportation Sector.
OK	12346488578	
	12343303953	Needs support from top administration in setting policies and get the message across to the Divisions to get them implemented
SC	12346025628	Incentive
NE	12343626137	
OH	12343527019	business case for sustainability. We tried to have a consultant create this several years ago. However, it missed the mark. A solid reasoning "why" a DOT should consider sustainability could go a long way.
CA	12340881716	
	12340794191	Wildlife connectivity mapping
	12339908587	I couldn't say right now. Maybe technical support in studying the effects of sea level rise highway facilities.
	12337612173	
	12337443587	
	12359628762	Would like to explore use of ratings tools as educational / information piece for making sustainable project decisions as opposed to ratings tools. Need further research on effective ghg reduction and vmt reduction measures
	12337666575	
PA	12338840160	
TN	12338106458	
HI	12337302726	Funding opportunities that shift federal spending from a reactive, post-disaster approach toward proactive, pre-disaster investments, which presents an opportunity for HDOT and other state partners.
MN	12337083267	
	12336865901	
	12336427295	

	12355731550	Would be helpful to have a dedicated peer network of DOT sustainability staff (to exchange best practices, etc.). Would be great if it included a non-public website where we can post questions, documents, etc.
MA	12336537334	More quality empirical research on “what works” and what is cost effective to achieve results in various impact areas of sustainability would be helpful. Ultimately DOTs need financial resources to invest in capital projects and operations that support sustainable outcomes.
AR	12453275040	
UT	12453265632	
	12453024447	
NV	12413455610	Guidance and technical support on recommended tools available. Case studies.
FL	12465787716	

APPENDIX B: USER'S GUIDE FOR "SCORN" SUSTAINABILITY RATING SYSTEM

SCORN Developer's Guide

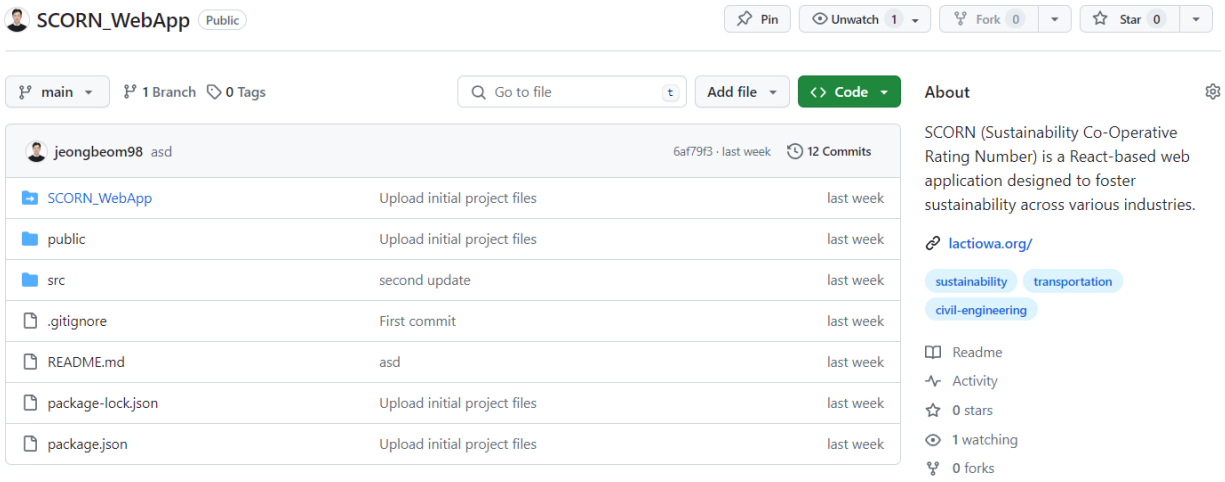
Laboratory for Advanced Construction Technology

Table of Contents

1. Environment Setup

1.1. Software Requirements

To start development with the SCORN web application, setting up the right environment is essential. The foundation of this setup includes having the latest version of Node.js installed on your system, which is pivotal for running and developing React applications like SCORN. Node.js comes bundled with Node Package Manager, an indispensable tool for managing packages and dependencies within the project. Equally crucial is Git, a version control system that facilitates code management, allowing developers to clone the project repository, track changes, and collaborate efficiently.



1.2. Download the Project Repository with Git

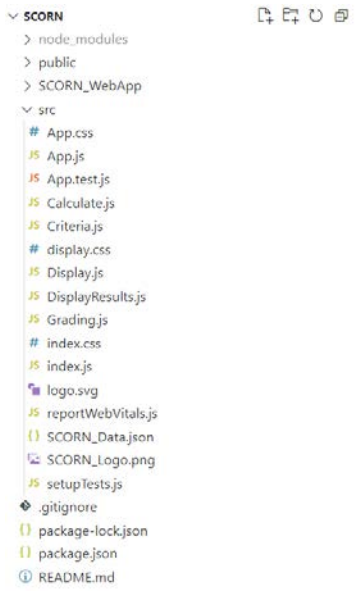
Once the software prerequisites are in place, the next step involves downloading the SCORN project repository. This can be achieved through Git by executing a clone command that copies the entire project structure to your local machine. This process ensures that you have a personal copy of the project's codebase, making it possible to embark on development, perform tests, and contribute to the project.

2. Project Structure and Key Files Explanation

The SCORN web application is structured around several key JavaScript (JS) files that collectively define its functionality, interface, and the dynamic interactions users experience. Understanding the role of each file is crucial for developers looking to contribute to the project, as it enables efficient navigation and modification of the codebase. Here's an overview of the core files:

2.1 App.js

This is the heart of the SCORN application, serving as the main entry point. `App.js` orchestrates the rendering of the entire application, managing state transitions, routing, and the display of major components such as `Criteria`, `Display`, and `DisplayResults`. It integrates the different parts of the application into a cohesive user experience.



2.2 Criteria.js

This file defines the `Criteria` component, which is responsible for presenting the sustainability assessment criteria to the user. It lays out the evaluation standards and domains in an informative manner, guiding users on how to assess their sustainability practices effectively. The `Criteria` component is crucial for the educational aspect of SCORN, ensuring users understand the basis of their sustainability evaluation.

2.3 Display.js

The `Display` component, defined in this file, handles the presentation and interaction of the questionnaire. It dynamically generates questions based on the criteria selected by the user, captures responses, and manages the navigation through different parts of the questionnaire. This file is key to the interactive nature of SCORN, making the assessment process engaging and user-friendly.

2.4 DisplayResults.js

After users complete the questionnaire, the `DisplayResults` component takes over to show the calculated sustainability grade. Defined in this file, it processes the grading results, displays them in a clear and concise manner, and offers functionality to export the results for further analysis or record-keeping. This component brings closure to the assessment process by providing users with tangible feedback on their sustainability efforts.

2.5 CalculateGrade.js

The logic for calculating the sustainability grade based on user responses is encapsulated in this file. `CalculateGrade.js` is a critical component of SCORN, as it directly impacts the outcome of the assessment. It takes into account the points associated with each response, applies

the grading logic, and determines the final grade. This file is essential for ensuring the accuracy and reliability of the assessment results.

Together, these files form the backbone of the SCORN application, each playing a distinct role in delivering a comprehensive sustainability assessment tool. For developers contributing to SCORN, familiarity with these files is the first step towards effective collaboration and enhancement of the project.

3. Getting Started

The commencement of development activities for the SCORN web application is predicated upon a methodical installation process, followed by procedural steps to operationalize the project on a local computational environment. This segment elucidates a structured guide aimed at facilitating developers in establishing their development milieu efficiently and initiating contributions to the project.

3.1 Installation

The foundational step in preparing for development on the SCORN project involves the installation of Node.js, inclusive of npm (Node Package Manager). Given that SCORN is constructed utilizing the React framework, the presence of Node.js is imperative for the activation of the development server, whilst npm is utilized for the management of packages and dependencies within the project framework.

3.2 Running the Project

Subsequent to the installation of Node.js, it is requisite to clone the SCORN repository to a local directory. This can be achieved by executing the following command in a terminal or command prompt, thereby navigating to the desired directory where the project will reside:

>>> git clone https://github.com/jeongbeom98/SCORN_WebApp.git

Post-cloning, one must transition into the SCORN project directory via:

>>> cd SCORN_WebApp

Within the project directory, the installation of necessary npm packages is accomplished by executing:

>>> npm install

This command interprets the `package.json` file and procures all requisite dependencies for the project.

Upon completion of the installation, the project is ready to be executed locally. Within the project's directory, the development server is initiated by executing:

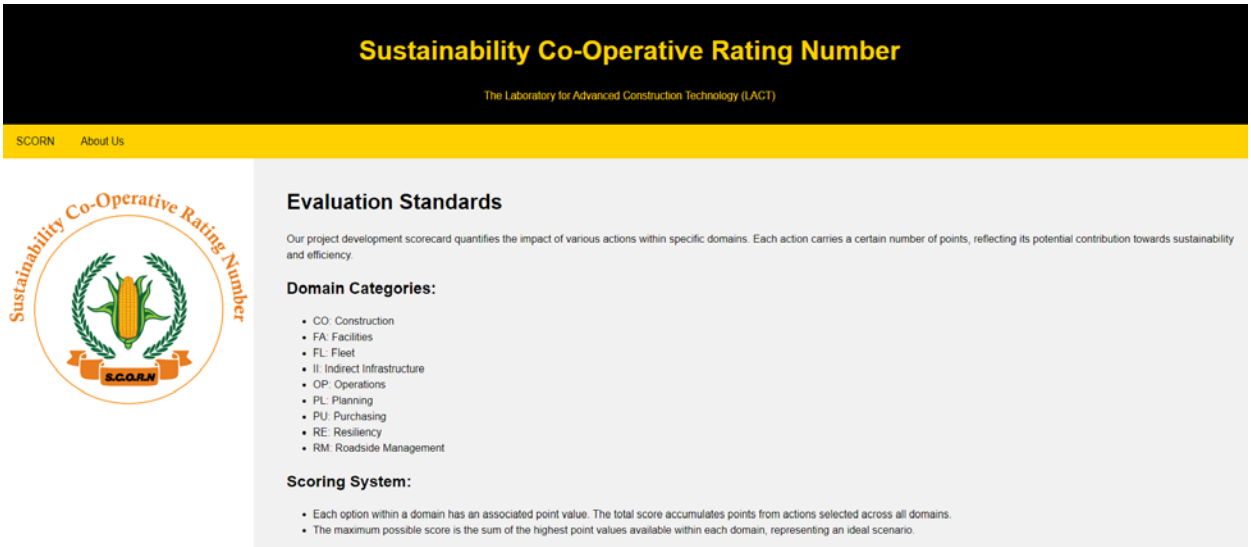
>>> npm start

This action activates the React development server and automatically renders the SCORN application within the default web browser. Typically, the application is accessible at `http://localhost:3000`, offering an interactive platform for engaging with the SCORN questionnaire, implementing new functionalities, or ameliorating extant code.

```
PS D:\LACT\scorn> npm start
Compiled successfully!

You can now view scorn in the browser.

  Local:            http://localhost:3000
  On Your Network:  http://10.10.4.91:3000

Note that the development build is not optimized.
To create a production build, use npm run build.

webpack compiled successfully
```

The local execution of SCORN permits developers to witness real-time reflections of their modifications, facilitating an immediate feedback loop essential for development and diagnostic processes. As modifications are made to the codebase, the development server seamlessly reloads the application within the browser, instantaneously showcasing the implemented alterations.

Through adherence to these installation and execution directives, developers are equipped to commence with contributions towards the SCORN project, thus augmenting the tool's functionality and further endorsing its objective of propagating sustainability practices across varied domains.



4. Contributing to SCORN

Engagement with the SCORN project, by means of contributing to its development, is encouraged under a structured framework designed to facilitate meaningful and coherent additions. This section delineates the protocol for engaging with the project, encompassing the initial steps of forking the repository, the intricacies of integrating modifications—specifically the addition of new questions—and the procedural approach to submitting these changes for review through pull requests.

The initial phase in the contribution process entails creating a personal copy of the SCORN repository. This is accomplished by navigating to the SCORN GitHub page and utilizing the 'Fork' feature, thereby generating a replica of the repository under your GitHub account. This forked repository serves as a private platform where modifications can be freely implemented without affecting the original codebase.

To integrate new questions into the SCORN web app, developers need to update the `SCORN_Data.json` file, which serves as the database for all sustainability-related questions presented within the application. Here's a detailed guide and template you can include in the SCORN Developer's Guide:

4.1. Prepare the Data

- Ensure your new questionnaire data is organized with the necessary attributes: `Category`, `Abbreviation`, `Number`, `Title`, `Option`, and `Points`.

- For new questions, assign a unique `Number` within each `Category`. The `Option` field should detail the possible answers, and `Points` assign a score to each option.

4.2. Format the Data

- Convert your data into a JSON array format. Each question and its options should be a separate object within the array, similar to the example provided.

4.3. Update the `SCORN_Data.json` File

- Replace the existing content of `SCORN_Data.json` with your newly formatted JSON data. Ensure the format is correct to avoid errors in the application.

4.4. Test Your Changes

- After updating the JSON file, run the SCORN web app locally to ensure the new questions are displayed correctly and that the grading logic functions as expected.

- Template for `SCORN_Data.json`:

```
[{ "Category": "Your Category",
   "Abbreviation": "Abbreviation",
```

"Number": 1,

"Title": "Question Title",

"Option": "Answer Option",

"Points": 1.0},

{"Category": "Your Category",

"Abbreviation": "Abbreviation",

"Number": 1,

"Title": "Question Title",

"Option": "Another Answer Option",

"Points": 2.0},

// Add more questions and options here]

- Example Addition: If you're adding a new question about "Reducing Plastic Use" within the "Facilities" category, your entry might look like this:

[{"Category": "Facilities",

"Abbreviation": "FA",

"Number": 3, // Assuming 1 and 2 are already taken

"Title": "Reduce Plastic Use",

"Option": "Reduce single-use plastic by 10%",

"Points": 1.0},

{"Category": "Facilities",

"Abbreviation": "FA",

"Number": 3,

"Title": "Reduce Plastic Use",

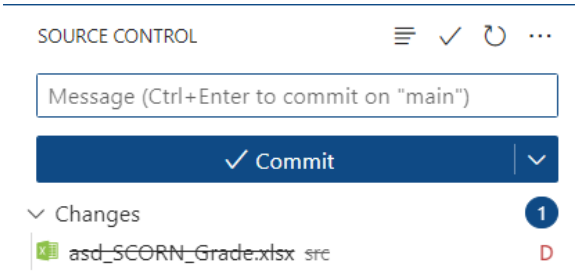
"Option": "Not Applicable",

"Points": -1.0}

// Continue adding other options as needed]

Upon the completion of modifications, contributors are required to initiate a pull request—a formal proposal to merge their changes into the original SCORN repository. This is

achieved by navigating to the 'Pull Requests' section of the original SCORN GitHub repository and selecting 'New Pull Request'. Contributors must then choose their forked repository as the 'compare' branch and outline the nature and rationale of their contributions in the provided description field.



The submission of a pull request triggers a review process, during which the proposed changes are evaluated by the project's maintainers. This review ensures that contributions align with the project's objectives, standards, and quality requirements. Upon approval, the changes are merged into the SCORN repository, marking the successful contribution of new content or features to the project.

5. Deploying SCORN to AWS Amplify

To make SCORN accessible as a fully functional web application, deployment through AWS Amplify is recommended. AWS Amplify streamlines hosting both the backend and frontend of web applications, ensuring scalability and reliability. Follow these steps to deploy SCORN to AWS:

5.1 Setting up AWS Amplify

Before you begin, ensure you have the AWS Amplify CLI installed and configured as outlined in Part II of the initial setup guide. The CLI will interface with your AWS account to provision cloud resources.

5.2 Initializing Your Project in AWS Amplify

In your project's root directory, initiate the Amplify project by running:

```
>>> amplify init
```

Follow the prompts to:

- Name your project and environment.
- Specify the default code editor.
- Choose 'javascript' for the type of app and 'react' for the framework.
- Accept default configurations for paths.
- Select the AWS profile you've set up during the Amplify CLI configuration.

5.3 Deploying the Backend

To deploy the backend resources to your Amplify environment, execute:

```
>>> amplify push
```

Confirm when prompted to proceed with the deployment.

5.4 Hosting Your Application

For hosting the frontend, run:

```
>>> amplify add hosting
```

Choose 'Amplify Console' and 'Manual deployment'. Once hosting is set up, publish your application by running:

```
>>> amplify publish
```

Confirm with 'yes' when prompted.

5.5 Verifying the Deployment

After the deployment, the Amplify Console will provide a URL to your hosted application. Visit this link to ensure that the SCORN web application is live and functional.

5.6 Removing Your Application

Should you need to remove your application from AWS, avoid deleting directly from AWS services. Instead, use the Amplify CLI with the command:

```
>>> amplify delete
```

This ensures a clean removal of services provisioned by AWS Amplify for your project.

APPENDIX C: USER'S GUDIE FOR "DOSPIR" SUSTAINABILITY PRACTICE DATABASE

DOSPIR on ArcGIS Pro

User's Guide

Laboratory for Advanced Construction Technology

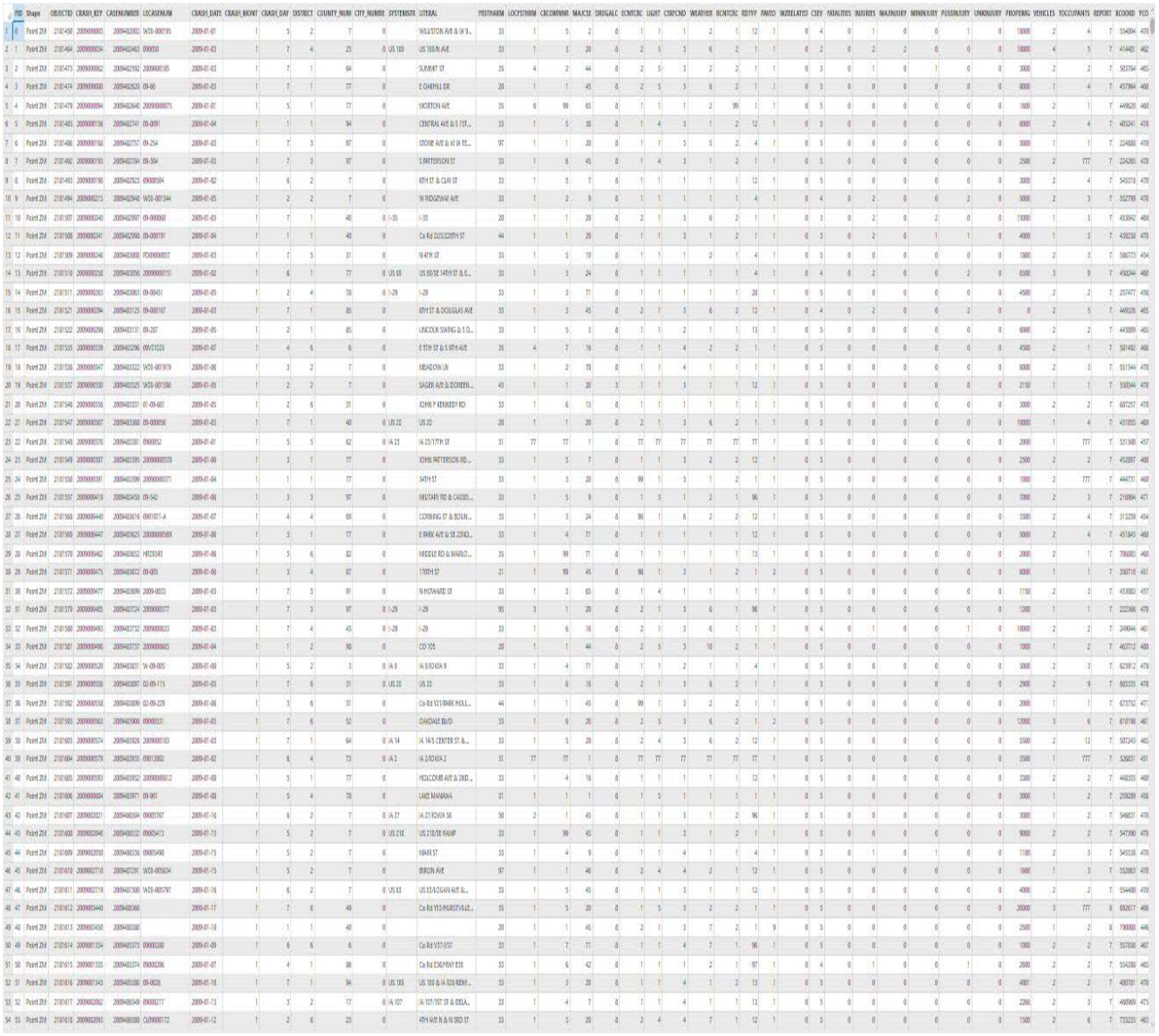
Table of Contents

1. Original data from Iowa DOT

a. Crash Data

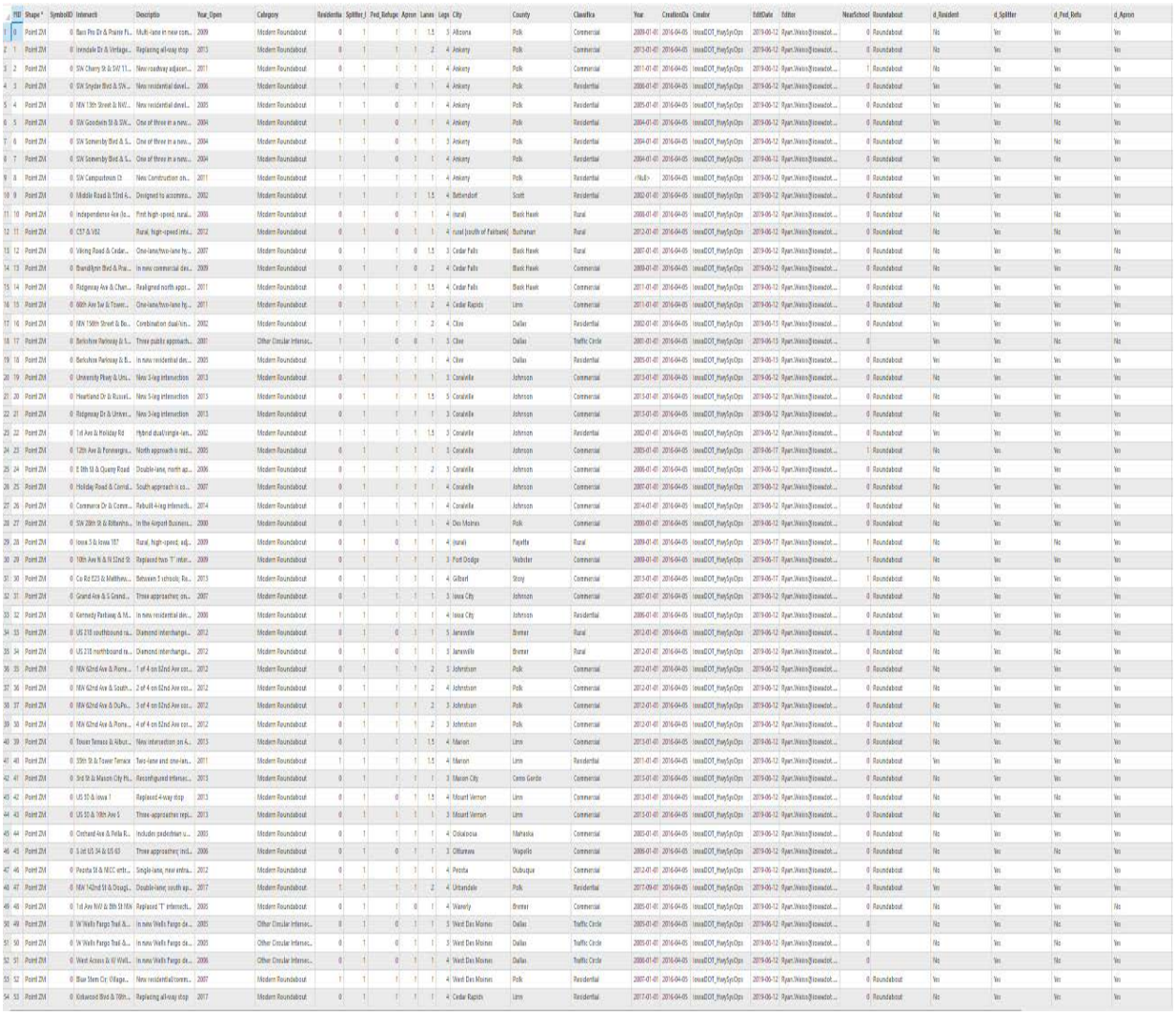
- Data obtained from https://data.iowadot.gov/datasets/84cc3a98db944e71aed9e4a984a3ff60/explore

- 792,337 total crashes from 2009 to 2023



b. Roundabout Data

- Data obtained from SAMUEL.STURTZ@iowadot.us
- 110 roundabouts constructed from 2000 to 2023



	FID	Shape *	SymbolID	Intersecti	Descriptio	Year_Open	Category	Residentia	Splitter_I	Ped_Refuge	Apron	Lanes	Legs	City	County	Classifica	Year	CreationDa	Creator	EditDate	Editor	NearSchool	Roundabout	d_Resident	d_Splitter	d_Ped_Refu	d_Apron
1	0	Point ZM	0	Bass Pro Dr & Prairie Pk...	Multi-lane in new con...	2009	Modern Roundabout	0	1	1	1	1.5	5	Altoona	Polk	Commercial	2009-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes
2	1	Point ZM	0	Irrindale Dr & Vintage...	Replacing all-way stop	2013	Modern Roundabout	0	1	1	1	2	4	Ankeny	Polk	Commercial	2013-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes
3	2	Point ZM	0	SW Cherry St & SW 11...	New roadway adjacen...	2011	Modern Roundabout	0	1	1	1	1	4	Ankeny	Polk	Commercial	2011-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	1	Roundabout	No	Yes	Yes	Yes
4	3	Point ZM	0	SW Snyder Blvd & SW...	New residential devel...	2006	Modern Roundabout	1	1	0	1	1	4	Ankeny	Polk	Residential	2006-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	Yes	Yes	No	Yes
5	4	Point ZM	0	NW 13th Street & NW J...	New residential devel...	2005	Modern Roundabout	1	1	0	1	1	4	Ankeny	Polk	Residential	2005-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	Yes	Yes	No	Yes
6	5	Point ZM	0	SW Goodwin St & SW...	One of three in a new...	2004	Modern Roundabout	1	1	0	1	1	4	Ankeny	Polk	Residential	2004-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	Yes	Yes	No	Yes
7	6	Point ZM	0	SW Somersby Blvd & S...	One of three in a new...	2004	Modern Roundabout	1	1	0	1	1	3	Ankeny	Polk	Residential	2004-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	Yes	Yes	No	Yes
8	7	Point ZM	0	SW Somersby Blvd & S...	One of three in a new...	2004	Modern Roundabout	1	1	0	1	1	4	Ankeny	Polk	Residential	2004-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	Yes	Yes	No	Yes
9	8	Point ZM	0	SW Campostrum Ct	New Construction on...	2011	Modern Roundabout	1	1	1	1	1	4	Ankeny	Polk	Residential	<Null>	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	Yes	Yes	Yes	Yes
10	9	Point ZM	0	Middle Road & 53rd &...	Designed to accommo...	2002	Modern Roundabout	1	1	1	1	1.5	4	Bettendorf	Scott	Residential	2002-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	Yes	Yes	Yes	Yes
11	10	Point ZM	0	Independence Ave (for...	First high-speed, rural...	2006	Modern Roundabout	0	1	0	1	1	4	Rural	Black Hawk	Rural	2006-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	No	Yes
12	11	Point ZM	0	C57 & V62	Rural, high-speed inte...	2012	Modern Roundabout	0	1	0	1	1	4	rural (south of Fairbank)	Buchanan	Rural	2012-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	No	Yes
13	12	Point ZM	0	Viking Road & Cedar...	One-lane/two-lane hy...	2007	Modern Roundabout	0	1	1	0	1.5	3	Cedar Falls	Black Hawk	Rural	2007-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	No
14	13	Point ZM	0	Brandilynn Blvd & Pra...	In new commercial dev...	2009	Modern Roundabout	0	1	1	0	2	4	Cedar Falls	Black Hawk	Commercial	2009-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	No
15	14	Point ZM	0	Ridgeway Ave & Chen...	Realigned north spur...	2011	Modern Roundabout	0	1	1	1	1.5	4	Cedar Falls	Black Hawk	Commercial	2011-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes
16	15	Point ZM	0	66th Ave Sw & Tower...	One-lane/two-lane hy...	2011	Modern Roundabout	0	1	1	1	2	4	Cedar Rapids	Linn	Commercial	2011-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes
17	16	Point ZM	0	NW 158th Street & Bo...	Combination dual/sin...	2002	Modern Roundabout	1	1	1	1	2	4	Clive	Dallas	Residential	2002-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-13	Ryan.Weiss@iowadot....	0	Roundabout	Yes	Yes	Yes	Yes
18	17	Point ZM	0	Berkshire Parkway & S...	Three public approach...	2001	Other Circular Intersec...	1	1	0	0	1	3	Clive	Dallas	Traffic Circle	2001-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-13	Ryan.Weiss@iowadot....	0		Yes	Yes	No	No
19	18	Point ZM	0	Berkshire Parkway & B...	In new residential dev...	2005	Modern Roundabout	1	1	1	1	1	4	Clive	Dallas	Residential	2005-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-13	Ryan.Weiss@iowadot....	0	Roundabout	Yes	Yes	Yes	Yes
20	19	Point ZM	0	University Pkwy & Uni...	New 3-leg intersection	2013	Modern Roundabout	0	1	1	1	1	3	Coralville	Johnson	Commercial	2013-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes
21	20	Point ZM	0	Heartland Dr & Russell...	New 5-leg intersection	2015	Modern Roundabout	0	1	1	1	1.5	5	Coralville	Johnson	Commercial	2015-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes
22	21	Point ZM	0	Ridgeway Dr & Univer...	New 3-leg intersection	2013	Modern Roundabout	0	1	1	1	1	3	Coralville	Johnson	Commercial	2013-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes
23	22	Point ZM	0	1st Ave & Holiday Rd	Hybrid dual/single-lan...	2002	Modern Roundabout	1	1	1	1	1.5	3	Coralville	Johnson	Residential	2002-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	Yes	Yes	Yes	Yes
24	23	Point ZM	0	12th Ave & Pennsylvan...	North approach is mid...	2005	Modern Roundabout	0	1	1	1	1	3	Coralville	Johnson	Commercial	2005-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-17	Ryan.Weiss@iowadot....	1	Roundabout	No	Yes	Yes	Yes
25	24	Point ZM	0	E 9th St & Quarry Road	Double-lane, north ap...	2006	Modern Roundabout	0	1	1	1	2	3	Coralville	Johnson	Commercial	2006-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes
26	25	Point ZM	0	Holiday Road & Corrid...	South approach is co...	2007	Modern Roundabout	0	1	1	1	1	4	Coralville	Johnson	Commercial	2007-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes
27	26	Point ZM	0	Commerce Dr & Corre...	Rebuilt 4-leg intersecti...	2014	Modern Roundabout	0	1	1	1	1	4	Coralville	Johnson	Commercial	2014-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes
28	27	Point ZM	0	SW 28th St & Bilbrains...	In the Airport Busines...	2000	Modern Roundabout	0	1	1	1	1	4	Des Moines	Polk	Commercial	2000-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes
29	28	Point ZM	0	Iowa 3 & Iowa 187	Rural, high-speed, adj...	2009	Modern Roundabout	0	1	0	1	1	4	rural	Fayette	Rural	2009-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-17	Ryan.Weiss@iowadot....	1	Roundabout	No	Yes	No	Yes
30	29	Point ZM	0	10th Ave N & N 32nd St	Replaced two "T" inter...	2009	Modern Roundabout	0	1	1	1	1	3	Fort Dodge	Webster	Commercial	2009-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-17	Ryan.Weiss@iowadot....	1	Roundabout	No	Yes	Yes	Yes
31	30	Point ZM	0	Co Rd E23 & Matthews...	Between 3 schools; Ro...	2013	Modern Roundabout	0	1	1	1	1	4	Gilbert	Story	Commercial	2013-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-17	Ryan.Weiss@iowadot....	1	Roundabout	No	Yes	Yes	Yes
32	31	Point ZM	0	Grand Ave & S Gramd...	Three approaches; on...	2007	Modern Roundabout	0	1	1	1	1	3	Iowa City	Johnson	Commercial	2007-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes
33	32	Point ZM	0	Kennedy Parkway & M...	In new residential dev...	2006	Modern Roundabout	1	1	1	1	1	4	Iowa City	Johnson	Residential	2006-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	Yes	Yes	Yes	Yes
34	33	Point ZM	0	US 218 southbound ra...	Diamond interchange...	2012	Modern Roundabout	0	1	0	1	1	3	Janesville	Bremer	Rural	2012-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	No	Yes
35	34	Point ZM	0	US 218 northbound ra...	Diamond interchange...	2012	Modern Roundabout	0	1	0	1	1	3	Janesville	Bremer	Rural	2012-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	No	Yes
36	35	Point ZM	0	NW 62nd Ave & Prora...	1 of 4 on 62nd Ave cor...	2012	Modern Roundabout	0	1	1	1	2	3	Johnston	Polk	Commercial	2012-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes
37	36	Point ZM	0	NW 62nd Ave & South...	2 of 4 on 62nd Ave cor...	2012	Modern Roundabout	0	1	1	1	2	4	Johnston	Polk	Commercial	2012-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes
38	37	Point ZM	0	NW 62nd Ave & DuPo...	3 of 4 on 62nd Ave cor...	2012	Modern Roundabout	0	1	1	1	2	3	Johnston	Polk	Commercial	2012-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes
39	38	Point ZM	0	NW 62nd Ave & Prora...	4 of 4 on 62nd Ave cor...	2012	Modern Roundabout	0	1	1	1	2	3	Johnston	Polk	Commercial	2012-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes
40	39	Point ZM	0	Tower Terrace & Albur...	New intersection on A...	2013	Modern Roundabout	0	1	1	1	1.5	4	Marion	Linn	Commercial	2013-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-13	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	No	Yes
41	40	Point ZM	0	35th St & Tower Terrace	Two-lane and one-lan...	2011	Modern Roundabout	1	1	1	1	1.5	4	Marion	Linn	Residential	2011-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	Yes	Yes	Yes	Yes
42	41	Point ZM	0	3rd St & Mason City Hi...	Reconfigured intersec...	2013	Modern Roundabout	0	1	1	1	1	3	Mason City	Cerro Gordo	Commercial	2013-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes
43	42	Point ZM	0	US 30 & Iowa 1	Replaced 4-way stop	2013	Modern Roundabout	0	1	0	1	1.5	4	Mount Vernon	Linn	Commercial	2013-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	No	Yes
44	43	Point ZM	0	US 30 & 10th Ave E	Three-approaches repl...	2013	Modern Roundabout	0	1	1	1	1	3	Mount Vernon	Linn	Commercial	2013-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes
45	44	Point ZM	0	Orchard Ave & Pella R...	Includes pedestrian u...	2003	Modern Roundabout	0	1	1	1	1	4	Oskaloosa	Mahaska	Commercial	2003-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes
46	45	Point ZM	0	S Jct US 34 & US 63	Three approaches; incl...	2006	Modern Roundabout	0	1	0	1	1	3	Ottumwa	Wapello	Commercial	2006-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	No	Yes
47	46	Point ZM	0	Peosta St & NCC entr...	Single-lane, near entra...	2012	Modern Roundabout	0	1	1	1	1	4	Peosta	Dubuque	Commercial	2012-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes
48	47	Point ZM	0	NW 142nd St & Douga...	Double-lane; south ap...	2017	Modern Roundabout	1	1	1	1	2	4	Urbandale	Polk	Residential	2017-09-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	Yes	Yes	Yes	Yes
49	48	Point ZM	0	1st Ave NW & 8th St NW	Replaced "T" intersecti...	2005	Modern Roundabout	0	1	1	0	1	4	Waverly	Bremer	Commercial	2005-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	No
50	49	Point ZM	0	W Wells Fargo Trail &...	In new Wells Fargo de...	2005	Other Circular Intersec...	0	1	0	1	1	5	West Des Moines	Dallas	Traffic Circle	2005-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0		No	Yes	No	Yes
51	50	Point ZM	0	W Wells Fargo Trail &...	In new Wells Fargo de...	2005	Other Circular Intersec...	0	1	0	1	1	5	West Des Moines	Dallas	Traffic Circle	2005-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0		No	Yes	No	Yes
52	51	Point ZM	0	West Access & W Wells...	In new Wells Fargo de...	2006	Other Circular Intersec...	0	1	0	1	1	4	West Des Moines	Dallas	Traffic Circle	2006-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0		No	Yes	No	Yes
53	52	Point ZM	0	Blue Stem Cir, Village...	New residential comm...	2007	Modern Roundabout	1	1	1	1	1	4	West Des Moines	Polk	Residential	2007-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	Yes	Yes	Yes	Yes
54	53	Point ZM	0	Kirkwood Blvd & 78th...	Replacing all-way stop	2017	Modern Roundabout	0	1	1	1	1	4	Cedar Rapids	Linn	Residential	2017-01-01	2016-04-05	IowaDOT_HwySysOps	2019-06-12	Ryan.Weiss@iowadot....	0	Roundabout	No	Yes	Yes	Yes

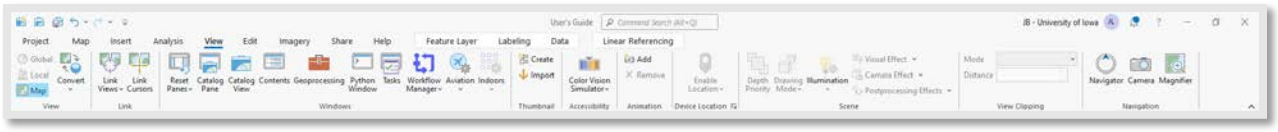
2. Data Preprocessing in ArcGIS Pro

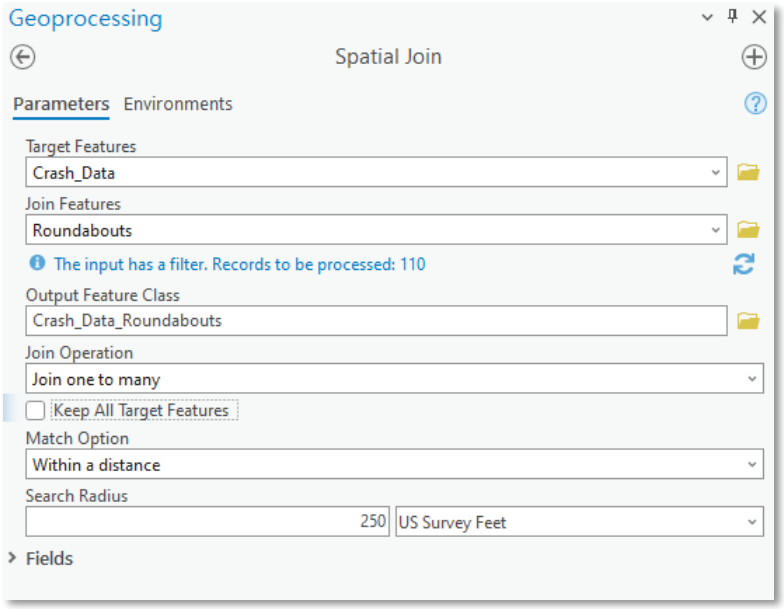
In this phase, we will employ ArcGIS Pro to conduct preliminary processing on two datasets, setting the stage for subsequent in-depth analysis and visualization. This involves refining and consolidating the data to ensure it is optimally structured for our intended uses.

2-1. Performing Spatial Join on Layer Files

By performing a spatial join between the 'Crash_Data' and 'Roundabouts' layers, we can create a merged layer file that displays crash data occurring within a 250-foot radius of each roundabout

- From the ArcGIS Pro Navigation bar, select 'View' > 'Geoprocessing' > 'Spatial Join'.





- Parameters:

a. Target Features: Crash_Data

b. Joined Features: Roundabouts

c. Output Feature Class: Crash_Data_Roundabouts

- This will be the name for the new layerfile.

d. Join Operation: Join one to many

e. Uncheck ‘Keep All Target Features’

f. Match Option: Within a Distance

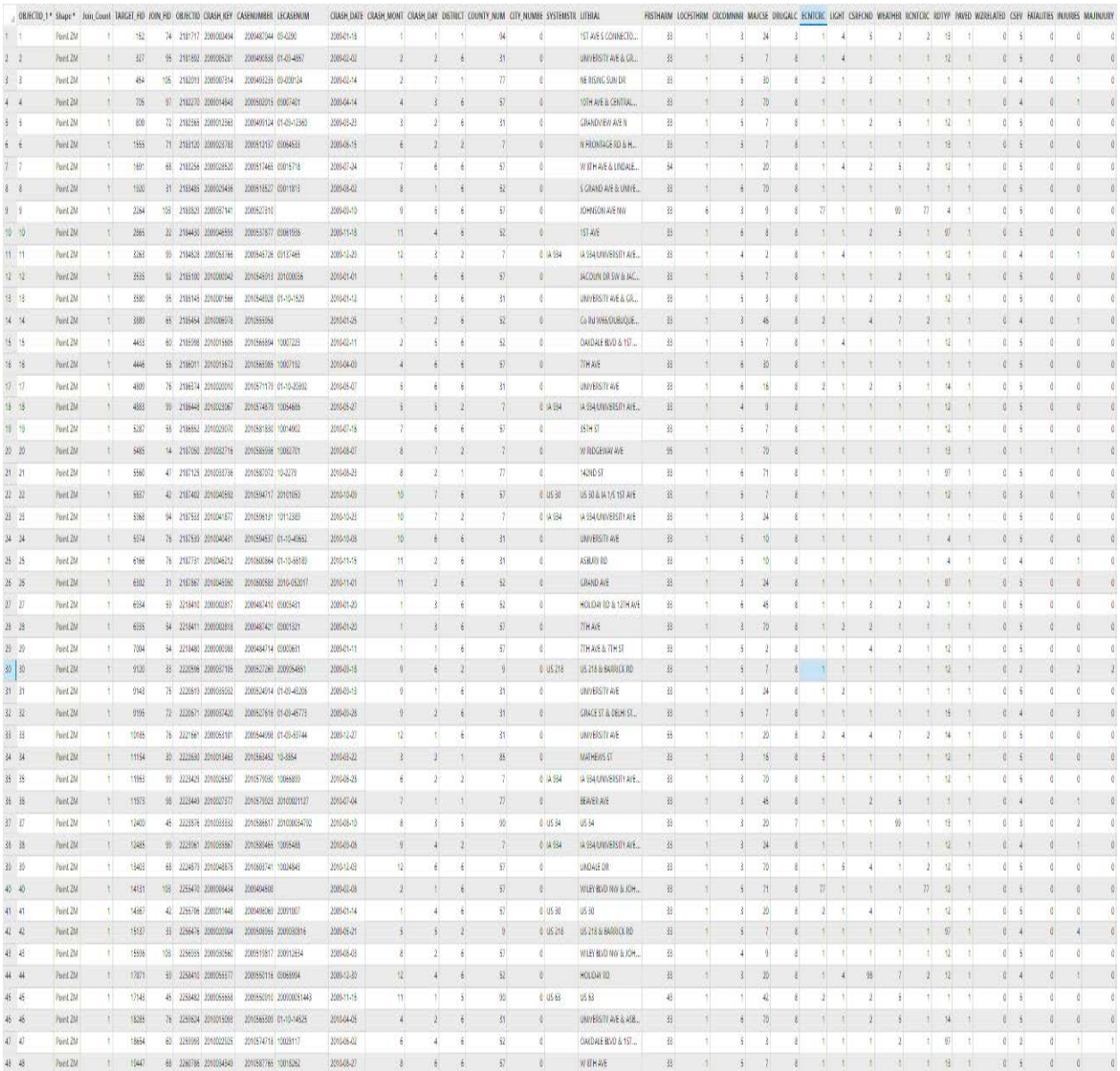
g. Search Radius: 250 US Survey Feet

> Click the 'Run' button to perform the spatial join of the two layers.

a. Spatial-Joined Data (Crash_Data_Roundabouts)

- 110 total roundabouts constructed from 2000 to 2023

- 2,671 total crashes from 2009 to 2023



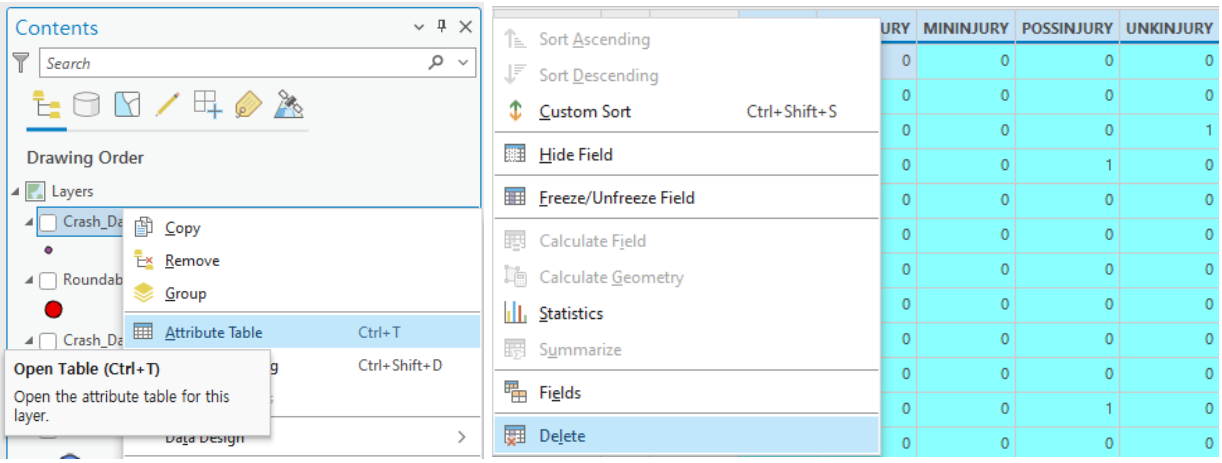
	OBJECTID_1 *	Shape *	Join_Count	TARGET_FID	JOIN_FID	OBJECTID	CRASH_KEY	CASENUMBER	LEGACYNUM	CRASH_DATE	CRASH_MONT	CRASH_DAY	DISTRICT	COUNTY_NUM	CITY_NUMBE	SYSTEMSTR	LITERAL
1	1	Point ZM	1	152	74	2181717	2009002494	2009487044	09-0200	2009-01-18	1	1	1	94	0		1ST AVE S CONNECTIO...
2	2	Point ZM	1	327	99	2181892	2009005281	2009490888	01-01-4857	2009-02-02	2	2	6	31	0		UNIVERSITY AVE & GI...
3	3	Point ZM	1	454	126	2182019	2009007314	2009492236	09-0001J4	2009-01-14	2	7	1	77	0		NE RISING SUN DR
4	4	Point ZM	1	726	97	2182270	2009014840	2009502015	01007401	2009-04-14	4	3	6	57	0		10TH AVE & CENTRAL...
5	5	Point ZM	1	800	72	2182265	2009012363	2009499124	01-01-12360	2009-03-23	3	2	6	31	0		GRANDVIEW AVE N
6	6	Point ZM	1	1555	71	2183120	2009023783	2009512137	01006433	2009-06-15	6	2	2	7	0		N FRONTAGE RD & M...
7	7	Point ZM	1	1691	68	2183256	2009026520	2009517465	01015718	2009-07-24	7	6	6	57	0		W 8TH AVE & LINDALE...
8	8	Point ZM	1	1800	81	2183485	2009029436	2009519527	01011813	2009-08-02	8	1	6	52	0		S GRAND AVE & UNIVE...
9	9	Point ZM	1	2264	108	2183820	2009037141	2009527310		2009-10-10	9	6	6	57	0		JOHNSON AVE NW
10	10	Point ZM	1	2665	32	2184430	2009046559	2009537877	01001936	2009-11-16	11	4	6	52	0		1ST AVE
11	11	Point ZM	1	3263	99	2184828	2009053786	2009545726	01013485	2009-12-20	12	3	2	7	0	IA 004	IA 004/UNIVERSITY AVE...
12	12	Point ZM	1	3535	92	2185100	2010000042	2010046913	2010000058	2010-01-01	1	6	6	57	0		JACQUIN DR SW & BAC...
13	13	Point ZM	1	3580	99	2185145	2010001566	2010048028	01-10-1520	2010-01-12	1	3	6	31	0		UNIVERSITY AVE & GI...
14	14	Point ZM	1	3880	65	2185454	2010006370	2010055958		2010-01-25	1	2	6	52	0		Co Rd W66/DUBUQUE...
15	15	Point ZM	1	4433	60	2185998	2010015605	2010065894	10007235	2010-02-11	2	5	6	52	0		OAKDALE BLVD & 1ST ...
16	16	Point ZM	1	4446	55	2186011	2010015672	2010065985	10007192	2010-04-03	4	6	6	57	0		7TH AVE
17	17	Point ZM	1	4609	76	2186174	2010020010	2010071170	01-10-20302	2010-03-07	3	6	6	31	0		UNIVERSITY AVE
18	18	Point ZM	1	4883	99	2186448	2010023067	2010074870	10054668	2010-03-27	3	3	2	7	0	IA 004	IA 004/UNIVERSITY AVE...
19	19	Point ZM	1	5287	55	2186852	2010029070	2010081880	10014002	2010-07-15	7	6	6	57	0		35TH ST
20	20	Point ZM	1	5485	14	2187050	2010032716	2010085598	10002701	2010-08-07	8	7	2	7	0		W RIDGEWAY AVE
21	21	Point ZM	1	5560	47	2187125	2010033738	2010087072	10-2279	2010-08-23	8	2	1	77	0		142ND ST
22	22	Point ZM	1	5637	42	2187402	2010034592	2010094717	20101093	2010-10-09	10	7	6	57	0	US 30	US 30 & IA 1/S 1ST AVE
23	23	Point ZM	1	5968	94	2187533	2010034977	2010096131	10112383	2010-10-25	10	7	2	7	0	IA 004	IA 004/UNIVERSITY AVE
24	24	Point ZM	1	5974	76	2187539	2010040481	2010094937	01-10-40662	2010-10-08	10	6	6	31	0		UNIVERSITY AVE
25	25	Point ZM	1	6166	78	2187731	2010046212	2010080364	01-10-48160	2010-11-15	11	2	6	31	0		ASBURY RD
26	26	Point ZM	1	6182	31	2187867	2010045390	2010080583	2010-052017	2010-11-01	11	2	6	52	0		GRAND AVE
27	27	Point ZM	1	6184	93	2216410	2009002817	2009487410	01003401	2009-01-20	1	3	6	52	0		HOLIDAY RD & 12TH AVE
28	28	Point ZM	1	6335	94	2216411	2009002818	2009487421	01001521	2009-01-20	1	3	6	57	0		7TH AVE
29	29	Point ZM	1	7094	94	2216480	2009003388	2009484714	01003631	2009-01-11	1	1	6	57	0		7TH AVE & 7TH ST
30	30	Point ZM	1	9120	83	2220596	2009007195	2009527280	2009054851	2009-03-18	9	6	2	9	0	US 218	US 218 & BARRICK RD
31	31	Point ZM	1	9143	75	2220610	2009035202	2009534014	01-01-48306	2009-03-19	9	1	6	31	0		UNIVERSITY AVE
32	32	Point ZM	1	9199	72	2220671	2009037420	2009527618	01-01-48773	2009-09-28	9	2	6	31	0		GRACE ST & DELMI ST...
33	33	Point ZM	1	10185	76	2221661	2009053101	2009544098	01-01-50144	2009-12-27	12	1	6	31	0		UNIVERSITY AVE
34	34	Point ZM	1	11154	80	2222630	2010013483	2010082452	10-8864	2010-03-22	3	2	1	85	0		MATHEWS ST
35	35	Point ZM	1	11193	90	2223429	2010026587	2010107080	10066809	2010-08-25	8	2	2	7	0	IA 004	IA 004/UNIVERSITY AVE...
36	36	Point ZM	1	11973	98	2223440	2010027377	2010070029	2010002127	2010-07-04	7	1	1	77	0		BEAVER AVE
37	37	Point ZM	1	12400	45	2223876	2010033332	2010086617	2010003047102	2010-08-10	8	3	6	90	0	US 34	US 34
38	38	Point ZM	1	12485	99	2223961	2010035567	2010080466	10095488	2010-09-08	9	4	2	7	0	IA 004	IA 004/UNIVERSITY AVE...
39	39	Point ZM	1	13403	68	2224879	2010048875	2010093741	10024943	2010-12-05	12	6	6	57	0		LINDALE DR
40	40	Point ZM	1	14151	108	2225470	2010008434	2009494908		2009-02-08	2	1	6	57	0		WILEY BLVD NW & JOH...
41	41	Point ZM	1	14687	42	2226706	2010011448	2009498360	20011007	2009-01-14	1	4	6	57	0	US 30	US 30
42	42	Point ZM	1	15137	83	2226476	2010020064	2009508366	2009038016	2009-05-21	5	3	2	9	0	US 218	US 218 & BARRICK RD
43	43	Point ZM	1	15916	108	2226935	2009018560	2009510817	2009112854	2009-08-05	8	2	6	57	0		WILEY BLVD NW & JOH...
44	44	Point ZM	1	17071	93	2226410	2009026377	2009552116	01068994	2009-12-30	12	4	6	52	0		HOLIDAY RD
45	45	Point ZM	1	17145	45	2226482	2009026868	2009552010	2009003051443	2009-11-15	11	1	6	90	0	US 63	US 63
46	46	Point ZM	1	18289	79	2229324	2010015092	2010065309	01-10-54525	2010-04-25	4	2	6	31	0		UNIVERSITY AVE & ASB...
47	47	Point ZM	1	18664	60	2229393	2010022025	2010074716	10023117	2010-08-02	8	4	6	52	0		OAKDALE BLVD & 1ST ...
48	48	Point ZM	1	19447	68	2230196	2010034340	2010087765	10018262	2010-08-27	8	6	6	57	0		W 8TH AVE

	CITY_NAME	SYSTEMSTR	LITERAL	FIRSTHARM	LOCFIRSTHRM	CRCOMNNR	MAXCSE	DRUGALC	RCNTCRC	LIGHT	CSRFCND	WEATHER	RCNTCRC	RDTYP	PAVED	WZRELATED	CSEV	FATALITIES	INJURIES	MAJINJURY
1			1ST AVE S CONNECTIO...	33	1	3	24	3	1	4	5	2	2	13	1	0	5	0	0	0
2			UNIVERSITY AVE & GI...	33	1	5	7	8	1	4	1	1	1	12	1	0	5	0	0	0
3			NE RISING SUN DR	33	1	5	35	8	2	1	3	1	1	1	1	0	4	0	1	0
4			10TH AVE & CENTRAL...	33	1	3	70	8	1	1	1	1	1	1	1	0	4	0	1	0
5			GRANDVIEW AVE N	33	1	5	7	8	1	1	2	5	1	12	1	0	5	0	0	0
6			N FRONTAGE RD & M...	33	1	5	7	8	1	1	1	1	1	13	1	0	5	0	0	0
7			W 8TH AVE & LINDALE...	54	1	1	20	8	1	4	2	5	2	12	1	0	5	0	0	0
8			S GRAND AVE & UNIVE...	33	1	6	70	8	1	1	1	1	1	1	1	0	5	0	0	0
9			JOHNSON AVE NW	33	6	3	9	8	77	1	1	99	77	4	1	0	5	0	0	0
10			1ST AVE	33	1	6	8	8	1	1	2	5	1	97	1	0	5	0	0	0
11		IA 004	IA 004/UNIVERSITY AVE...	33	1	4	2	8	1	4	1	1	1	12	1	0	4	0	1	0
12			JACQUIN DR SW & BAC...	33	1	5	7	8	1	1	2	1	1	12	1	0	5	0	0	0
13			UNIVERSITY AVE & GI...	33	1	5	3	8	1	1	2	2	1	12	1	0	5	0	0	0
14			Co Rd W66/DUBUQUE...	33	1	3	45	8	2	1	4	7	2	1	1	0	4	0	1	0
15			OAKDALE BLVD & 1ST ...	33	1	5	7	8	1	4	1	1	1	12	1	0	5	0	0	0
16			7TH AVE	33	1	6	35	8	1	1	1	1	1	1	1	0	5	0	0	0
17			UNIVERSITY AVE	33	1	6	16	8	2	1	2	5	1	14	1	0	5	0	0	0
18		IA 004	IA 004/UNIVERSITY AVE...	33	1	4	9	8	1	1	1	1	1	12	1	0	5	0	0	0
19			35TH ST	33	1	5	7	8	1	1	1	1	1	12	1	0	5	0	0	0
20			W RIDGEWAY AVE	99	1	1	70	8	1	1	1	1	1	13	1	0	1	1	1	0
21			142ND ST	33	1	6	71	8	1	1	1	1	1	97	1	0	5	0	0	0
22		US 30	US 30 & IA 1/S 1ST AVE	33	1	5	7	8	1	1	1	1	1	12	1	0	5	0	1	0
23		IA 004	IA 004/UNIVERSITY AVE	33	1	3	24	8	1	1	1	1	1	1	1	0	5	0	0	0
24			UNIVERSITY AVE	33	1	5	10	8	1	1	1	1	1	4	1	0	5	0	0	0
25			ASBURY RD	33	1	5	10	8	1	1	1	1	1	4	1	0	4	0	1	0
26			GRAND AVE	33	1	3	24	8	1	1	1	1	1	97	1	0	5	0	0	0
27			HOLIDAY RD & 12TH AVE	33	1	6	45	8	1	1	2	2	2	1	1	0	5	0	0	0
28			7TH AVE	33	1	3	70	8	1	2	2	1	1	1	1	0	5	0	0	0
29			7TH AVE & 7TH ST	33	1	5	2	8	1	1	4	2	1	12	1	0	5	0	0	0
30		US 218	US 218 & BARRICK RD	33	1	5	7	8	1	1	1	1	1	12	1	0	2	0	2	2
31			UNIVERSITY AVE	33	1	3	24	8	1	2	1	1	1	1	1	0	5	0	0	0
32			GRACE ST & DELMI ST...	33	1	5	7	8	1	1	1	1	1	15	1	0	4	0	3	0
33			UNIVERSITY AVE	33	1	1	20	8	2	4	4	7	2	14	1	0	5	0	0	0
34			MATHEWS ST	33	1	3	16	8	5	1	1	1	1	12	1	0	5	0	0	0
35		IA 004	IA 004/UNIVERSITY AVE...	33	1	3	70	8	1	1	1	1	1	12	1	0	5	0	0	0
36			BEAVER AVE	33	1	3	45	8	1	1	2	5	1	1	1	0	4	0	1	0
37		US 34	US 34	33	1	3	20	7	1	1	1	99	1	13	1	0	3	0	2	0
38		IA 004	IA 004/UNIVERSITY AVE...	33	1	3	24	8	1	1	1	1	1	12	1	0	4	0	1	0
39			LINDALE DR	33	1	3	70	8	1	6	4	1	2	12	1	0	5	0	0	0
40			WILEY BLVD NW & JOH...	33	1	5	71	8	77	1	1	1	77	12	1	0	5	0	0	0
41		US 30	US 30	33	1	3	20	8	2	1	4	7	1	12	1	0	5	0	0	0
42		US 218	US 218 & BARRICK RD	33	1	5	7	8	1	1	1	1	1	97	1	0	4	0	4	0
43			WILEY BLVD NW & JOH...	33	1	4	9	8	1	1	1	1	1	12	1	0	5	0	0	0
44			HOLIDAY RD	33	1	3	20	8	1	4	98	7	2	12	1	0	4	0	1	0
45		US 63	US 63	48	1	1	42	8	2	1	2	5	1	1	1	0	5	0	0	0
46			UNIVERSITY AVE & ASB...	33	1	6	70	8	1	1	2	5	1	14	1	0	5	0	0	0
47			OAKDALE BLVD & 1ST ...	33	1	5	3	8	1	1	1	2	1	97	1	0	2	0	1	1
48			W 8TH AVE	33	1	5	7	8	1	1	1	1	1	13	1	0	5	0	0	0

2-2. Removing Unnecessary Columns in Crash_Data_Roundabouts

"In the 'Crash_Data_Roundabouts' dataset, we'll focus on retaining only the essential columns for our analysis. These include: 'OBJECTID', 'Shape', ‘XCOORD’, ’YCOORD’, 'JOIN_FID', 'CRASH_DATE', 'CSEV', 'FATALITIES', 'PROPDMG', 'Year_Open', 'Category', 'City', and 'County'. The 'Shape', ‘XCOORD’, and ’YCOORD’ columns provide spatial information (coordinates). 'Year_Open' indicates the construction year of the roundabouts, 'JOIN_FID' is the unique identifier for each roundabout, 'CSEV' represents crash severity, and 'PROPDMG' details the property damage."

To manually remove unnecessary columns, right-click on 'Crash_Data_Roundabouts' in the Contents pane, select 'Attribute Table', then right-click on the columns you wish to remove and choose 'Delete.



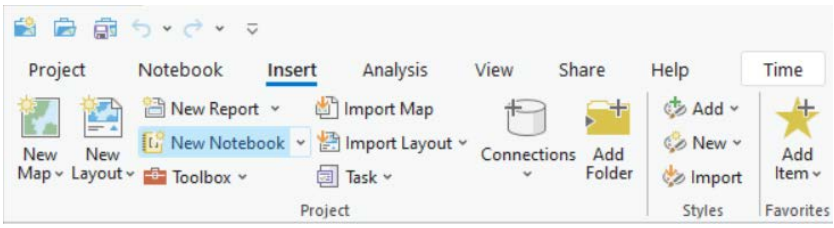
a. Streamlined ‘Crash_Data_Roundabouts’

	OBJECTID_1 *	Shape *	JOIN_FID	CRASH_DATE	CSEV	FATALITIES	PROPDMG	XCOORD	YCOORD	Year_Open	Category	City	County	Classifica
1	1	Point ZM	74	1/18/2009	5	0	3000	402829	4706531	2016	Modern Roundabout	Fort Dodge	Webster	Commercial
2	2	Point ZM	95	2/2/2009	5	0	1200	689968	4707698	2020	Modern Roundabout	Dubuque	Dubuque	Commercial
3	3	Point ZM	105	2/14/2009	4	0	4000	461011	4604945	2018	Modern Roundabout	Pleasant Hill	Polk	Commercial
4	4	Point ZM	97	4/14/2009	4	0	1800	615937	4654753		Planned Roundabout	Marion	Linn	Mini Roundabout
5	5	Point ZM	72	3/23/2009	5	0	2500	689989	4707556	2016	Modern Roundabout	Dubuque	Dubuque	Commercial
6	6	Point ZM	71	6/15/2009	5	0	1800	546552	4706933	2016	Modern Roundabout	Cedar Falls	Black Hawk	Commercial
7	7	Point ZM	68	7/24/2009	5	0	2000	614235	4654548	2019	Planned Roundabout	Marion	Linn	Residential
8	8	Point ZM	31	8/2/2009	5	0	1750	621097	4612888	2007	Modern Roundabout	Iowa City	Johnson	Commercial
9	9	Point ZM	103	9/10/2009	5	0	2745	605616	4647395	2019	Modern Roundabout	Cedar Rapids	Linn	Commercial
10	10	Point ZM	22	11/18/2009	5	0	1600	619274	4616659	2002	Modern Roundabout	Coralville	Johnson	Residential
11	11	Point ZM	99	12/29/2009	4	0	10000	548373	4706208	2017	Modern Roundabout	Cedar Falls	Black Hawk	Commercial
12	12	Point ZM	92	1/1/2010	5	0	2500	605080	4647106	2019	Modern Roundabout	Cedar Rapids	Linn	Commercial
13	13	Point ZM	95	1/12/2010	5	0	3100	689968	4707698	2020	Modern Roundabout	Dubuque	Dubuque	Commercial
14	14	Point ZM	65	1/25/2010	4	0	11500	619719	4619943	2022	Planned Roundabout	Coralville	Johnson	Residential
15	15	Point ZM	60	2/11/2010	5	0	3100	619590	4617624	2020	Planned Roundabout	Coralville	Johnson	Residential
16	16	Point ZM	56	4/9/2010	5	0	3000	617291	4654440	2016	Modern Roundabout	Marion	Linn	Commercial
17	17	Point ZM	76	5/7/2010	5	0	1600	689302	4707827	2020	Planned Roundabout	Dubuque	Dubuque	Commercial
18	18	Point ZM	99	5/27/2010	5	0	2500	548373	4706208	2017	Modern Roundabout	Cedar Falls	Black Hawk	Commercial
19	19	Point ZM	58	7/16/2010	5	0	5000	617966	4656349	2016	Modern Roundabout	Marion	Linn	Residential
20	20	Point ZM	14	8/7/2010	1	1	0	544838	4702053	2011	Modern Roundabout	Cedar Falls	Black Hawk	Commercial
21	21	Point ZM	47	8/23/2010	5	0	5500	432611	4608886	2017	Modern Roundabout	Urbandale	Polk	Residential
22	22	Point ZM	42	10/9/2010	3	0	3000	630774	4641663	2013	Modern Roundabout	Mount Vernon	Linn	Commercial
23	23	Point ZM	94	10/23/2010	5	0	3000	547100	4706888		Modern Roundabout	Cedar Falls	Black Hawk	Residential
24	24	Point ZM	76	10/8/2010	5	0	2500	689284	4707830	2020	Planned Roundabout	Dubuque	Dubuque	Commercial
25	25	Point ZM	76	11/15/2010	4	0	3000	689272	4707878	2020	Planned Roundabout	Dubuque	Dubuque	Commercial
26	26	Point ZM	31	11/1/2010	5	0	3300	621105	4612885	2007	Modern Roundabout	Iowa City	Johnson	Commercial
27	27	Point ZM	59	1/20/2009	5	0	4200	617924	4616873	2015	Modern Roundabout	Coralville	Johnson	Residential
28	28	Point ZM	54	1/20/2009	5	0	11000	615702	4654421	2016	Modern Roundabout	Marion	Linn	Commercial
29	29	Point ZM	54	1/11/2009	5	0	10000	615655	4654420	2016	Modern Roundabout	Marion	Linn	Commercial

3. Advanced Data Preprocessing with Python in Jupyter Notebook

Python in ArcGIS Pro offers powerful scripting capabilities for spatial analysis and automating geoprocessing tasks. Jupyter Notebooks, integrated within ArcGIS Pro, provide an interactive environment where you can write and execute Python code, visualize data, and document the process in a single, easy-to-use interface.

To open a new Notebook in ArcGIS Pro, go to the Navigation bar, click on ‘Insert’, and then select ‘New Notebook’.




```
In [1]: print("Hello, World")
        Hello, World
```

3-1. Loading 'Crash_Data_Roundabouts' Layer into a Pandas DataFrame in Jupyter Notebook

The code snippet below will access the "Crash_Data_Roundabouts" layer from an ArcGIS Pro project and converts it into a pandas DataFrame. It will retrieve all data and field names from the layer, allowing for efficient data manipulation and analysis within a Jupyter Notebook environment.

```
import arcpy
import pandas as pd
# Access the current ArcGIS Pro project
project = arcpy.mp.ArcGISProject("CURRENT")
arcmap = project.listMaps("Layers")[0]
# Access the "Crash_Data_Roundabouts" layer
layer = [lyr for lyr in arcmap.listLayers() if lyr.name == "Crash_Data_Roundabouts"][0]
# Use SearchCursor to extract data from the layer
data = [row for row in arcpy.da.SearchCursor(layer, "*")]
# Get the field names
field_names = [field.name for field in arcpy.ListFields(layer)]
# Create a pandas DataFrame from the data
original_data = pd.DataFrame(data, columns=field_names)
# Display DataFrame 'original_data'
original_data.head()
```

	OBJECTID_1	Shape	JOIN_FID	CRASH_DATE	CSEV	FATALITIES	PROPDMG	XCOORD	YCOORD	Year_Open	Category	City	County	Classifica
0	1	(-94.18270383781186, 42.505045555208255)	74	2009-01-18	5	0	3000	402829	4706531	2016	Modern Roundabout	Fort Dodge	Webster	Commercial
1	2	(-90.68811838405617, 42.498333890496724)	95	2009-02-02	5	0	1200	689968	4707698	2020	Modern Roundabout	Dubuque	Dubuque	Commercial
2	3	(-93.46782795179848, 41.59525399037943)	105	2009-02-14	4	0	4000	461011	4604945	2018	Modern Roundabout	Pleasant Hill	Polk	Commercial
3	4	(-91.5993114487643, 42.03627658719478)	97	2009-04-14	4	0	1800	615937	4654753		Planned Roundabout	Marion	Linn	Mini Roundabout
4	5	(-90.68791011905671, 42.4970509437461)	72	2009-03-23	5	0	2500	689989	4707556	2016	Modern Roundabout	Dubuque	Dubuque	Commercial

3-2. Converting CRASH_DATE to YEAR (From YYYY-MM-DD to YYYY)

```
original_data['CRASH_DATE'] = pd.to_datetime(original_data['CRASH_DATE']).dt.year
# Display the DataFrame to verify the new 'YEAR' column
original_data
```

3-3. Reversing Severity Scale in 'CSEV'

The original 'Severity' column ranges from 1 to 5, with 5 indicates crashes involving unknown injuries and 1 indicates the most severe incidents, potentially involving fatalities. For enhanced clarity in our visualization, we will reverse this order in the 'CSEV' column. After this adjustment, a severity rating of 1 will indicate unknown injuries, while a rating of 5 will represent the most severe cases with potential fatalities.

```
# Remap 'CSEV' column values
original_data['CSEV'] = 6 - original_data['CSEV']
# Display the DataFrame to verify the changes
original_data
```

3-4. Adding ‘Standard’ Column

To analyze the impact of roundabouts on crash occurrences, we will introduce a new column, 'standard', with three categories: 'Before', 'After', and 'Same'. This categorization is based on comparing 'CRASH_DATE' with 'Year_Open'. If the 'CRASH_DATE' occurs before 'Year_Open', the category is set to 'Before'. If it occurs after, it's classified as 'After'. When both dates are the same, the category is marked as 'Same'.

```
# Replace non-numeric values in 'Year_Open' with NaN, then convert to integer
original_data['Year_Open'] = pd.to_numeric(original_data['Year_Open'], errors='coerce').fillna(0).astype(int)
# Remove rows where 'Year_Open' is 0
original_data = original_data[original_data['Year_Open'] != 0]
# Function to determine the standard category
def categorize(row):
    if row['CRASH_DATE'] < row['Year_Open']:
        return 'Before'
    elif row['CRASH_DATE'] > row['Year_Open']:
        return 'After'
    else:
        return 'Same'
# Apply the function to create the 'standard' column
original_data['standard'] = original_data.apply(categorize, axis=1)
# Display the DataFrame to verify the changes
original_data.head()
```

	OBJECTID_1	Shape	JOIN_FID	CRASH_DATE	CSEV	FATALITIES	PROPDMG	XCOORD	YCOORD	Year_Open	Category	City	County	Classifica	standard
0	1	(-94.18270383781186, 42.505045555208255)	74	2009	1	0	3000	402829	4706531	2016	Modern Roundabout	Fort Dodge	Webster	Commercial	Before
1	2	(-90.68811838405617, 42.498333890496724)	95	2009	1	0	1200	689968	4707698	2020	Modern Roundabout	Dubuque	Dubuque	Commercial	Before
2	3	(-93.46782795179848, 41.59525399037943)	105	2009	2	0	4000	461011	4604945	2018	Modern Roundabout	Pleasant Hill	Polk	Commercial	Before
4	5	(-90.68791011905671, 42.4970509437461)	72	2009	1	0	2500	689989	4707556	2016	Modern Roundabout	Dubuque	Dubuque	Commercial	Before
5	6	(-92.43332062784464, 42.51336786973144)	71	2009	1	0	1800	546552	4706933	2016	Modern Roundabout	Cedar Falls	Black Hawk	Commercial	Before

3-5 Excluding Roundabouts with Insufficient Crash Data History

To ensure a comprehensive comparison, we will remove roundabouts constructed between 2000 and 2011, as well as those constructed in 2021, 2022, and 2023. This is because our crash data spans from 2009 to 2023, and we aim to have at least three years of crash data (2009, 2010, 2011) for each roundabout for a robust analysis.

```
# Make a copy of 'original_data'
df_total = original_data.copy()
# Get sorted list of unique 'Year_Open' values
sorted_unique_years = sorted(df_total['Year_Open'].unique())
# Identify the first two and last two 'Year_Open' values
first_ten_years = sorted_unique_years[:10]
last_two_years = sorted_unique_years[-2:]
# Combine the years to be removed
years_to_remove = first_ten_years + last_two_years
#Unique Year List
unique_years = [x for x in sorted_unique_years if x not in years_to_remove]
# Drop rows where 'Year_Open' is in years_to_remove
df_total = df_total[~df_total['Year_Open'].isin(years_to_remove)]
df_total.head()
```

	OBJECTID_1	Shape	JOIN_FID	CRASH_DATE	CSEV	FATALITIES	PROPDMG	XCOORD	YCOORD	Year_Open	Category	City	Co
0	1	(-94.18270383781186, 42.505045555208255)	74	2009	1	0	3000	402829	4706531	2016	Modern Roundabout	Fort Dodge	We
2	3	(-93.46782795179848, 41.59525399037943)	105	2009	2	0	4000	461011	4604945	2018	Modern Roundabout	Pleasant Hill	
4	5	(-90.68791011905671, 42.4970509437461)	72	2009	1	0	2500	689989	4707556	2016	Modern Roundabout	Dubuque	Dub
5	6	(-92.43332062784464, 42.51336786973144)	71	2009	1	0	1800	546552	4706933	2016	Modern Roundabout	Cedar Falls	
6	7	(-91.61990822948115, 42.03467983550604)	68	2009	1	0	2000	614235	4654548	2019	Planned Roundabout	Marion	

3-6. Analyzing Crash Data Relative to Roundabout Construction Years

To analyze the impact of roundabout construction on road safety, we group crash data by each roundabout's identifier ('JOIN_FID') and the crash dates. We pivot this data to align each roundabout's crash history with its construction year. Then, we calculate the average number of crashes before and after each roundabout was built. The resulting DataFrame, 'crash_count', clearly shows how crash frequencies change relative to the construction dates of roundabouts. For further analysis, key columns like 'FID', 'Year_Open', 'Avg_Before', and 'Avg_After' are saved in a new DataFrame named "Crash".

```
crash_count = df_total.groupby(['JOIN_FID', 'CRASH_DATE']).size().reset_index(name='count')
crash_count = crash_count.pivot(index='JOIN_FID', columns='CRASH_DATE', values='count').fillna(0)
crash_count['Total'] = crash_count.sum(axis=1)
crash_count = crash_count[crash_count['Total'] >= 12]
# Create the mapping of JOIN_FID to Year_Open
year_open = df_total.groupby('JOIN_FID')['Year_Open'].first()
# Join this mapping with the crash_count DataFrame
crash_count = crash_count.join(year_open, on='JOIN_FID')
# Reorder columns to put Year_Open at the beginning
crash_count = crash_count[['Year_Open'] + [col for col in crash_count.columns if col != 'Year_Open']]
# Calculate Avg_Before, Avg_After
for index, row in crash_count.iterrows():
    year_open = row['Year_Open']
    years_before = [col for col in crash_count.columns[1:] if isinstance(col, int) and col < year_open]
    years_after = [col for col in crash_count.columns[1:] if isinstance(col, int) and col > year_open]
    avg_before = row[years_before].sum() / len(years_before) if years_before else 0
    avg_after = row[years_after].sum() / len(years_after) if years_after else 0
    crash_count.at[index, 'Avg_Before'] = avg_before
    crash_count.at[index, 'Avg_After'] = avg_after
# Convert all columns to integers except 'Avg_Before' and 'Avg_After'
int_columns = [col for col in crash_count.columns if col not in ['Avg_Before', 'Avg_After', 'Year_Open']]
crash_count[int_columns] = crash_count[int_columns].fillna(0).astype(int)
# Round 'Avg_Before' and 'Avg_After' to four decimal places
crash_count['Avg_Before'] = crash_count['Avg_Before'].round(4)
crash_count['Avg_After'] = crash_count['Avg_After'].round(4)
# Calculate and append the average of averages
avg_of_avgs = pd.DataFrame({'Avg_Before': [crash_count['Avg_Before'].mean()],
                            'Avg_After': [crash_count['Avg_After'].mean()]},
                           index=['Average'])
crash_count = pd.concat([crash_count, avg_of_avgs])
# Reset index and rename columns
crash_count = crash_count.reset_index()
crash_count = crash_count.rename(columns={'index': 'FID'})
# Display the updated DataFrame
crash_count
```

	FID	Year_Open	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total	Avg_Before	Avg_After
0	1	2013.0	0.0	0.0	0.0	1.0	4.0	2.0	3.0	1.0	4.0	5.0	4.0	2.0	9.0	12.0	10.0	57.0	0.250000	5.200000
1	26	2014.0	0.0	0.0	0.0	1.0	1.0	2.0	1.0	1.0	0.0	1.0	0.0	0.0	3.0	0.0	2.0	12.0	0.400000	0.888900
2	30	2013.0	0.0	1.0	0.0	0.0	3.0	0.0	3.0	0.0	2.0	1.0	1.0	2.0	1.0	0.0	0.0	14.0	0.250000	1.000000
3	33	2012.0	9.0	3.0	3.0	2.0	1.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.0	5.000000	0.363600
4	35	2012.0	1.0	0.0	0.0	0.0	3.0	1.0	0.0	1.0	0.0	2.0	1.0	2.0	0.0	4.0	0.0	15.0	0.333300	1.272700
5	36	2012.0	1.0	0.0	2.0	1.0	0.0	4.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	12.0	1.000000	0.727300
6	38	2012.0	0.0	1.0	2.0	1.0	4.0	3.0	2.0	0.0	0.0	4.0	3.0	0.0	1.0	2.0	1.0	24.0	1.000000	1.818200
7	42	2013.0	3.0	7.0	6.0	7.0	9.0	13.0	18.0	17.0	22.0	19.0	19.0	9.0	15.0	6.0	2.0	172.0	5.750000	14.000000
8	43	2013.0	3.0	2.0	3.0	1.0	2.0	1.0	3.0	1.0	4.0	3.0	4.0	0.0	0.0	0.0	0.0	27.0	2.250000	1.600000
9	47	2017.0	1.0	5.0	0.0	3.0	5.0	4.0	6.0	3.0	4.0	2.0	7.0	10.0	5.0	13.0	14.0	82.0	3.375000	8.500000
10	53	2017.0	2.0	0.0	0.0	0.0	3.0	1.0	4.0	2.0	4.0	1.0	3.0	1.0	3.0	2.0	2.0	28.0	1.500000	2.000000
11	54	2016.0	12.0	3.0	5.0	3.0	2.0	6.0	8.0	7.0	7.0	9.0	12.0	11.0	5.0	10.0	9.0	109.0	5.571400	9.000000
12	56	2016.0	0.0	2.0	1.0	1.0	1.0	0.0	1.0	1.0	1.0	1.0	0.0	2.0	3.0	4.0	5.0	23.0	0.857100	2.285700
13	57	2014.0	3.0	1.0	2.0	2.0	3.0	0.0	2.0	0.0	2.0	2.0	0.0	2.0	0.0	1.0	0.0	20.0	2.200000	1.000000
14	58	2016.0	0.0	5.0	5.0	3.0	5.0	7.0	4.0	8.0	5.0	5.0	3.0	5.0	5.0	2.0	6.0	68.0	4.142900	4.428600
15	59	2015.0	8.0	2.0	3.0	1.0	1.0	3.0	0.0	5.0	4.0	3.0	1.0	4.0	4.0	7.0	2.0	48.0	3.000000	3.750000
16	68	2019.0	2.0	3.0	2.0	0.0	2.0	2.0	5.0	3.0	1.0	1.0	2.0	2.0	1.0	3.0	1.0	30.0	2.100000	1.750000
17	69	2016.0	0.0	0.0	1.0	1.0	2.0	0.0	0.0	1.0	0.0	3.0	3.0	2.0	4.0	2.0	3.0	22.0	0.571400	2.428600
18	70	2016.0	0.0	0.0	0.0	1.0	2.0	2.0	0.0	0.0	11.0	22.0	8.0	12.0	14.0	16.0	18.0	106.0	0.714300	14.428600
19	71	2016.0	4.0	6.0	4.0	4.0	2.0	7.0	4.0	6.0	1.0	3.0	2.0	3.0	5.0	2.0	2.0	55.0	4.428600	2.571400
20	72	2016.0	6.0	4.0	3.0	2.0	6.0	6.0	4.0	4.0	8.0	7.0	5.0	4.0	2.0	4.0	5.0	70.0	4.428600	5.000000
21	73	2015.0	0.0	1.0	1.0	2.0	0.0	1.0	1.0	0.0	1.0	2.0	1.0	0.0	2.0	0.0	0.0	12.0	0.833300	0.750000
22	74	2016.0	2.0	2.0	2.0	2.0	4.0	3.0	3.0	3.0	3.0	2.0	5.0	2.0	6.0	2.0	3.0	44.0	2.571400	3.285700
23	81	2017.0	1.0	0.0	0.0	2.0	1.0	4.0	3.0	0.0	6.0	3.0	0.0	9.0	6.0	7.0	7.0	49.0	1.375000	5.333300
24	82	2017.0	0.0	0.0	1.0	2.0	1.0	0.0	1.0	1.0	2.0	1.0	0.0	0.0	2.0	1.0	0.0	12.0	0.750000	0.666700
25	83	2016.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	5.0	1.0	0.0	3.0	0.0	2.0	13.0	0.000000	1.857100
26	87	2019.0	2.0	3.0	3.0	3.0	2.0	2.0	8.0	1.0	1.0	0.0	1.0	1.0	2.0	1.0	0.0	30.0	2.500000	1.000000
27	88	2018.0	0.0	3.0	3.0	3.0	5.0	5.0	3.0	7.0	1.0	0.0	2.0	3.0	6.0	2.0	3.0	46.0	3.333300	3.200000
28	89	2019.0	2.0	0.0	1.0	2.0	3.0	2.0	2.0	1.0	2.0	1.0	1.0	2.0	1.0	2.0	2.0	24.0	1.600000	1.750000
29	90	2012.0	0.0	1.0	0.0	0.0	1.0	1.0	2.0	6.0	2.0	2.0	3.0	3.0	6.0	7.0	2.0	36.0	0.333300	3.181800
30	91	2019.0	1.0	0.0	2.0	4.0	1.0	3.0	1.0	3.0	3.0	2.0	1.0	2.0	2.0	2.0	0.0	27.0	2.000000	1.500000
31	92	2019.0	0.0	7.0	8.0	3.0	3.0	6.0	2.0	8.0	3.0	4.0	4.0	1.0	1.0	2.0	1.0	53.0	4.400000	1.250000
32	93	2017.0	1.0	2.0	3.0	3.0	2.0	2.0	1.0	2.0	3.0	3.0	2.0	1.0	2.0	2.0	2.0	31.0	2.000000	2.000000
33	99	2017.0	8.0	10.0	5.0	5.0	7.0	6.0	7.0	5.0	8.0	6.0	2.0	3.0	7.0	6.0	6.0	91.0	6.625000	5.000000
34	103	2019.0	9.0	5.0	7.0	6.0	4.0	6.0	3.0	6.0	2.0	4.0	1.0	3.0	7.0	2.0	2.0	67.0	5.200000	3.500000
35	104	2019.0	0.0	1.0	1.0	1.0	1.0	0.0	0.0	1.0	0.0	0.0	3.0	1.0	0.0	3.0	1.0	13.0	0.500000	1.250000
36	Average	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	2.309553	3.320506

3-7. Creating Roundabout Crash Data Bar Charts with Matplotlib

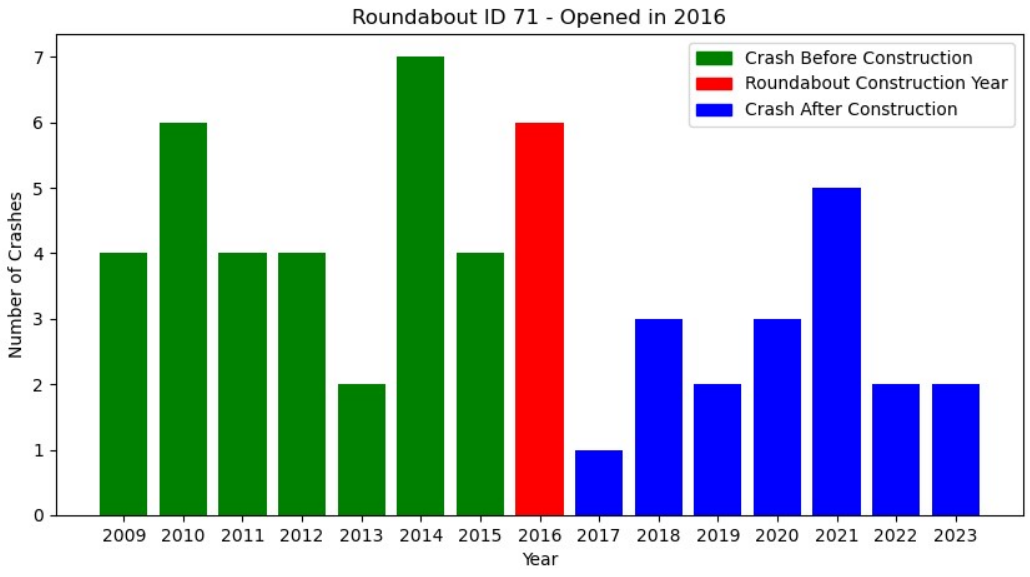
To plot a bar chart for each roundabout's crash data, we will utilize Matplotlib, a powerful plotting library in Python. The code will prompt the user to specify a directory where the charts should be saved. It will then create a new folder in that directory to store the individual bar charts.

For each roundabout, identified by 'FID', we will generate a bar chart showing the number of crashes per year. These charts will be color-coded: years before the roundabout's

construction will be marked in green, the construction year in red, and years after construction in blue. This color scheme will help in visually distinguishing the data points relative to the roundabout's construction year.

After creating each chart, we will add a legend to clarify the color coding and then save the chart as a PNG file in the designated folder. The code will loop through all the roundabouts in the 'crash_count' DataFrame, ensuring each one has a corresponding bar chart, which will be stored in the newly created folder. This systematic approach allows for an efficient and organized way to analyze and visualize the crash data in relation to the construction years of roundabouts.

```
import os
import matplotlib.pyplot as plt
import matplotlib.patches as mpatches
# Ask the user for a directory to save the charts
save_path = input("Enter the directory path where you want to save the charts: ")
# Create a new folder in the specified directory
folder_name = "Roundabout_Crash_Data_Charts"
full_path = os.path.join(save_path, folder_name)
os.makedirs(full_path, exist_ok=True)
# Iterate through each row in the DataFrame
for index, row in crash_count.iterrows():
    year_open = int(row['Year_Open'])
    roundabout_id = row['FID']
    # Prepare data for the bar chart
    years = [year for year in range(2009, 2024)]  # Adjust the range as per your data
    values = [row[year] for year in years]
    colors = ['green' if year < year_open else 'red' if year == year_open else 'blue' for year in years]
    # Create the bar chart
    plt.figure(figsize=(10, 5))
    plt.bar(years, values, color=colors)
    plt.title(f'Roundabout ID {roundabout_id} - Opened in {year_open}')
    plt.xlabel('Year')
    plt.ylabel('Number of Crashes')
    plt.xticks(years)
    # Create custom legends
    green_patch = mpatches.Patch(color='green', label='Crash Before Construction')
    red_patch = mpatches.Patch(color='red', label=f'Roundabout Construction Year')
    blue_patch = mpatches.Patch(color='blue', label='Crash After Construction')
    plt.legend(handles=[green_patch, red_patch, blue_patch])
    # Save the plot
    file_name = f"{roundabout_id}.png"
    plt.savefig(os.path.join(full_path, file_name))
    plt.close()
print(f"All charts saved in {full_path}")
```



3-8 Uploading Roundabout Crash Data Charts to AWS S3 Bucket

To display bar charts on an interactive online map, we need to save the PNG files to a server and include their URLs in the "Crash" DataFrame we created earlier. We will use Amazon Web Services (AWS) S3 bucket for hosting these files. Alternatively, if you have a different server or cloud service, you can upload the charts there and use those URLs instead. Here is how to proceed with this task:

i. Set Up AWS Account and S3 Bucket:

First, you need to have an AWS account. If you don’t have one, you can create it at AWS Management Console.

Once logged in, navigate to the S3 service and create a new bucket. While creating it, you can set the bucket's privacy settings. Make sure to comply with AWS's best practices for security and privacy.

ii. Upload Files to the S3 Bucket:

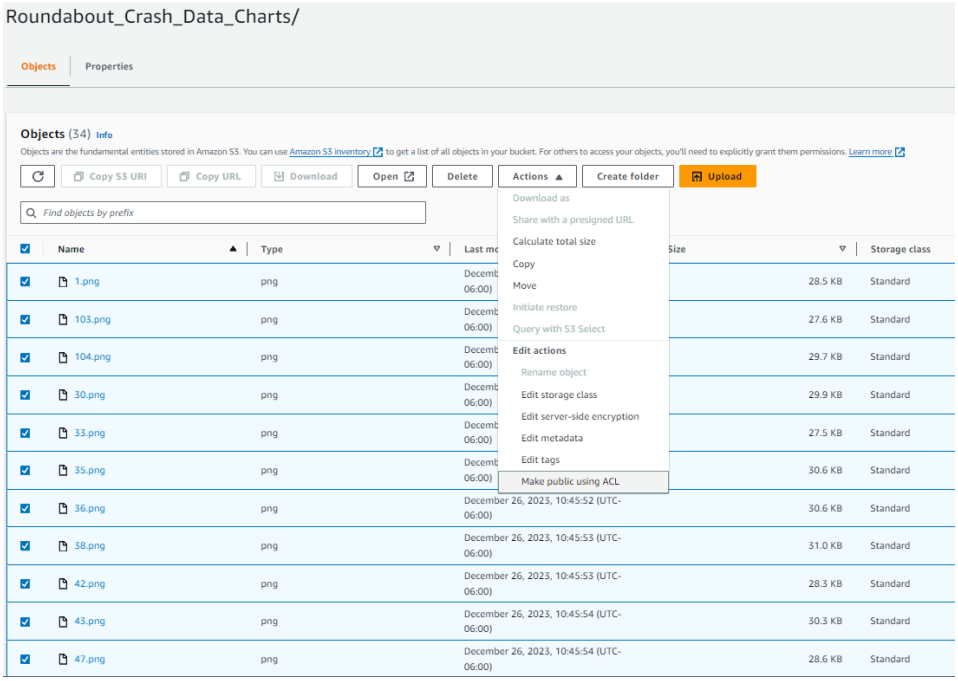
Once your bucket is set up, you can upload your files. Navigate to the 'Roundabout_Crash_Data_Charts' folder we created and proceed to upload your files there.

iii. Set Access Control List (ACL) for Public Access:

To make an individual file publicly accessible, you need to change its ACL (Access Control List).

In the S3 console, select the file, then choose the 'Permissions' tab. Under the 'Access control list (ACL)' section, you can set the file to be publicly readable.

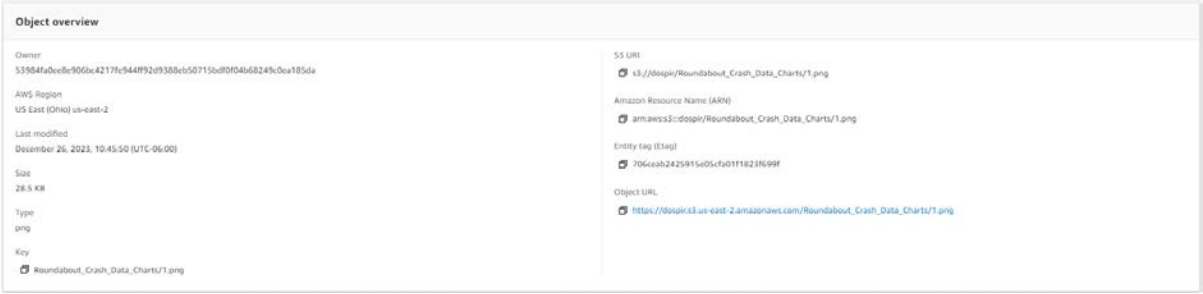
Be cautious with public access as it allows anyone on the internet to view or download the file.



iv. Retrieve the File URL:

Once the file is uploaded and the ACL is set, each file in the S3 bucket has a unique URL.

You can find this URL in the S3 console by selecting the file. The 'Object URL' is typically in the format: https://[bucket-name].s3.[region].amazonaws.com/[filename].



3-9 Add URL to the DataFrame

To integrate the URLs of our saved bar charts into the 'Crash' DataFrame, we add a new column titled 'URL'. This is achieved by concatenating a base URL with the 'FID' of each roundabout, followed by the '.png' file extension, creating a complete URL for each corresponding bar chart. The base URL points to the location where the charts are stored on the AWS S3 bucket, ensuring each 'URL' column entry is a direct link to the respective bar chart image. We also adjust the DataFrame display settings to ensure the full URLs are visible without truncation.

```
# Assuming 'Crash' is your existing DataFrame
base_url = "https://dospir.s3.us-east-2.amazonaws.com/Roundabout_Crash_Data_Charts/"
# Add a new column 'URL' to the DataFrame
Crash['URL'] = Crash['FID'].apply(lambda x: f"{base_url}{x}.png")
# Set option to display full content in a DataFrame column
pd.set_option('display.max_colwidth', None)
# Display the DataFrame to verify the new 'URL' column
Crash
```

	FID	Year_Open	Avg_Before	Avg_After	URL
0	1	2013.0	0.2500	5.2000	https://dospir.s3.us-east-2.amazonaws.com/Roundabout_Crash_Data_Charts/1.png
1	26	2014.0	0.4000	0.8889	https://dospir.s3.us-east-2.amazonaws.com/Roundabout_Crash_Data_Charts/26.png
2	30	2013.0	0.2500	1.0000	https://dospir.s3.us-east-2.amazonaws.com/Roundabout_Crash_Data_Charts/30.png
3	33	2012.0	5.0000	0.3636	https://dospir.s3.us-east-2.amazonaws.com/Roundabout_Crash_Data_Charts/33.png
4	35	2012.0	0.3333	1.2727	https://dospir.s3.us-east-2.amazonaws.com/Roundabout_Crash_Data_Charts/35.png

3-10 Calculating and Integrating Average Crash Severity and Property Damage

To calculate the average crash severity ('CSEV') and property damage ('PROPDMG') before and after roundabout construction, we will use a custom Python function. This function ensures accurate averaging, even in cases where all data points are zero. It calculates the average 'CSEV' and 'PROPDMG' for each roundabout, separated into 'Before' and 'After' construction categories. We then group our data by each roundabout's unique identifier ('JOIN_FID') and apply this function. Finally, to focus on relevant roundabouts, we filter these averages to include only those found in our 'Crash' DataFrame, ensuring our analysis is specific and targeted.

```
# Function to calculate average, keeping zero values if they are the only ones present
def calculate_average(df, column):
    if df[column].eq(0).all():  # If all values are zero
        return 0
    else:
        return df[df[column] != 0][column].mean()  # Calculate average excluding zeros

# Group by 'JOIN_FID' and calculate averages using the custom function
avg_df = df_total.groupby('JOIN_FID').apply(lambda x: pd.Series({
    'CSEV_Before': calculate_average(x[x['standard'] == 'Before'], 'CSEV'),
    'CSEV_After': calculate_average(x[x['standard'] == 'After'], 'CSEV'),
    'PROPDMG_Before': calculate_average(x[x['standard'] == 'Before'], 'PROPDMG'),
    'PROPDMG_After': calculate_average(x[x['standard'] == 'After'], 'PROPDMG')
})).reset_index()
# Filter out rows where JOIN_FID is not in Crash's unique FID list
unique_fid_list = Crash['FID'].unique()
avg_df = avg_df[avg_df['JOIN_FID'].isin(unique_fid_list)]
# Display the resulting DataFrame
avg_df.head()
```

	JOIN_FID	CSEV_Before	CSEV_After	PROPDMG_Before	PROPDMG_After
0	1	3.0	1.250000	13500.0	3939.423077
3	26	1.5	1.000000	3000.0	7306.250000
4	30	1.0	1.200000	7500.0	3878.000000
5	33	1.8	1.000000	9280.0	9325.000000
7	35	1.0	1.142857	2500.0	4310.714286

Next, we will create a new DataFrame, 'Average', as a copy of the previously created 'Crash' DataFrame. Into 'Average', we will integrate the calculated average crash severity and property damage data. This integration is done by merging 'Average' with our calculated averages dataframe ('avg_df'), ensuring that each roundabout's unique identifier ('FID') in 'Crash' aligns with 'JOIN_FID' in 'avg_df'. After the merge, we'll drop any redundant columns and refine the data, including rounding specific columns to the desired decimal places and converting identifier columns to integers.

```
# Create a copy of the 'Crash' DataFrame
Average = Crash.copy()
# Merge 'Average' with 'avg_df'
# Ensure that 'JOIN_FID' in 'avg_df' matches 'FID' in 'Average'
Average = Average.merge(avg_df, left_on='FID', right_on='JOIN_FID', how='left')
# Drop the extra 'JOIN_FID' column if not needed
Average.drop('JOIN_FID', axis=1, inplace=True)
# Round 'Avg_Before' and 'Avg_After' to four decimal places
Average['Avg_Before'] = crash_count['Avg_Before'].round(4)
Average['Avg_After'] = crash_count['Avg_After'].round(4)
# Convert 'FID' and 'Year_Open' to integers
Average['FID'] = Average['FID'].astype(int)
Average['Year_Open'] = Average['Year_Open'].astype(int)
# Round the other specified columns to three decimal places
columns_to_round = ['Crash_Before', 'Crash_After', 'CSEV_Before', 'CSEV_After',
                    'PROPDMG_Before', 'PROPDMG_After', 'Avg_Before', 'Avg_After']
Average[columns_to_round] = Average[columns_to_round].round(3)
# Display the updated DataFrame
Average.head()
```

	FID	Year_Open	Crash_Before	Crash_After	URL	CSEV_Before	CSEV_After	PROPDMG_Before	PROPDMG_After	Avg_Before	Avg_After
0	1	2013	0.250	5.200	https://dospir.s3.us-east-2.amazonaws.com/Roundabout_Crash_Data_Charts/1.png	3.0	1.250	13500.0	3939.423	0.250	5.200
1	26	2014	0.400	0.889	https://dospir.s3.us-east-2.amazonaws.com/Roundabout_Crash_Data_Charts/26.png	1.5	1.000	3000.0	7306.250	0.400	0.889
2	30	2013	0.250	1.000	https://dospir.s3.us-east-2.amazonaws.com/Roundabout_Crash_Data_Charts/30.png	1.0	1.200	7500.0	3878.000	0.250	1.000
3	33	2012	5.000	0.364	https://dospir.s3.us-east-2.amazonaws.com/Roundabout_Crash_Data_Charts/33.png	1.8	1.000	9280.0	9325.000	5.000	0.364
4	35	2012	0.333	1.273	https://dospir.s3.us-east-2.amazonaws.com/Roundabout_Crash_Data_Charts/35.png	1.0	1.143	2500.0	4310.714	0.333	1.273

To export this DataFrame ‘Average’ to an excel file, you can use ‘to_excel’ method provided by pandas.

```
# Export the DataFrame 'Average' to an Excel file
excel_filename = 'data/Average_Data.xlsx'
Average.to_excel(excel_filename, index=False)
print(f"'{excel_filename}' has been saved.")
```

	A	B	C	D	E	F	G	H	I
1	FID	Year_Open	Crash_B	Crash_A	URL	CSEV_B	CSEV_A	PROPDMG_B	PROPDMG_A
2	1	2013	0.25	5.2	https://dospir.s3.us-east-2.amazonaws.com/Roundabout_Crash_Data_Charts/1.png	3	1.25	13500	3939.423
3	26	2014	0.4	0.889	https://dospir.s3.us-east-2.amazonaws.com/Roundabout_Crash_Data_Charts/26.png	1.5	1	3000	7306.25
4	30	2013	0.25	1	https://dospir.s3.us-east-2.amazonaws.com/Roundabout_Crash_Data_Charts/30.png	1	1.2	7500	3878
5	33	2012	5	0.364	https://dospir.s3.us-east-2.amazonaws.com/Roundabout_Crash_Data_Charts/33.png	1.8	1	9280	9325
6	35	2012	0.333	1.273	https://dospir.s3.us-east-2.amazonaws.com/Roundabout_Crash_Data_Charts/35.png	1	1.143	2500	4310.714
7	36	2012	1	0.727	https://dospir.s3.us-east-2.amazonaws.com/Roundabout_Crash_Data_Charts/36.png	1	1	2500	3490
8	38	2012	1	1.818	https://dospir.s3.us-east-2.amazonaws.com/Roundabout_Crash_Data_Charts/38.png	2	1.1	2233.333	4452.5
9	42	2013	5.75	14	https://dospir.s3.us-east-2.amazonaws.com/Roundabout_Crash_Data_Charts/42.png	1.261	1.279	6715.217	5717.307
10	43	2013	2.25	1.7	https://dospir.s3.us-east-2.amazonaws.com/Roundabout_Crash_Data_Charts/43.png	1.556	1.412	8222.222	6887.824

4. Enhancing ArcGIS Pro Maps with Interactive Charts and Data Pop-ups

To enhance the interactivity of our ArcGIS Pro map, we will integrate the charts and dataframe that we have meticulously prepared. This task is accomplished using two pivotal functionalities within ArcGIS Pro. Initially, we'll employ the "Calculate Field" tool, a more stable alternative to exporting dataframes through a Jupyter Notebook—a method which, while possible, tends to be susceptible to crashes and lacks reliability. By leveraging "Calculate Field," we can seamlessly modify and incorporate our data into the active map layer.

Following this integration, we will enrich the map's user experience by configuring pop-ups with the "Configure Pop-ups" feature. This will not only display the geographic information but will also imbue the map with dynamic visual elements and provide data-driven insights via the interactive charts and pop-ups, making the map both informative and engaging.

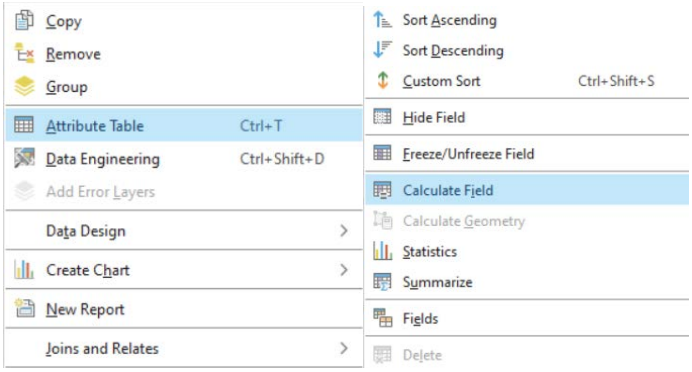
4-1. Establishing a Persistent "Rndbt_ID" Identifier Column

In the "Roundabouts" layer, the "FID" column uniquely identifies each row. However, these identifiers are subject to change during certain operations, such as when rows are deleted, or the dataset is otherwise altered. To preserve the original "FID" values and maintain a consistent reference to each roundabout, we will create a new column named "Rndbt_ID". This new field will duplicate the current "FID" values, ensuring that the original identifiers remain unaltered regardless of subsequent modifications to the layer.

Here's how we accomplish this:

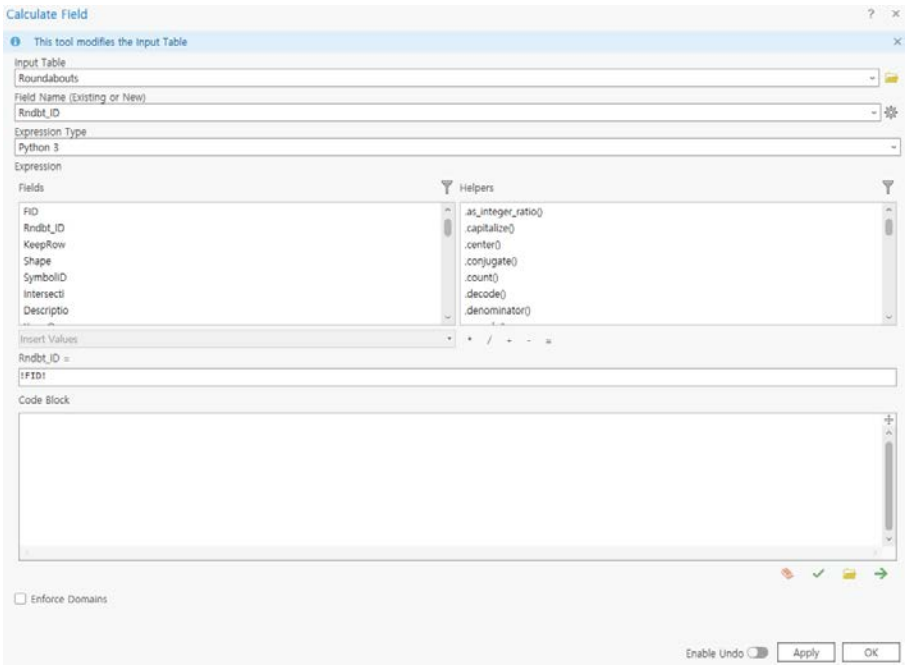
1. Begin by right-clicking on the 'Roundabouts' layer in ArcGIS Pro and selecting “Attribute Table” to open it.

2. Once the attribute table is open, right-click on any column header and choose "Calculate Field."

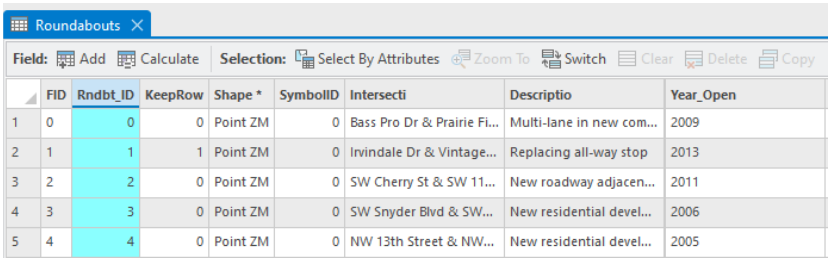


3. Configure the tool by selecting "Rndbt_ID" as the field to calculate, and simply set the expression to !FID!, which instructs ArcGIS Pro to copy the "FID" field values directly into "Rndbt_ID".

4. Choose "Long Integer" as the field type to support whole number identifiers.



5. Execute the calculation. The "Rndbt_ID" column will now mirror the "FID" column, creating a stable and unchanging identifier for each roundabout feature.



	FID	Rndbt_ID	KeepRow	Shape *	SymbolID	Intersecti	Descriptio	Year_Open
1	0	0	0	Point ZM	0	Bass Pro Dr & Prairie Fi...	Multi-lane in new com...	2009
2	1	1	1	Point ZM	0	Irvindale Dr & Vintage...	Replacing all-way stop	2013
3	2	2	0	Point ZM	0	SW Cherry St & SW 11...	New roadway adjacen...	2011
4	3	3	0	Point ZM	0	SW Snyder Blvd & SW...	New residential devel...	2006
5	4	4	0	Point ZM	0	NW 13th Street & NW...	New residential devel...	2005

4-2. Removing Unnecessary Rows Using the "Calculate Field" Tool

To streamline our "Roundabouts" layer by removing unnecessary rows, we will once again utilize the "Calculate Field" tool. This time, the tool will be used to flag roundabouts that we wish to retain, facilitating manual deletion of unwanted rows. The list of Roundabout IDs to be kept corresponds with the values in the FID column that we previously exported to an Excel file (DataFrame ‘Average’).

Here’s the step-by-step process for our "Roundabouts" layer:

1. Open the “Calculate Field” tool in ArcGIS Pro.

2. Add a new field named "KeepRow" to the layer. This field will act as a flag, indicating whether a row should be kept (1) or not (0).

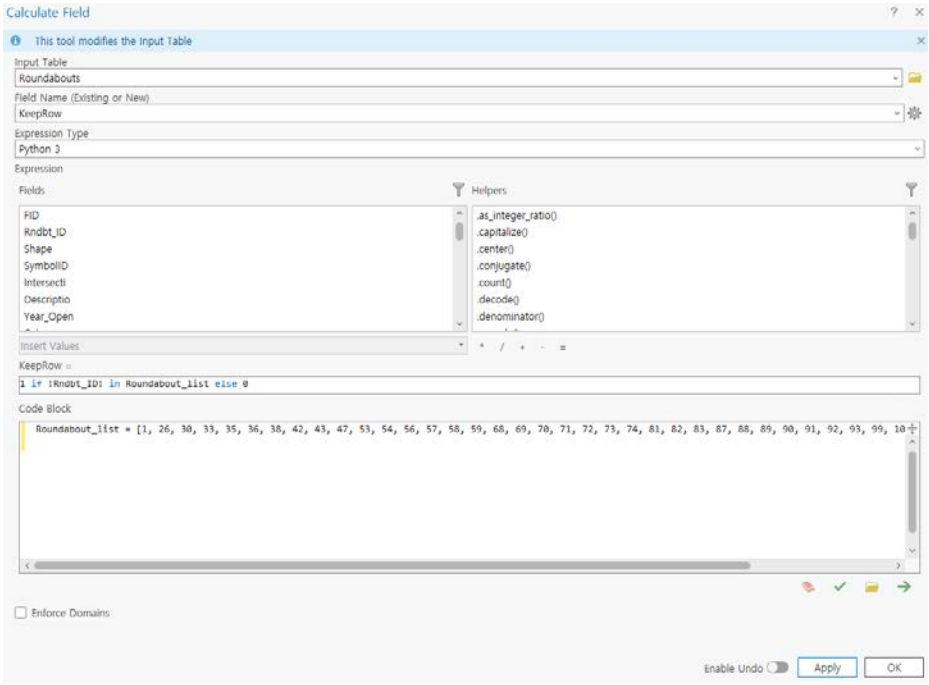
3. Inside the tool's Code Block, define your list of FIDs as follows:

>>> Roundabout_list = [1, 26, 30, 33, 35, 36, 38, 42, 43, 47, 53, 54, 56, 57, 58, 59, 68, 69, 70, 71, 72, 73, 74, 81, 82, 83, 87, 88, 89, 90, 91, 92, 93, 99, 103, 104]

4. Set the expression in the tool to:

>>> 1 if !Rndbt_ID! in Roundabout_list else 0

5. Execute the "Calculate Field" tool.



To finalize the removal of unwanted rows, proceed as follows:

6. Sort the "KeepRow" column in ascending order within the attribute table. This will group all rows with a '0' together.

7. Select these rows and use the 'Delete Rows' command to remove them from the layer.

	FID	KeepRow	Shape *	Intersecti	SymbolID	Descriptio	Year_Open
1	1	1	Point ZM	Irvindale Dr & Vintage...	0	Replacing all-way stop	2013
2	26	1	Point ZM	Commerce Dr & Comm...	0	Rebuilt 4-leg intersecti...	2014
3	30	1	Point ZM	Co Rd E23 & Matthew...	0	Between 3 schools; Re...	2013
4	33	1	Point ZM	US 218 southbound ra...	0	Diamond interchange...	2012
5	35	1	Point ZM	NW 62nd Ave & Pione...	0	1 of 4 on 62nd Ave cor...	2012

By following these steps, we ensure that our "Roundabouts" layer is streamlined to include only the essential records. This refinement is guided by the predetermined list of FID values, which was meticulously compiled during our earlier data preprocessing phase using Python.

4-3. Importing Excel Data and Performing Table Joins in ArcGIS Pro

In this section, we focus on importing the 'Average_Data' Excel file into ArcGIS Pro and executing a table join with the 'Roundabouts' layer.

1. Importing the 'Average_Data' Excel File:

- Begin by opening ArcGIS Pro and accessing the ‘Map’ tab.

- Use the ‘Add Data’ option and select ‘Add Data from File’ to import the 'Average_Data.xlsx' file.

- Locate and select your Excel file, integrating it as a new table in your project.

2. Executing a Table Join:

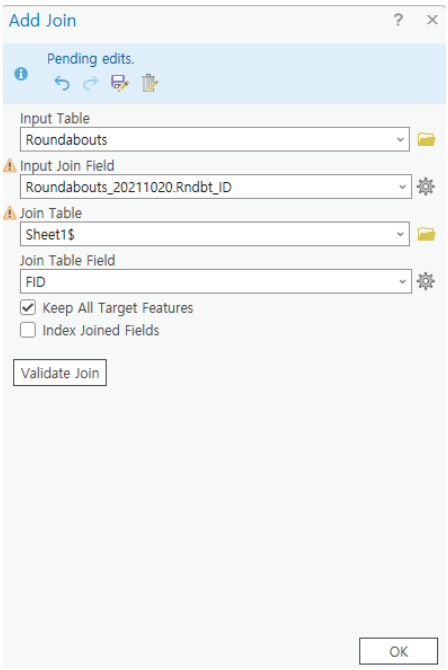
- Right-click on the 'Roundabouts' layer in the Contents pane.

- Navigate to ‘Joins and Relates’ and choose ‘Add Join’.

- In the 'Add Join' dialog, select the 'Rndbt_ID' field from the 'Roundabouts' layer.

- Then, select the imported 'Average_Data' table and its 'FID' field.

- The join operation will append the fields from 'Average_Data' to the 'Roundabouts' layer, based on the matching criteria between 'Rndbt_ID' and 'FID'.

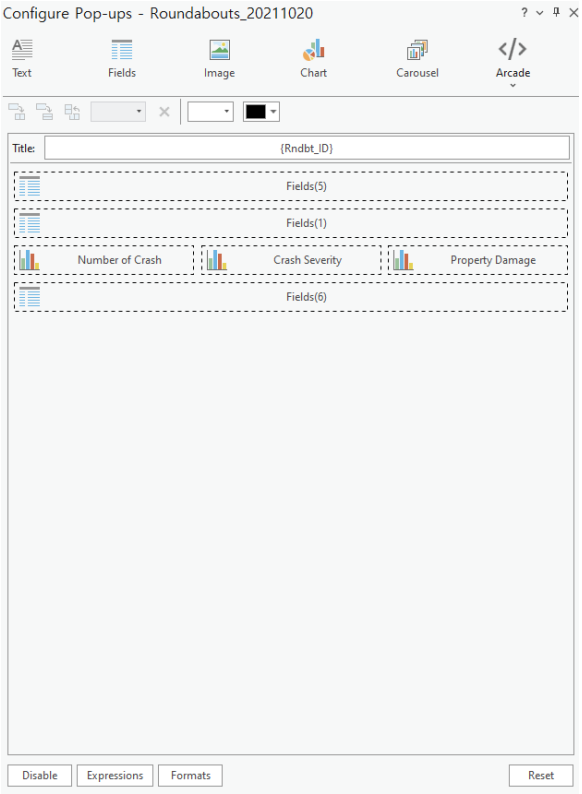


After performing the "Add Join" operation, your attribute table should display additional columns from the 'Average_Data' table alongside the existing 'Roundabouts' layer fields, as illustrated below:

	FID	Rndbt_ID	Shape *	Descriptio	Year_Open	Category	City	County	Crash_A	Crash_B	CSEV_A	CSEV_B	PROPDMG_A	PROPDMG_B	URL
1	0	1	Point ZM	Replacing all-way stop	2013	Modern Roundabout	Ankeny	Polk	5.2	0.25	1.25	3	3939.423	13500	https://dospir.s3.us-east
2	1	26	Point ZM	Rebuilt 4-leg intersecti...	2014	Modern Roundabout	Coralville	Johnson	0.889	0.4	1	1.5	7306.25	3000	https://dospir.s3.us-east
3	2	30	Point ZM	Between 3 schools; Re...	2013	Modern Roundabout	Gilbert	Story	1	0.25	1.2	1	3878	7500	https://dospir.s3.us-east
4	3	33	Point ZM	Diamond interchange...	2012	Modern Roundabout	Janesville	Bremer	0.364	5	1	1.8	9325	9280	https://dospir.s3.us-east
5	4	35	Point ZM	1 of 4 on 62nd Ave cor...	2012	Modern Roundabout	Johnstson	Polk	1.273	0.333	1.143	1	4310.714	2500	https://dospir.s3.us-east

4-4. Customizing Pop-Up Displays for the "Roundabouts" Layer

The next step in our DOSPIR is to enhance the interactivity of the "Roundabouts" layer by configuring custom pop-ups. These pop-ups will activate when a point on the map is clicked, displaying a tailored window of information that caters to the specific needs and interests of the users. By setting up pop-ups, we can provide immediate access to detailed data, such as annual crash statistics, directly within the map's interface, improving the user experience and offering insightful context at a glance. The configuration of these pop-ups will be designed to meet user requirements, ensuring that the most relevant and useful information is presented efficiently.



- Access the Configure Pop-ups Window:

  Right-click on the layer for which you want to configure pop-ups and select "Configure Pop-ups".

- Customize the Pop-up Content:

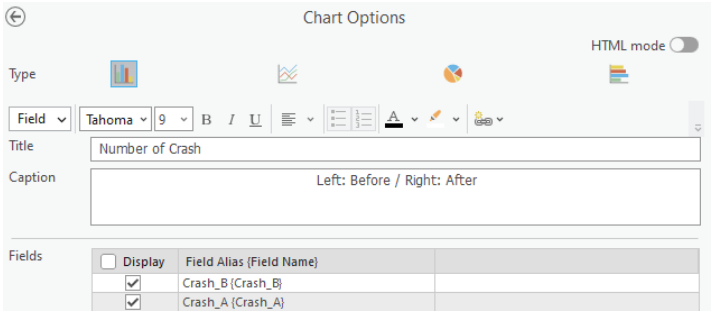
  The pop-up configuration window will appear, displaying various elements that you can add or adjust.

  The title of the pop-up can be set to show a unique identifier or name from the feature, such as "Rndbt_ID" in this case.

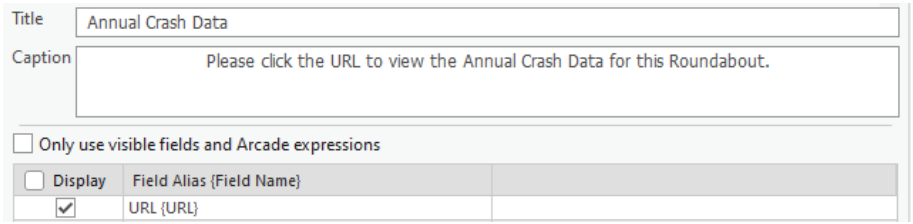
- Adding Fields and Charts:

  To display specific data, click on the "Fields" option to choose which attributes from the layer you want to show in the pop-up.

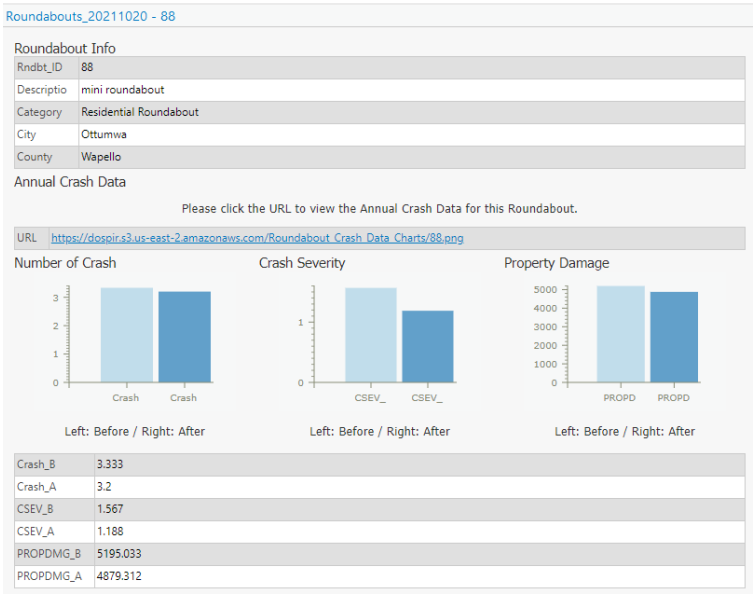
To add a visual element, click on the "Chart" option to create a chart that graphically represents the attribute data, making the pop-up more informative and engaging.



To display the Annual Crash Data for each roundabout, we will create a field within the pop-up that exclusively shows the "URL". This URL links to the corresponding bar charts hosted on AWS S3, which we have prepared earlier.



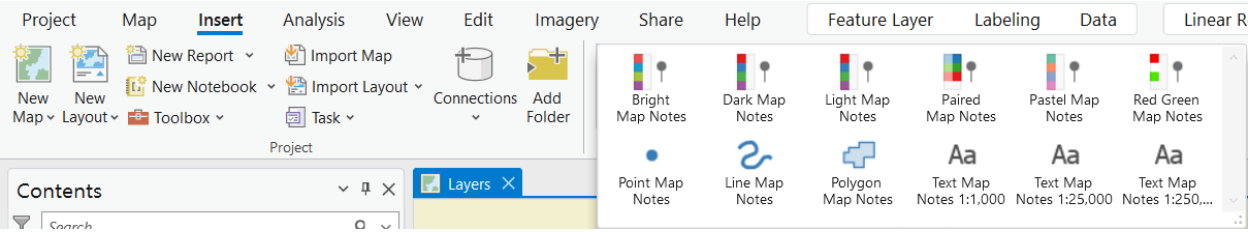
Once satisfied with the configuration, you can save your settings, and these pop-ups will be enabled for the layer.



5. Creating a Point and Storing Data in ArcGIS Pro

5-1. Creating a New Point Layer

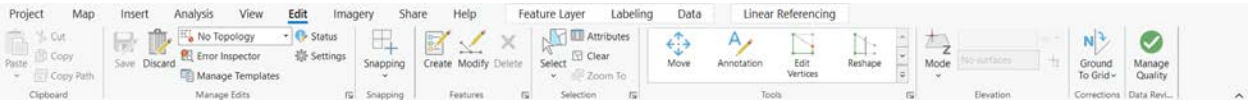
To add a new point layer for data collection on your map:



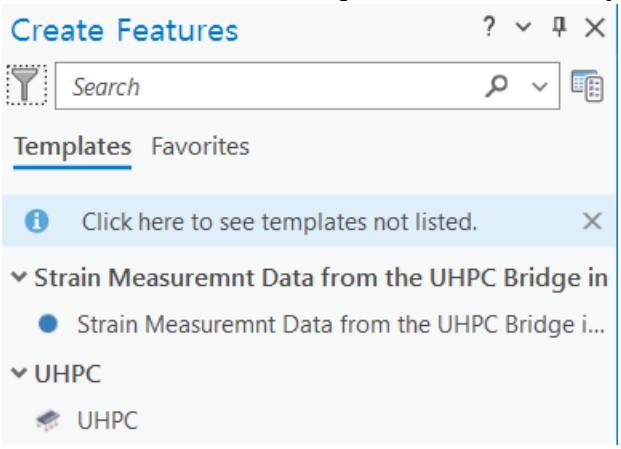
1. Open ArcGIS Pro and load your existing map.
2. Navigate to the Insert tab on the ribbon.
3. Select New Map Notes and choose Point from the dropdown menu.
4. Name the layer appropriately (e.g., Field_Observations) and click OK. This new point layer will be added to the Contents pane.

5-2. Enabling Editing for the New Layer

To prepare the new layer for data entry:



1. Switch to the Edit tab on the ribbon.
2. Click Create in the Features group to open the Create Features pane.
3. In the Create Features pane, select the newly created point map notes layer.

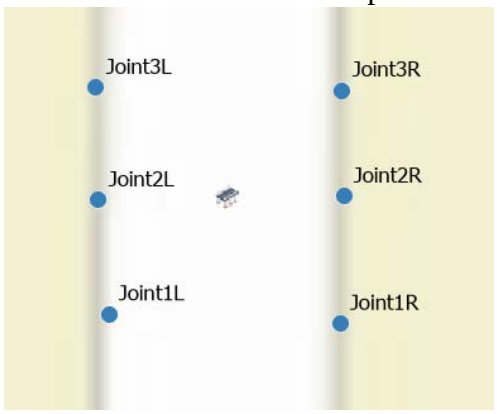


5-3. Adding a Point Feature

To add a point feature on the map:

1. With the point map notes layer selected, choose the Point tool.

2. Click on the map at the desired location to place the point feature.
3. This action will create a point at the clicked location.



5-4. Entering Attribute Data for the Point

To input data for the newly added point:

1. After placing the point, the Attributes pane will automatically open. If it doesn't, open it by clicking Attributes in the Edit tab.
2. In the Attributes pane, fill in the necessary data fields for the point, such as observation details, coordinates, or any other relevant information.

Strain Measuremnt Da...Buchanon County

Field: Add Calculate Selection: Select By Attributes Zoom To Switch Clear Delete Copy

	OBJECTID *	Shape *	Name	Date1	Strain1	Date2	Strain2	Date3	Strain3	Date4	Strain4
1	1	Point Z	Joint1L	2015-10-15	36	2017-09-17	13	2017-10-17	21	2019-08-19	23
2	2	Point Z	Joint1R	2015-10-15	34	2017-09-17	15	2017-10-17	16	2019-08-19	16
3	3	Point Z	Joint2L	2015-10-15	<Null>	2017-09-17	10	2017-10-17	11	2019-08-19	13
4	4	Point Z	Joint2R	2015-10-15	27	2017-09-17	10	2017-10-17	12	2019-08-19	14
5	5	Point Z	Joint3L	2015-10-15	12	2017-09-17	10	2017-10-17	13	2019-08-19	12
6	6	Point Z	Joint3R	2015-10-15	13	2017-09-17	11	2017-10-17	13	2019-08-19	17

Click to add new row.

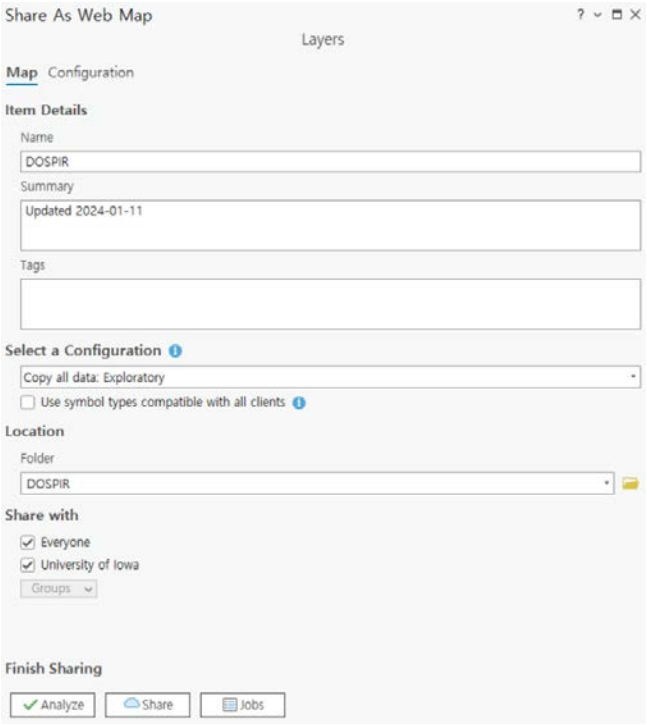
5-5. Saving Your Edits

1. To save the new point feature and its data:
2. Go to the Manage Edits group in the Edit tab.
3. Click Save to save your changes. This will ensure the point and its associated data are stored on the map.

6. Publishing the Updated Layer Online

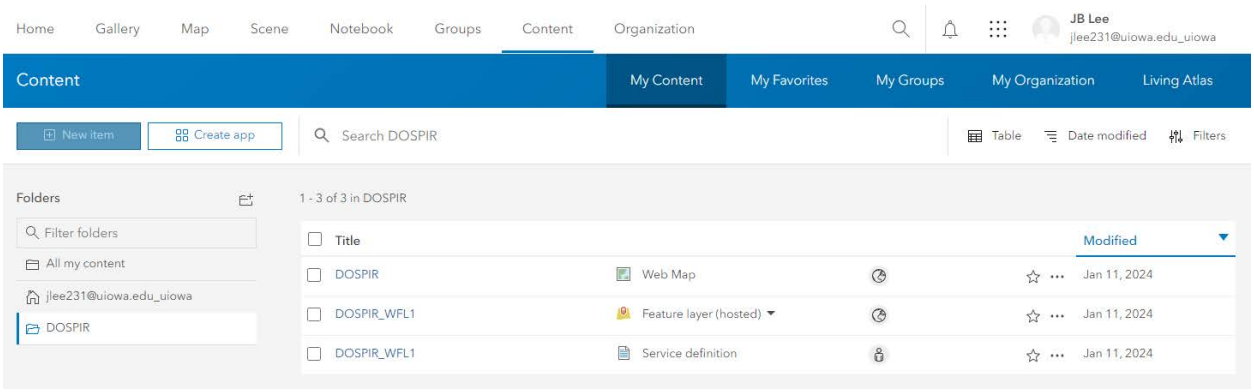
The next step in our GIS project is to publish the newly updated "DOSPIR" layer as a Web Map to our ArcGIS online account. This process will involve:

- Naming the map package "DOSPIR."
- Saving it within a designated folder in the ArcGIS online account.
- Clicking 'Analyze' to inspect the package for any potential issues.



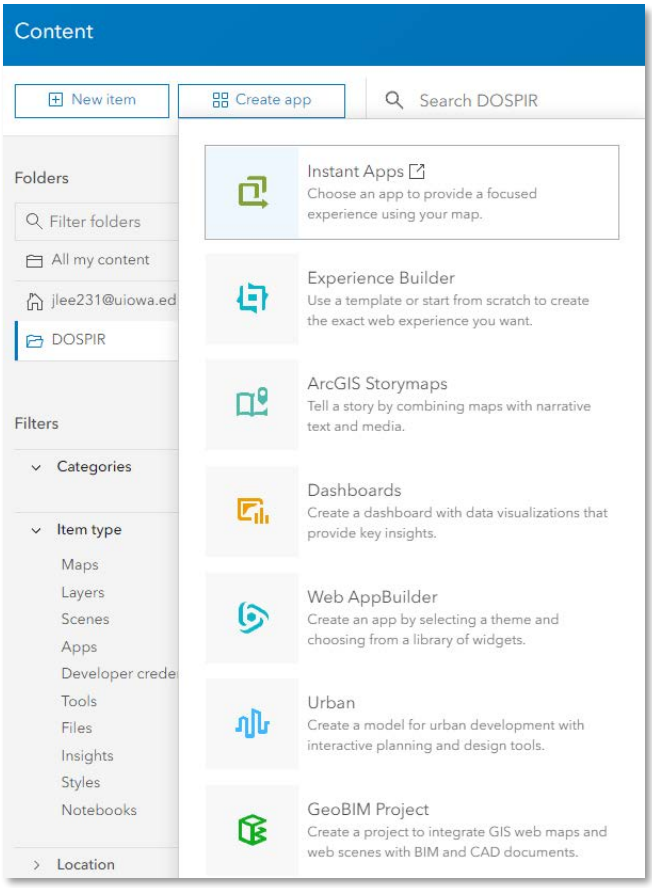
During the analysis phase, it's common to encounter warnings or errors related to layer properties or ArcGIS Pro configurations. These can be addressed by reviewing the error messages and making the necessary adjustments directly within the tool. Once all issues have been resolved and the package is free of errors, we're ready to share "DOSPIR" online, thereby providing access to a wider audience and extending the reach of our GIS data beyond the confines of ArcGIS Pro.

To view the "DOSPIR" Web Map, begin by opening a web browser and heading to the ArcGIS Online portal at https://www.arcgis.com. Log in with your ArcGIS Online account credentials. Once logged in, proceed to the “My Content” section where you can find all your saved items. In the designated folder where you uploaded the "DOSPIR" Web Map, you will be able to see and manage your file. This is where you can perform various actions such as viewing the map, editing its properties, or sharing it with others.



6-1. Leveraging the DOSPIR Web Map for Various Applications

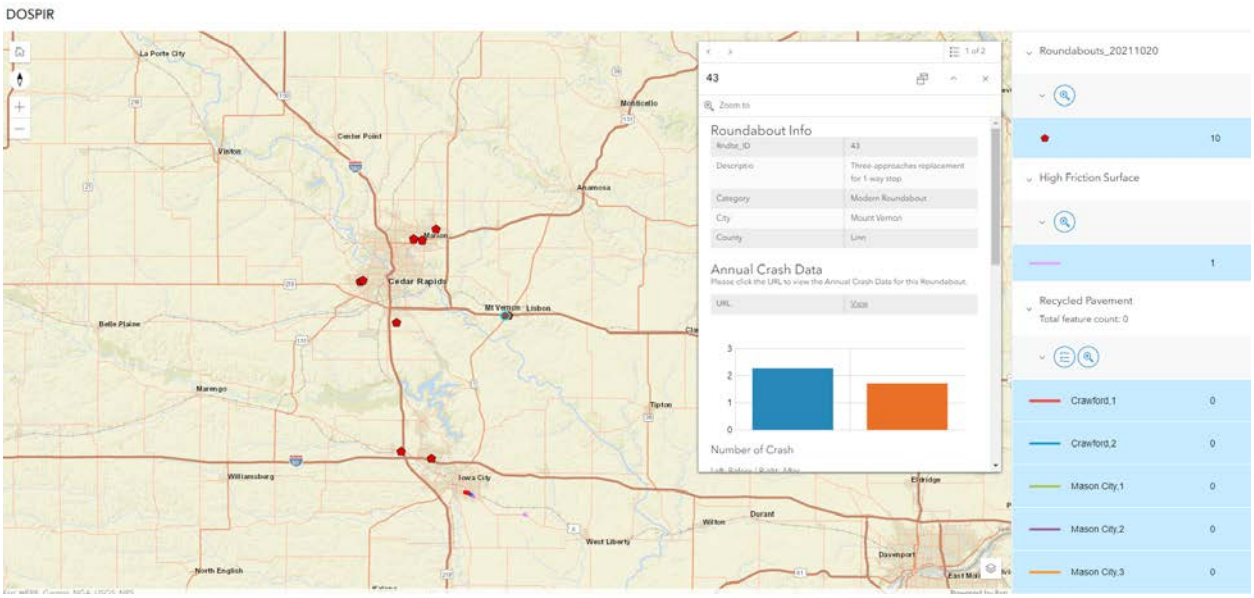
The DOSPIR Web Map on ArcGIS Online can serve multiple purposes depending on the objectives set for the database. For instance, to provide users with an intuitive and engaging way to explore the data, one could create an "Instant App" featuring an Interactive Legend. This type of app streamlines the process of sharing GIS information by offering a ready-to-use application with customizable options. Here's a brief overview of creating an Instant App:



- Select the DOSPIR Web Map: Navigate to the DOSPIR Web Map in your ArcGIS Online content and select it.

- Choose to Create an App: From the item details page, look for the option to create an app and select "Instant Apps" from the available choices.
- Configure the App: Select a template that suits your presentation needs, such as one with an Interactive Legend if you wish to allow users to toggle map layers on and off.
- Customize App Settings: Tailor the app's settings to enhance the user experience. This includes configuring the legend, map extent, search options, and more, depending on the chosen template.
- Preview and Publish: Before making the app public, preview it to ensure it meets your requirements. Once satisfied, publish the app so it becomes accessible to your intended audience.

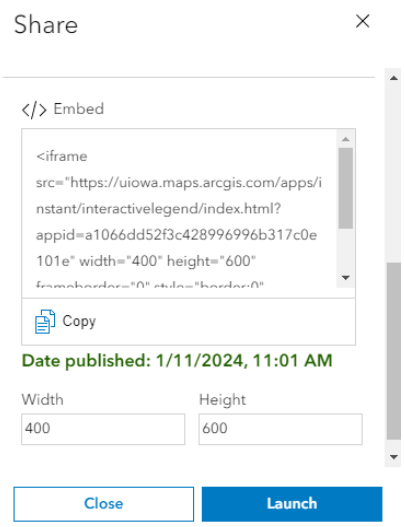
Creating an Instant App in this manner allows for the effective dissemination of the DOSPIR database, catering to interactive and informative user experiences.



https://uiowa.maps.arcgis.com/apps/instant/interactivelegend/index.html?appid=e8fd8f3be8e64153813b3edae9d88675

6-2. Embedding the DOSPIR Instant App into Your Webpage

Upon successfully publishing the DOSPIR Instant App, ArcGIS Online provides you with an HTML iframe code snippet. This embed code is the key to incorporating the DOSPIR interactive map within your own website, granting users the convenience of exploring the map directly on the page. To integrate the DOSPIR Web Map, simply place the iframe code into the appropriate section of your website's HTML. This integration ensures that visitors can fully engage with the DOSPIR map's features and data without the need to navigate away from your webpage.


Share
Embed
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Copy
Date published: 1/11/2024, 11:01 AM
Width
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Height
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Close
Launch