AASHTO
AASHTO INNOVATION INITIATIVE

AASHTO Innovation Initiative

[Proposed] Nomination of Innovation Ready for Implementation

Sponsor

Nominations must be submitted by an AASHTO member DOT willing to help promote the innovation. If selected, the sponsoring DOT will be asked to promote the innovation to other states by participating on a Lead States Team supported by the AASHTO Innovation Initiative.

1. Sponsoring DOT (State): Iowa DOT

2. Name and Title: Halil Ceylan, Ph.D., F.ASCE

Organization: Iowa State University

Street Address: 410 Town Engr, 813 Bissell Rd

City: Ames

State: Iowa

Zip Code: 50011-1066

Email: hceylan@iastate.edu

Phone: 515-294-8051

Fax: (515) 294-8216

Innovation Description (10 points)

The term “innovation” may include processes, products, techniques, procedures, and practices.

3. Name of the innovation:

Electrically Conductive Concrete Heated Pavement System

4. Please describe the innovation.

Our innovation, an Electrically Conductive Concrete (ECON) Heated Pavement System (HPS), is a smart, promising, cost-effective, and environmentally friendly alternative to conventional snow and ice removal, enhancing sustainability and resiliency of the transportation infrastructure network. ECON HPS represents an effort for electrification and automation of winter maintenance of transportation infrastructure systems to reduce the environmental impact of de-icing chemicals on the surrounding ecosystem. ECON HPS utilizes the inherent electrical resistance of concrete to maintain the pavement surface above freezing and thus prevent snow and ice accumulation on the surface. This technology fully complies with the Americans with Disabilities Act (ADA) mission to ease commuting by individuals with disabilities, especially during the winter season and can also help with the ongoing efforts for electrification of infrastructure systems. Our overall goal with this innovative technology is to keep the transportation infrastructure systems safe, open, and accessible during winter weather events in a resilient and sustainable manner. The key components of ECON HPS technology include an ECON layer (heating element), electrodes, temperature sensors, electrical wiring, polyvinyl chloride (PVC) conduits, control system, and power supply. This technology can be either constructed as an overlay on top of an existing pavement system if the pavement is in good condition, or as a top layer of a two-lift paving for a new construction.

5. What is the existing baseline practice that the innovation intends to replace/improve?

Winter road and surface maintenance operations, presently consisting of plowing snow/ice and applying de-icing chemicals, are vital in keeping the transportation infrastructure system safe and operational during the winter season. Transportation networks sometimes experience a significant reduction in mobilization capacity due to speed reduction, delays, and in some cases, a complete shutdown of parts of the network due to snow and ice storms every winter season. The current state of practice for winter maintenance operations is time-consuming, labor-intensive, and environmentally unfriendly.

6. What problems associated with the baseline practice does the innovation propose to solve?

Many transportation agencies annually allocate significant time and resources to remove ice and snow from their paved surfaces to achieve a safe, accessible, and operational transportation network. For example, U.S. freeways, including interstates, experience 5 to 40 percent average speed reduction and 12 to 27 percent mobilization capacity reduction during snow and ice precipitation. Since 70 percent of U.S. roads (115,000 miles of highways) are in snowy regions, 21 percent of car crashes each year are weather-related (FHWA 2020). Flight delays in airports, one-third of which are weather-related, especially impact the U.S. economy during the winter season. It has been estimated that the U.S. air transportation sector in 2019 incurred 33 billion dollars of revenue loss due to flight delays alone, and the estimated cost per minute of such delays in 2019 was $74.24 (Airlines for America 2019; FAA APO-100 2019). Current winter maintenance practices include using snowplowing and de-icing chemicals, all of which are time-consuming, labor-intensive, and environmentally unfriendly. The U.S. consumed 22.8 million metric tons of rock salt (43% of total U.S. salt consumption and about 153 lb per American) for roadway de-icing purposes in 2020, a 2,300 percent increase from 1960 (Bolen 2020). Salt and de-icing chemicals contaminate soil, surface runoff, and groundwater and impact the ecological system. It has been estimated that 50 percent of the world's arable land would be salinized by 2050, potentially directly affecting the global food supply (Jamil et al., 2011). De-icing not only affects the ecosystem but also speeds up the corrosion process of America's aging infrastructure. It has been estimated that the corrosion damage from salting highways alone costs the US about $5 billion USD per year (Vox 2015).

7. Briefly describe the history of its development.

The current stage of development of this technology is through extensive laboratory testing and material characterization, theoretical and numerical modeling studies, and most importantly, through two full-scale demonstration projects, one project constructed at the Des Moines International Airport (Abdualla et al., 2018) and the other project implemented at the Iowa Department of Transportation (DOT) headquarters (Malakooti et al., 2020) in Ames, Iowa. A new full-scale implementation project will be initiated in 2021 for a bus stop enhancement project at the City of Iowa City. The research and development of this technology began seven years ago through the following research projects funded by the Iowa DOT, Iowa Highway Research Board, Federal Aviation Administration, and National Science Foundation (NSF):

- Self-Heating electrically Conductive Concrete Demonstration Project, Iowa DOT, and IHRB
- Implementing a Self-Heating, Electrically Conductive Concrete Heated Pavement system for Bus Stop Enhancement Project in the City of Iowa City, Iowa DOT and IHRB
- I-Corps: Self Heating, electrically Conductive concrete Heated Pavement System for Sustainable Winter Maintenance Operation, NSF
- Development of Nanostructured Superhydrophobic Coatings and Conductive Concrete to Achieve Ice- and Snow-Free Airport Pavements, FAA
- Advanced Construction Techniques for Heated Airport Pavements, FAA
- Investigation into the Feasibility of Using Electrically Conductive Asphalt Cement Concrete for Heated Airport Pavements, FAA
- Superhydrophobic and Ice-phobic Materials for Nano-Modified Heated Asphalt Cement Concrete Pavements, FAA
- Full-Scale Demonstration of Heated Portland Cement Concrete Pavement Systems, FAA
- Updating FAA Advisory Circular 150/5370-17, Airside Use of Heated Pavements, FAA

8. What resources—such as technical specifications, training materials, and user guides—have you developed to assist with the deployment effort? If appropriate, please attach or provide weblinks to reports, videos, photographs, diagrams, or other images illustrating the appearance or functionality of the innovation (if electronic, please provide a separate file). Please list your attachments or weblinks here.

Two draft technical specifications have been developed for ECON HPS technologies, including:

- Updating FAA Advisory Circular 150/5370-17, Airside Use of Heated Pavements, FAA
- ECON HPS specification for Iowa Statewide Urban Design and Specifications (SUDAS)

Two patents base on this technology have also been filed:

- Ceylan, Halil, Alireza Sassani, Hesham Abdualla, Sunghwan Kim, Ali Arabzadeh, Peter C. Taylor, and Kasthurirangan Gopalakrishnan. "Electrically conductive concrete composition and system design for resistive heating of pavements with low volume fractions of carbon microfiber." U.S. Patent Application 16/705,443 filed on August 20, 2020.
- Ceylan, Halil, Ali Arabzadeh, Sunghwan Kim, Alireza Sassani, Kasthurirangan Gopalakrishnan, and Mohammad Ali Notani. "Electrically-conductive asphalt concrete containing carbon fibers." U.S. Patent Application 16/931,179 filed on January 28, 2021.

In addition, numerous technical reports and peer-reviewed journal and conference articles have been published and presented. A partial list of those publications and presentations is listed below:

- Malakooti, Amir, Hesham Abdualla, Sajed Sadati, Halil Ceylan, Sunghwan Kim, and Kristen Cetin. "Experimental and theoretical characterization of electrodes on electrical and thermal performance of electrically conductive concrete." Composites Part B: Engineering (2021): 109003.
- Malakooti, A., Theh, W. S., Sadati, S. M. S., Ceylan, H., Kim, S., Mina, M., Cetin, K., and Taylor, P. C. (2020). "Design and Full-Scale Implementation of the Largest Operational Electrically Conductive Concrete Heated Pavement System," Construction & Building Materials, Vol. 255, Article Number: 119229.
- Sadati, S. S. M., Cetin, K. S., Ceylan, H., and Kim. S. (2020). "Energy Efficient Design of a Carbon Fiber based Self-heating Concrete Pavement System through Finite Element Analysis," Journal of Clean Technologies and Environmental Policy, https://doi.org/10.1007/s10098-020-01857-4.
- Sassani, A., Arabzadeh, A., Ceylan, H., Kim, S., Gopalakrishnan, K., Taylor P. C., and Nahvi, A. (2019). "Polyurethane-Carbon Microfiber Composite Coating for Electrical Heating of Concrete Pavement Surfaces," the Journal of Heliyon, Volume 5, Issue 8, e02359.
- Arabzadeh, A., Notani, M., Zadeh, A. K., Nahvi, A., Sassani, A., and Ceylan, H. (2019). "Electrically Conductive Asphalt Concrete: An Alternative for Automating the Winter Maintenance Operations of Transportation
- Nahvi, A., Pyrialakou, D. V., Anand, P., Sadati, S., Gkritza, K., Ceylan, H., Cetin, K., Kim, S., Gopalakrishnan, K., and Taylor, P. C. (2019). "Integrated Stochastic Life Cycle Benefit Cost Analysis of Hydronic Heated Apron Pavement System," the Journal of Cleaner Production, Vol. 224, pp. 994-1003.
- Notani, M. A., Arabzadeh, A., Ceylan, H., Kim, S., and Gopalakrishnan, K. (2019). "Effect of Carbon Fiber Properties on Volumetrics and Ohmic Heating of Electrically Conductive Asphalt Concrete," ASCE Journal of Materials in Civil Engineering, Vol. 31, Issue 9, 04019200.
- Arabzadeh, A., Sassani, A., Ceylan, H., Kim, S., Gopalakrishnan, K., and Taylor, P.C. (2019). "Comparison between Cement Paste and Asphalt Mastic Modified by Carbonaceous Materials: Electrical and Thermal Properties," Construction and Building Materials, Vol. 213, pp. 121-130.

- Nahvi, A., Sadoughi, M. A., Arabzadeh, A., Sassani, A., Ceylan, H., Hu, C., and Kim, S. (2018). "Multi-objective Bayesian Optimization of Super hydrophobic Coatings on Asphalt Concrete Surfaces," the Journal of Computational Design and Engineering, Vol. 6, Issue 4, pp. 693-704.
- Sassani, A., Arabzadeh, A., Ceylan, H., Kim, S., Sadati, S., Gopalakrishnan, K., Taylor, P. C., and Abdualla, H. (2018). "Carbon fiber-based Electrically Conductive Concrete for Salt-free De-icing of Pavements," the Journal of Cleaner Production, Vol. 203, pp. 799-809.
- Sadati, S. M., Cetin, K., Ceylan, H., Sassani, A., and Kim, S. (2018). "Energy and Thermal Performance Evaluation of an Electrified Snow Removal System at Airports Using Numerical Modeling and Field Measurements," the Journal of Sustainable Cities and Society, Vol. 43, pp. 238-250.
- Arabzadeh, A., Ceylan, H., Kim, S., Sassani, A., Gopalakrishnan, K., and Mani Mina. (2018). "Electrically-conductive Asphalt Mastic: Temperature Dependence and Heating efficiency," Materials & Design, Vol. 157, pp. 303-313
- Nahvi, A., Sadati, S. M., Cetin, K., Ceylan, H., Sassani, A., and Kim, S. (2018). "Towards Resilient Infrastructure Systems for Winter Weather Events: Integrated Stochastic Economic Evaluation of Electrically Conductive Heated Airfield Pavements," the Journal of Sustainable Cities and Society, Vol. 41, pp. 195-204.
- Abdualla, H., Ceylan, H., Kim, S., Mina, M., Cetin, K. S., Taylor, P. C., Gopalakrishnan, K., Cetin, B., Yang, S., Sassani, A., and Vidyadharan, A. (2018). "Design and Construction of The World's Full-Scale Electrically Conductive Concrete Heated Airport Pavement System at A US Airport," Presented at the 97th TRB Annual Meeting and Transportation Research Record: Journal of the Transportation Research Board, Vol. 2672, Issue. 23, pp. 82-94, https://doi.org/10.1177/0361198118791624.
- Sassani, A., Ceylan, H., Kim, S., Arabzadeh, A., Taylor, P. C., and Nahvi, A. (2018). "Development of Carbon Fiber-modified Electrically Conductive Concrete for Implementation in Des Moines International Airport," Case Studies in Construction Materials, Vol. 8, pp. 277-291.
- Sassani, A., Ceylan, H., Kim, S., Gopalakrishnan, K., Arabzadeh, A., and Taylor, P. C. (2017). "Influence of Mix Design Variables on Engineering Properties of Electrically Conductive Concrete," Construction & Building Materials, 152, pp. 168-181.
- Arabzadeh, A., Ceylan, H., Kim, S., Gopalakrishnan, K., Sassani, A., Sundararajan, S., and Taylor, P. C. (2017). "Superhydrophobic Coatings on Portland Cement Concrete Surfaces," Construction & Building Materials, 141, pp. 393-401.
- Abdualla, H., Ceylan, H., Kim, S., Gopalakrishnan, K., Taylor, P. C., Turkan, Y. (2016). "System Requirements for Electrically Conductive Concrete Heated Pavements," Transportation Research Record: Journal of the Transportation Research Board, No. 2569, pp. 70-79.
- Arabzadeh, A., Ceylan, H., Kim, S., Gopalakrishnan, K., and Sassani, A. (2016). "Superhydrophobic Coatings on Asphalt Concrete Surfaces: Towards Smart Solutions for Winter Pavement Maintenance," Transportation Research Record: Journal of the Transportation Research Board, No. 2551, pp. 10-17.

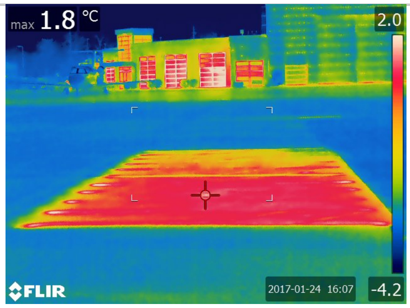
- Gopalakrishnan, K., Ceylan, H., Kim, S., Yang, S., and Abdualla, H. (2015). “Electrically Conductive Mortar Characterization for Self-Heating Airfield Concrete Pavement Mix Design” the International Journal of Pavement Research and Technology, Vol. 8, Issue 5, pp. 315-324.
- Shen, W., Gopalakrishnan, K., Kim, S., and Ceylan, H. (2015). “Assessment of the Greenhouse Gas Emissions from Geothermal Heated Airport Pavement System,” International Journal of Pavement Research and Technology, 8, Issue 4, pp. 233-242.

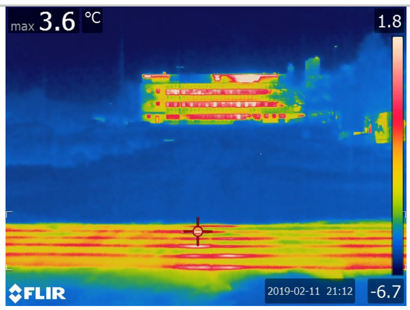
Moreover, this technology has been covered in numerous media outlets, including:

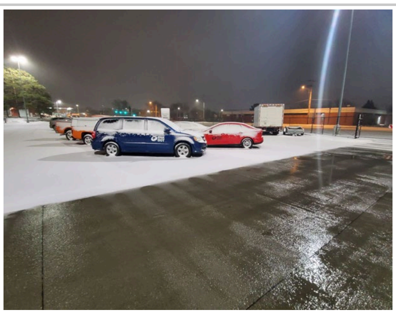
- Featured on Engineering News Record (ENR) “Concrete Projects to Watch: Heat Conducting Concrete” July 2019.
- Featured on ACI Concrete SmartBrief “Carbon fiber brings the heat to concrete pavement”, March 14, 2019.
- Featured on Iowa State University College of Engineering Research “Iowa State engineers work with Iowa DOT to scale up tests of heated pavement”, March 13, 2019.
- Interviewed with The Weather Channel Live (twice on this day), January 24, 2019.
- Featured on *Global Construction Review* “Electric concrete tested at US airport to melt snow”, March 22, 2018.
- Featured on *WUWT* “Could heated airport runways melt away your winter travel headaches?”, February 28, 2018.
- Featured on *NBC’s Nightly News* “How heated runways can help prevent airport weather delays?”, January 26, 2018.
- Featured on *NBC’s Today Show* “Could heated airport runways melt away your winter travel headaches?”, January 26, 2018.
- Featured on *Iowa State University College of Engineering Research* “Safer, more sustainable aviation- Iowa State’s partnership in FAA program advances airport runways, operating technology”. January 8, 2018.
- Featured on *Clay & Milk* “Heated pavement technology tests well at Des Moines Airport”, January 5, 2018.
- Featured on NBC *WHO-TV* “Des Moines Airport testing heated pavement”, January 5, 2018.
- Featured on *KCCI 8 News* “Heated pavement tech could be travelers' dream come true”, January 5, 2018.
- Featured on *KCRG News* “Heated pavements working at Des Moines Airport”, January 5, 2018.
- Featured on *The Gazette* “Iowa airports going green, saving on energy costs”, November 25, 2017.
- Featured on *NPR* “Winter is Coming. What if roads and runways could de-ice themselves?”, October 1, 2017.
- Featured on *Travel+Leisure* “Electric concrete at airports could save us all from winter flight delays”, April 18, 2017.
- Reported by Daily Planet- Discovery Canada “Heated airport pavements” April 10, 2017.

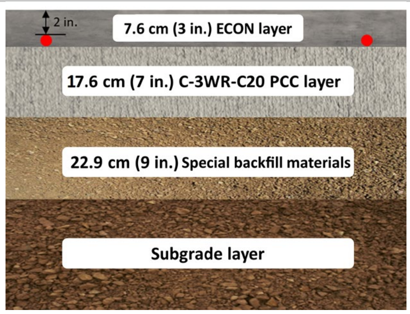
- Featured on *Highway Today* "Iowa State engineers test heated pavement technology at Des Moines International Airport", April 1, 2017.
- Reported by the *International Society for Concrete Pavements (ISCP)* "The first full-scale test slabs of electrically conductive concrete installed at an American airport" March 30, 2017.
- Featured on *News ATLAS* "Electrified concrete may keep airports ice-free", March 30, 2017.
- Featured on *Newswise* "Iowa State engineers test heated pavement technology at Des Moines International Airport", March 28, 2017.
- Featured on *Iowa State News Service* "Iowa State engineers test heated pavement technology at Des Moines International Airport", March 28, 2017.
- Featured on NBC *WHO-TV* "Heat pavement technology could melt away airport headaches", March 28, 2017.
- Featured on *ScienceDaily* "Iowa State engineers test heated pavement technology at Des Moines International Airport", March 28, 2017.
- Featured on *International Airport Review* "Innovative and sustainable airfield pavement engineering solution", May 24, 2016.
- Featured on *ASCE SmartBrief* "Engineers develop technologies to clear snow from concrete runways", April 3, 2015.
- Featured on *AOPA* "Just melt it-Iowa State tests new snow removal methods", March 21, 2015.
- Featured on *Iowa State Daily* "ISU researchers develop snow-free pavement technologies", March 12, 2015.
- Featured on *Ames Tribune* "*ISU researchers hope to prevent icy airport runways*", March 7, 2015.
- Featured on NBC *WHO-TV* "Iowa State University students developing heated pavement technology", March 5, 2015.
- Featured on *KCCI 8 News* "Researchers work to eliminate the snow shovel", March 4, 2015.
- Featured on *The Gazette* "Iowa State researchers study heated pavement as possible solution to flight delays", March 4, 2015.
- Featured on *KCCI 8 News* "See how new melting technologies work", March 3, 2015.
- Featured on *Iowa State University News Service* "Iowa State engineers developing pavement technologies to clear snow and ice from runways", March 2, 2015.
- Featured on *ScienceDaily* "Electrically conductive concrete to clear snow and ice from runways", March 2, 2015.

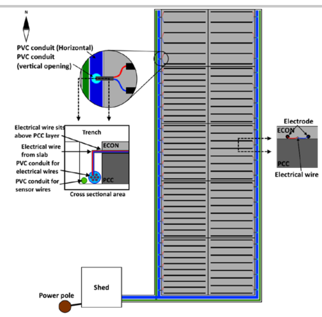
Attach photographs, diagrams, or other images here. If images are of larger resolution size, please provide as separate files.











State of Development (40 points)

Innovations must be successfully deployed in at least one State DOT. The AII selection process will favor innovations that have advanced beyond the research stage, at least to the pilot deployment stage, and preferably into routine use.

9. How ready is this innovation for implementation in an operational environment? Please select from the following options. Please describe.

☐ Prototype is fully functional and yet to be piloted

☐ Prototype has been piloted successfully in an operational environment

☒ Technology has been deployed multiple times in an operational environment

☒ Technology is ready for full-scale implementation

The current stage of development of this technology is through two full-scale demonstration projects conducted at the Iowa Department of Transportation (DOT) headquarters (Malakooti et al., 2020) and at the Des Moines International Airport (Abdualla et al., 2018). A new full-scale demonstration project will be initiated in 2021 for a bus stop enhancement project at the City of Iowa City.

10. What additional development is necessary to enable implementation of the innovation for routine use?

The ECON HPS technology is ready for use by transportation agencies. The required specifications and the fundamental science and engineering behind the technology have been developed and established, and proof of concept has been tested and studied through two full scale field implementation projects, one of which was built at the headquarters of Iowa DOT located in Ames, Iowa. Since the previous full scale field implementations were comprised of up to 10 concrete pavement slabs, this technology only requires implementation at a larger scale.

11. Are other organizations using, currently developing, or have they shown interest in this innovation or of similar technology?? ☒ Yes ☐ No

If so, please list organization names and contacts. Please identify the source of this information.

Organization	Name	Phone	Email
Federal Aviation Administration (FAA)	Matthew T. Brynick	(609) 485-8180	Matthew.T.Brynick@faa.gov
Wisconsin DOT	Emil Juni	(608) 266-3833	emil.juni@dot.wi.gov

Kansas City Area Transportation Authority	Keith Sanders	(816) 346-0359	ksanders@kcata.org
City of Ames	Tracy Warner	(515) 239-5163	twarner@city.ames.ia.us
Des Moines International Airport	Bryan Belt	(515) 256-5160	bmbelt@dsmairport.com
Columbus Regional Airport	Rod Borden	(614) 778-2519	borden.38@osu.edu
Colorado DOT	Tyler Weldon	(303) 512-5682	tyler.weldon@state.co.us
Denver International Airport	Kyle W. Lester	(303) 342-2000	kyle.lester@flydenver.com
City of Iowa City	Marri Van Dyke	(319) 356-5044	Marri-Vandyke@iowa-city.org
City of West Des Moines	Bret Hodne	(515) 222-3536	bret.hodne@wdm.iowa.gov
Federal Highway Administration	Tony Coventry	(202) 366-0754	tony.coventry@dot.gov
Federal Highway Administration	Jim Grove	(515) 231-2171	jim.grove@dot.gov

Potential Payoff (30 points)

Payoff is defined as the combination of broad applicability and significant benefit or advantage over baseline practice.

12. How does the innovation meet customer or stakeholder needs in your State DOT or other organizations that have used it?

Snow and ice removal are expensive components in winter road maintenance for the Iowa Department of Transportation (IA DOT) and counties and cities in Iowa. For example, the IA DOT is responsible for snow and ice removal on more than 9,000 miles of Iowa highways, uses approximately 900 snowplow trucks, and spreads approximately 200,000 tons of rock salt each year to remove snow and ice from Iowa roadways (IA DOT 2016). Self-heating ECON heated pavement systems have been successfully developed as a desirable alternative to current ice and snow removal practices that makes practical and economic sense for use in pavement systems.

13. Identify the top three benefit types your DOT has realized from using this innovation. Describe the type and scale of benefits of using this innovation over baseline practice. Provide additional information, if available, using quantitative metrics, to describe the benefits.

Benefit Types	Please describe:
Cost Savings	Automation of winter maintenance operation and reduce the cost of de-icing chemicals and sand
Improved Safety	Reduce accidents, slip-and-fall incidents, and associated lawsuits
Improved Quality	Longer-lasting pavement systems, reduction in pavement maintenance cost, slowing the corrosion process
Improved Operation Performance	The automated system detects snow and ice with minimal staff oversight
Environmental Benefits	Reduce salt and sand usage, reduce carbon dioxide emission due to snow plowers (electrification)

Provide any additional description, if necessary:

N/A

14 How broadly might this innovation be deployed for other applications. in the transportation industry (including other disciplines of a DOT, other transportation modes, and private industry)?

The proposed technology has many applications in different areas as explained in detail below:

- **Businesses and Municipalities**
  Locations with high foot traffic and high geometric complexity represent one of the best applications of heated pavement areas. Downtown areas with high populations would be one beneficiary of implementing this technology due to their high pedestrian traffic and high geometric complexity. Higher foot traffic increases the chance of slipping and falling during the winter season. Slip-and fall-lawsuits and associated settlements could be mitigated by treating the most prone areas with heated pavement technology. It is also more time-consuming for businesses and municipalities to clear snow and ice in locations where pedestrians are constantly walking, especially if there is high geometric design complexity (presence of obstacles). Based on the U.S. Bureau of labor and statistics, there were 25,370 ice, sleet, and snow-related injuries in 2019 alone (U.S. Bureau of labor and statistics 2019).

- **Airports**
  Airport pavement snow removal and runway de-icing operations are expensive components of airport operational costs, and these operations can occasionally lead to flight delays impacting travel both throughout the U.S. and worldwide. The estimated cost per minute of delay in 2019 in U.S. airports was about $74 (Airlines For America 2019). Airport authorities could minimize such delay and maximize enplanement and deplanement efficiency, potentially resulting in increased revenue and operation during the winter season.

- **Highways and Roadways**
  Potential locations for implementation of ECON HPS in highway and roadway systems include high traffic volume locations, rest areas, bridges, and ramps.
  - High traffic volume locations:
    There are some critical locations in highway and roadway systems that can affect the free flow of traffic in the whole system. Typically, since these locations experience high traffic flow, an accident in these locations due to winter season conditions can result in massive delays throughout the system.
  - Rest areas:
    Rest areas, specifically in the interstate highway system, experience high foot traffic throughout the year, and they are typically located in areas that would not be easily accessible to a winter maintenance crew for clearing snow and ice in a timely manner.
  - Bridges:
    Bridge decks are the first locations in a highway system to freeze during the onset of the winter season. Black ice and frost can create a thin layer of ice on top of the bridge deck, potentially resulting in vehicles sliding off the bridge and causing fatal accidents. The transportation agencies dedicate portions of their winter maintenance budget for de-icing such locations (so-called frost run) to mitigate this type of hazard.
  - Tunnels:
    Entrances to and exits from tunnels could be hazardous locations where vehicles and motorists transition from a poor-condition road to a good-condition road (or vice-versa), potentially resulting in sudden breaks and loss of vehicle control.
  - Ramps:
    Entrance and exit ramps in the highway system are potential hazards, particularly during the winter season, due to higher vehicle speed and the potential of sliding off the ramp.
- **Americans with Disabilities Act (ADA)**
  ECON HPS technology is in full compliance with ADA's mission to ease the commute conditions of individuals with disabilities, especially during the winter season. Based on the U.S. Bureau of Labor and Statistics, about 25 percent of ice- and snow-related falls occur in parking lots. Since snow and ice can cause significant hardship for individuals with disabilities, implementing heated pavement on ADA parking lots and ramps could be a way to mitigate such hardship. The Department of Transportation has also dedicated funding for ADA compliance projects that can be used to implement ECON HPS technology further, facilitating the contribution and integration of individuals with disabilities into our society.

Market Readiness (20 points)

The AII selection process will favor innovations that can be adopted with a reasonable amount of effort and cost, commensurate with the payoff potential.

15. What specific actions would another organization need to take along each of the following dimensions to adopt this innovation?

Check boxes that apply	Dimensions	Please describe:
☐	Gaining executive leadership support	Click or tap here to enter text.
☒	Communicating benefits	The organization should identify critical locations in which a heated pavement technology would be most beneficial.
☒	Overcoming funding constraints	The upfront cost of implementation of this technology is more than that of constructing a standard concrete pavement. Therefore, this cost should be clearly reflected when presenting the benefits of this technology.
☒	Acquiring in-house capabilities	The agency is required to work with licensed electrical engineers and electricians to install wiring needed for the implementation of this technology (this is the same requirement for any electrical work in construction projects).
☒	Addressing legal issues (if applicable) (e.g., liability and intellectual property)	Two patents have been filed on this technology, and licensing agreements should be in place prior to implementation.
☐	Resolving conflicts with existing national/state regulations and standards	Click or tap here to enter text.
☐	Other challenges	Click or tap here to enter text.

16. Please provide details of cost, effort, and length of time expended to deploy the innovation in your organization.

Cost:

- Research funding of $227,051 for research/demonstration project on "Implementing a Self-Heating, Electrically Conductive Concrete Heated Pavement System for the Bus Stop Enhancement Project in the City of Iowa City"
- Research funding of $326,063 for research/demonstration project on "Self-Heating Electrically Conductive Concrete Demonstration Project"

Level of Effort: Three graduate students, 2 postdoctoral research associates, and 5 faculty members were on the team during the development of this technology.

Time:

- Three years: Implementing a Self-Heating, Electrically Conductive Concrete Heated Pavement System for the Bus Stop Enhancement Project in the City of Iowa City
- Three years: Self Heating Electrically Conductive Concrete Demonstration Project

17. To what extent might implementation of this innovation require the involvement of third parties, including vendors, contractors, and consultants? If so, please describe. List the type of expertise required for implementation.

One benefit of this technology is that it does not require enabling technologies from third parties, and it can be adapted smoothly to different transportation infrastructure systems (pavements, bridge decks, sidewalks, parking lots, aprons, stairs, rest areas, tunnels, etc.). The contractor can easily use the specification developed by the ISU research team to design the ECON HPS and construct it similar to constructing a concrete pavement system. A licensed electrical engineer and an electrician are necessary for wiring and final inspection.