Transportation Consortium of South-Central States

Solving Emerging Transportation Resiliency, Sustainability, and Economic Challenges through the Use of Innovative Materials and Construction Methods: From Research to Implementation

Semi-Annual Progress Report #9

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Dr. Marwa Hassan, Director
marwa@lsu.edu
(225) 578-9189

3319 Patrick F. Taylor Hall
Louisiana State University
Baton Rouge, LA 70803

1. Accomplishments

Major Goals and Objectives of the Program

The **Vision** of Tran-SET is to "*address the accelerated deterioration of the transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes*."

The **Mission** of Tran-SET is to "*conduct all phases of research, technology transfer, education, workforce development, and outreach activities as to solve transportation challenges in Region 6 and support implementation*."

The following 14 objectives are at the heart of *all* Tran-SET activities[1]:

Table 1. Major Objectives of Tran-SET.

ID[1]	Objective
	RESEARCH
R1	Improve the durability and extend the service life of transportation infrastructure [IF2, IN1[2]]
R2	Preserve the environment [IF1, IN1]
R3	Preserve the existing transportation system [IF2, IN1]
R4	Address immediate transportation priorities in Region 6 [S1, IF2, IF3, IF4, IN1]
	TECHNOLOGY TRANSFER
TT1	Ensure that scientific and technological developments are accessible, disseminated, and transferred to a wide range of users including state agencies, universities, and industries [IN2]
TT2	Ensure that scientific and technological developments have long-term research value and significant impact to the transportation industry by direct collaboration with all levels of government and nonprofit institutions [IN2]
	EDUCATION
E1	Improve and support existing academic programs at Tran-SET's partnering institutions [IF4, A2]
E2	Improve and support transportation non-degree programs at Tran-SET's partnering institutions (architectural, business, mechanical, electrical, industrial engineering, etc.) [IF4, A2]
	WORKFORCE DEVELOPMENT
WF1	Ensure research outcomes are disseminated through educational and workforce development activities by supporting the development of seminars, workshops, and training courses [IF4, A2]
	EMPHASIS AREAS
EL1	Develop the next generation of leaders and graduate students of the transportation field by supporting mentoring, networking, training, and other development activities [IF4, A2]
EL2	Provide leadership to regional stakeholders and communities (state agencies, universities, and industries) and provide national leadership to applicable research communities [IN1, IN2]
EC1	Encourage and foster collaboration between partnering institutions and external stakeholders as to: (1) maximize sharing of human expertise and facilities among partners and stakeholders, (2) tackle transportation challenges only solvable by multi-disciplinary teams, (3) facilitate knowledge transfer among the team institutions and stakeholders, and (4) minimize duplicative research to optimize the use of available funds [IN2, A2]
ED1	Integrate diversity-related activities into Tran-SET's efforts as to increase participation of underrepresented students in STEM fields, particularly the transportation field [IF4, A2]
	MANAGEMENT
M1	Operate and manage Tran-SET as to ensure the highest degree of accountability, cost-efficiency, and optimum use of available funds, facilities, and capabilities [A2]

[1]All activities, outputs, outcomes, and impacts are categorized under Tran-SET's objectives (in blue).
[2]All Tran-SET objectives, activities, outputs, outcomes, and impacts are categorized under objectives of the US DOT Strategic Plan for FY2018-2022 (in green). Regarding ID abbreviations: S refers to Safety, IF refers to Infrastructure, IN refers to Innovation, and A refers to Accountability objectives, respectively.

Accomplishments (During this Reporting Period)

RESEARCH

Project Closeout of Third-Cycle Projects: Out of the 33 third-cycle projects, **14** projects ended their implementation phase, submitted their implementation reports, and were successfully completed and closed out in the previous reporting period**.** As of **May 2021**, **16** additional projects were successfully completed, closed out, and the corresponding final reports and datasets were archived and disseminated per UTC reporting requirements. The remaining **3** projects were granted a no-cost extension. [M1, A2]

Fourth-Cycle Projects in Progress: As of **Aug. 2021**, all the **40** fourth-cycle projects ended their technical phase. Tran-SET staff is currently conducting an initial review of the submitted final reports and datasets **(Sep. 2021)**. The 40 projects are expected to be completed and closed out in the next reporting period. Figures 1a and 1b present the distribution of these projects by research objective and transportation area, respectively. [R1, R2, R3, R4, S1, IF2, IF3, IF4, IN1]

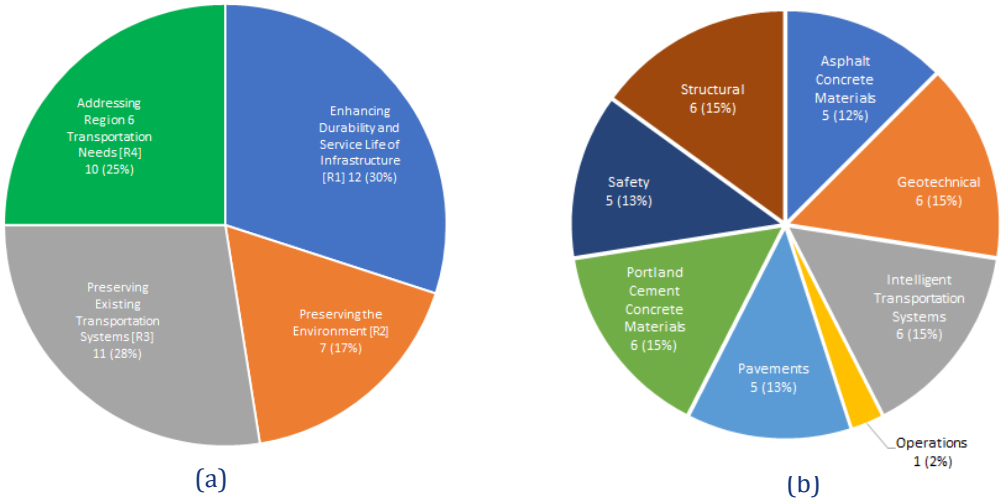

Figure 1. Fourth-Cycle Projects Categorized by: (a) Research Objective and (b) Transportation Area.

Award of Fifth-Cycle Projects: 38 proposals were reviewed by regional and national subject matter experts **(Apr. 2021)**, solicited for revisions by the PIs **(May 2021)**, and finalized **(Jun. 2021)**. Overall, 35 projects were selected for award and started on **Aug. 1, 2021**. Figures 2a and 2b show the distribution of projects by research objective and transportation area, respectively. Additional information about the projects is provided in Appendix A. [R1, R2, R3, R4, S1, IF2, IF3, IF4, IN1]

Problem Statements for Sixth-Cycle Projects: Tran-SET issued a call for problem statements **(May 2021)** for their sixth-cycle of research projects. A total of **68** problem statements were received from 14 institutions in Region 6 **(Aug. 2021).** Problem statements are currently under review and are ranked by regional transportation leaders/experts. Figures 3a and 3b show the distribution of problem statements by research objective and transportation area, respectively. [R1, R2, R3, R4, S1, IF2, IF3, IF4, IN1]

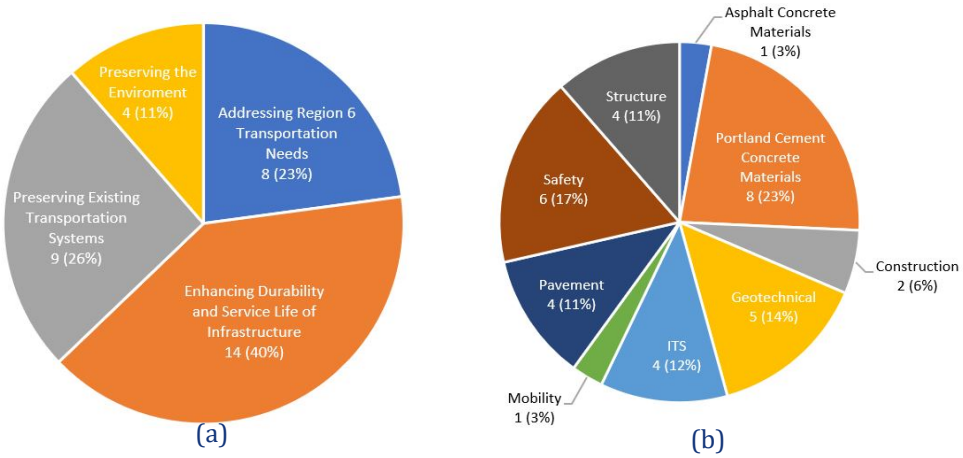

Figure 2. Fifth-Cycle Projects Categorized by: (a) Research Objective and (b) Transportation Area.

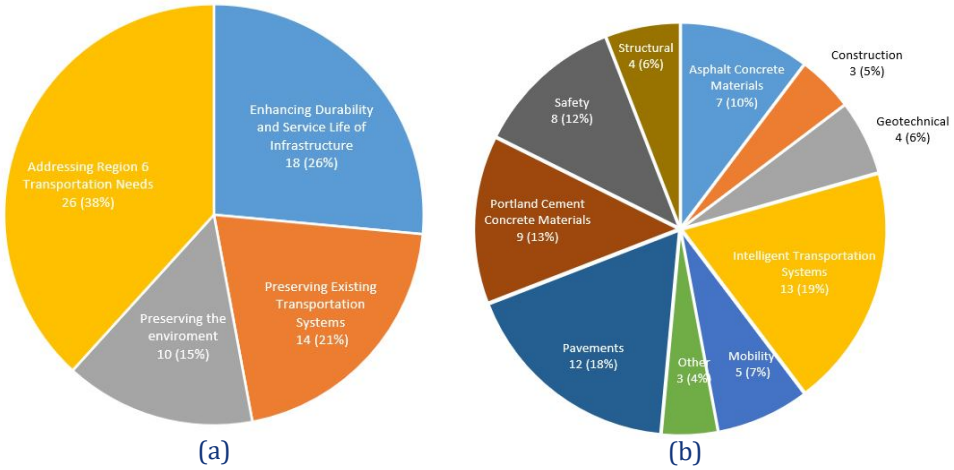

Figure 3. Sixth-Cycle Problem Statements Categorized by: (a) Research Objective and (b) Transportation Area.

TECHNOLOGY TRANSFER

2021 Tran-SET Conference: Tran-SET held its fourth annual conference virtually on **Jun. 3-4, 2021.** The conference was organized and e-hosted by Arkansas State University (ASU) and co-sponsored by the Judd Hill Foundation. The program included: **45** lectern presentations (covering all fourth-cycle projects), and **16** students' research showcase. The conference also hosted the business meeting with the center advisory board (CAB) members. The conference had over **110** attendees and provided a unique opportunity to network directly with Region 6 stakeholders and communicate how Tran-SET research products can help solve regional challenges. The conference program and published conference proceedings are available on Tran-SET's website. [TT1, TT2, EL2, IN2]

2021 TriDurLE Symposium: Tran-SET partnered **(Sep. 2021)** with TriDurLE UTC to collaborate as a co-sponsor in the upcoming 2021 TriDurLE Symposium that will be held virtually on Dec. 6-7, 2021. The symposium's main theme is "Transportation Infrastructure Innovations for Durability and

Resilience." More information about this symposium is available through the following link. In this symposium, Tran-SET will have two back-to-back presentations featuring Tran-SET's key research outcomes. [TT1, TT2, EL2, IN2]

2022 Tran-SET Conference: Tran-SET will hold its fifth annual Conference tentatively on **March 14-15, 2022**. The Conference will be organized and hosted by Oklahoma State University (OSU). In the reporting period, the following activities have been conducted: established Conference Planning Committee **(May 2021)** and selected venue and date **(June 2021)**. [TT1, TT2, EL2, IN2]

Joint Tran-SET Webinar Series: Tran-SET continued its quarterly webinar series with its 13th **(Jun. 2021)** and 14th webinars **(Sep. 2021).** Both webinars were on the topic of *"Advancements in Pedestrian and Bicyclist Safety.* "About 150 attendees participated in these webinars. Recorded webinars, presentation slides and other outreach materials are available on the Tran-SET's website. [TT1, TT2, EL1, EL2, EC1, IF4, IN2, A2]

Newsletter: Tran-SET continued to develop and disseminate its quarterly newsletter with the summer 2020 issue **(Jun. 2021)** and fall 2020 issue **(Sep. 2021).** Newsletters are disseminated via the Tran-SET's list serve. Current and past newsletters are available on the Tran-SET's website. [TT1, IN2]

Technology Transfer (T2) Plan: Tran-SET continues to implement the approved T2 plan, specifically: requiring fifth-cycle proposals to include project-specific T2 plans and utilizing these plans in the review/selection process **(May 2021)**, establishing project review committees (PRCs) for each fifth-cycle project **(Jul. 2021)**, and facilitating meetings between each research team and their respective PRC **(Aug. - Sep. 2021).** These meetings have proven effective: providing needed guidance to the research team, creating an engaged PRC, and identifying allies to champion T2 activities and implementation. [TT1, TT2, EC1, IN2, A2]

EDUCATION

Tran-SET Transportation Veteran Scholarship: As part of Tran-SET's initiative to advance the transportation workforce and to develop its next generation of leaders, Tran-SET offered a scholarship to three veterans. The scholarship awards $10,000 to each student over a period of two years **(spring 2020-fall 2021)**. During this reporting period, three students were awarded the scholarship and are participating in Tran-SET-funded research projects. [E1, EL1, EC1, ED1, IF4, A2]

LSU High School Student Research (HSSR) Intern Program: As a part of Tran-SET's dedication to engage high school students in transportation-related research, Tran-SET participated in the HSSR Intern program organized by LSU to involve 5 high school students to their research in **summer 2021.** Between **Apr. and Jul. 2021**, Tran-SET PIs mentored high school students efficiently on their research projects. On **Jul. 2021**, the students participated in the HSSR virtual poster presentation day. More information about these activities is on the LSU's website. [E1, EL1, EC1, ED1, IF4, A2]

eCybermission Competition: As part of Tran-SET's commitment to enhance education and workforce development, Tran-SET is collaborating with the U.S. Army Educational Outreach Program (AEOP) in their eCybermission. eCybermission is a web-based STEM competition for students in grades six through nine. More information about this competition could be found on their website. During the reporting period, Dr. Mousa (Tran-SET Program Manager) served as a volunteer ambassador to the program, where he had regular meetings with the organizers to discuss future outreach plans. [E1, EL1, EC1, ED1, IF4, A2]

Project-Level STEM Events: Tran-SET and its affiliates sponsored, organized, and participated in several STEM events. Examples of these activities are listed below. [E1, E2, EL1, IF4, A2]

- Dr. Avimanyu Sahoo (Tran-SET PI) from Oklahoma State University participated in the Discovery Day and Summer bridge program held **July 17 through August 5, 2021.**
- Dr. Brendy Rincon (Tran-SET PI) from the University of Texas at San Antonio (UTSA) served as First-Gen STEM Scholars Faculty Mentor at UTSA from **Aug. 2021.**
- Dr. Sharareh Kermanshachi (Tran-SET PI) from the University of Texas Arlington (UTA) participated in several student chapter meetings **(May- Aug. 2021).**
- Christopher Melson (Tran-SET PI) from Louisiana State University (LSU) participated and co-organized LSU student networking event with the Greater Baton Rouge chapter of WTS that was held in Baton Rouge on **April 15, 2021.**
- Dr. Fernando Moreu (Tran-SET PI) from the University of New Mexico (UNM) participated in the Engineering Open House, which was held on **September 11, 2021.**

WORKFORCE DEVELOPMENT

Project-Level Involvement: Tran-SET sponsored, organized, and participated in various workshops, developed and presented revised course materials, and contributed to several professional societies. Illustrative examples are provided below. [WF1, TT1, TT2, EL2, IF4, A2, IN2]

- Dr. Amit Kumar (Tran-SET PI) from UTSA was an invited speaker at the Global Summit on Civil, Architectural and Environmental Engineering GSCAEE-2021 in Barcelona, Spain **(July 2021).** In the summit, Dr. Amit educated the industry about inductance-based charging infrastructure planning for electric vehicles under zonal power constraints.
- Dr. Zahid Hossain (Tran-SET PI) from ASU facilitated an annual safety training for NEAR concrete plant operators, truck drivers, and technicians **(Aug. 2021).**
- Dr. Chao Sun (Tran-SET PI) from LSU presented *"Structural health monitoring of bridges"* to the LaDOTD Bridge Design group **(Jun. 2021).**

MANAGEMENT

Project Data Management Plan: Tran-SET required all fifth-cycle proposals to include project-specific data management plans. These plans are considered as part of the review/selection process **(Apr. 2021).** [M1, A2]

Section 508/Accessibility: Tran-SET has been working diligently to ensure all public facing contents (submitted to NTL and all content residing on the Tran-SET website) are 508-compliant. Completed contents include documents and reports on Tran-SET's website, Tran-SET's website and social media page, and videos content. [M1, A2]

CAB Engagement: Tran-SET prepared a survey to the CAB members to receive feedback on how well Tran-SET activities are addressing regional needs and impacting state-of-the-practice **(May 2021)**. An overall rating of 4.2 out of 5 (with 5 being perfect) was received. [M1, all, A2]

Dissemination of Results

Please see the "Technology Transfer" subsections of Sections 1 (above) and 3 (below) documenting Tran-SET's main outreach and dissemination activities. As detailed in these sections, results have been disseminated via social media (Tran-SET website, LinkedIn, Twitter, and YouTube), newsletters, other promotional documents (i.e., project briefs), conferences, educational materials, and peer-reviewed publications.

Activities Planned (for Next Reporting Period)

RESEARCH

- Archive and finalize remaining fourth-cycle project deliverables **(Dec. 2021).** [TT1, IN2]
- Review/rank sixth-cycle problem statements **(Oct. 2021)**, develop request for proposals for selected problem statements **(Nov. 2021)**, and finalize review of proposals **(Mar. 2022)**. [R1, R2, R3, R4, S1, IF2, IF3, IF4, IN1]

TECHNOLOGY TRANSFER

- Develop and disseminate Tran-SET newsletter for winter 2021 **(Dec. 2021)** and spring 2022 **(Mar. 2022).** [TT1, IN2]
- Organize and jointly host two webinars in the "Joint-Tran-SET Webinar Series" **(Dec. 2021, Mar. 2022)**. [TT1, TT2, EL1, EL2, EC1, IF4, IN2, A2]
- Continue planning activities for the 2022 Tran-SET Conference planned on **Mar. 14-15, 2022** including: finalizing revisions for the submitted papers **(Apr. 2021),** publishing the conference proceedings **(Jun. 2021),** etc. [TT1, TT2, EL2, IN2]
- Continue to develop, promote, and expand Tran-SET's educational video portfolio **(on-going)**; and upload videos from the 2022 Tran-SET Conference **(Mar. 2022).** [TT1, IN2]
- Promote and disseminate fourth-cycle reports and project datasets via Tran-SET listserv and social media **(Jan. 2022).** [TT1, IN2]
- Continue developing/disseminating "Project Highlights" for fifth-cycle projects **(Nov. 2021).** [TT1, IN2]

EDUCATION

- Continue to offer the Tran-SET Scholarship for Veterans, disseminate, and award three recipients in the **2022 spring** semester. [E1, EL1, EC1, ED1, IF4, A2]
- Participate in the 2022 CoE HSSR Program in LSU. At least four high school students will be selected **(Nov. 2022)** to work on four Tran-SET projects. [E1, EL1, EC1, ED1, IF4, A2]
- Participate in the Annual Southeastern Back-to-School STEM Fest in Southeastern Louisiana University **(Nov. 2021)**. [E1, IF4, A2]
- Continue coordinating with the U.S. Army Educational Outreach Program (AEOP) to recruit future virtual judges **(Dec. 2021)** to participate in eCybermission. [E1, EL1, EC1, ED1, IF4, A2]
- Continue coordinating with the PIs to develop new educational modules and publishing these educational modules on Tran-SET's website **(on-going).** [E1, EL1, EC1, ED1, IF4, A2]

WORKFORCE DEVELOPMENT

- Integrate developed educational modules and revised courses into the recently created LSU Construction Management online programs: B.S., Post Baccalaureate Certification, and M.S. degree programs **(on-going).** [WF1, TT1, TT2, EL2, IF4, A2, IN2]
- Continue sponsoring, organizing, and participating in workshops, developing and presenting revised course materials, and involvement in professional society activities **(on-going).** [WF1, TT1, TT2, EL2, IF4, A2, IN2]
- Collaborate with the Transportation Research Forum (TRF) to create a new student chapter at LSU **(Nov. 2021).** [WF1, TT1, TT2, EL2, IF4, A2, IN2]

MANAGEMENT

- Organize and host an in-person, mid-year meeting with Associate Directors, Program Directors, and CAB members to discuss the management/operation of Tran-SET and ways to improve our processes **(Jan. 2022).** [M1, all, A2]

- Provide 508-compliant captions for remaining video content **(Oct. 2021).** [M1, A2]

2. Participants & Collaborating Organizations

During this reporting period, Tran-SET partnered with **136** organizations (51 academic institutions, 37 government agencies, 38 industrial firms, and 10 nonprofits) to support and participate in its research, technology transfer, education, and workforce development activities. Please see Table 2 for details.

Tran-SET collaborated with **39** organizations/individuals (from 11 academic institutions, 10 government agencies, 5 industrial firms, and 13 nonprofits.). As shown in Table 3, these collaborations embody interdisciplinary approaches and numerous industrial partnerships.

Partners (Selected)

Table 2. Tran-SET Partners.

Organization Name	Type	Location	Description of Contribution [Tran-SET Affiliation]
Accenture Endowed Professorship in Mechanical Engineering	Industrial firm	Austin, TX	Collaborative research [PRC]
Admas Engineering	Academic institution	Purkynova, Czechia	Collaborative research [PRC]
AECOM	Industrial firm	Los Angeles, CA	Collaborative research [PRC]
Air Force Research Laboratory	Government	Albuquerque, NM	Early potential adopters and problem owners
Alabama Transportation Institute - University of Alabama	Academic institution	Tuscaloosa, AL	Collaborative research [PRC]
Alliance Safety Council (Industry)	Nonprofit	Baton Rouge, LA	Collaborative research [CAB]
Appalachian State University	Academic institution	Boone, NC	Collaborative research [PRC]
APS Engineering and Testing LLC	Industrial firm	Baton Rouge, LA	Collaborative research [PRC]
ARA	Industrial firm	Albuquerque, NM	Collaborative research [PRC]
Arkansas Concrete Pavement Association	Academic institution	Little Rock, AK	Collaborative research [PRC]
Arkansas Department of Energy & Environment	Government	Little Rock, AK	Collaborative research [PRC]
Arkansas Highway and Transportation Dep. (AK)	Government	Little Rock, AK	Collaborative research [CAB]
Association of American Railroads	Nonprofit	Washington, D.C.	Input about practicality and barriers of using tapping robots for the railroad industry
Atlas Asphalt Inc.	Industrial firm	Jonesboro, AR	In-kind support [fourth-cycle]; Atlas Asphalt Inc. has supplied testing materials for this project.
Barriere Construction Company (Industry)	Industrial firm	New Orleans, LA	Collaborative research [CAB]
Black Buffalo 3D Corporation	Academic institution	New York, NY	Collaborative research [PRC]
Boral Resources	Industrial firm	South Jordan, UT	Supply alternative SCMs

Collaborators (Selected)

Table 3. Tran-SET Collaborators.

Organization/Name	Type	Description of Collaboration [Tran-SET Affiliation]
AECOM	Industrial firm	Shared data pertaining to CRPC vanpool program development and inflow-outflow analysis
American Society of Civil Engineering (ASCE)	Nonprofit	Trade organization
ARDOT	Government	ARDOT District 10 helped to identify the RAP sources.
AREMA	Nonprofit	Discussing of new technologies for their use on railway safety
Arkansas Asphalt Pavement Association (AAPA)	Nonprofit	AAPA helped to indentiy another local paving company API as a research collaborator.
Asia-Pacific-Euro Summer School on Smart Structures Technology	Nonprofit	Trade organization
Automated Railroad Maintenance Systems (ARMS)	Industrial firm	Provide feedback and assessment of the work
Build Baton Rouge (East Baton Rouge Redevelopment Authority)	Government	Shared unpublished plan documents and information pertaining to station area development planning and strategy
Chinese Earthquake Administration (CEA)	Nonprofit	Laboratory for testing LiDAR in large scale facilities and input on large scale applications
City of Jonesboro	Government	City of Jonesbore engineer has been brief about the project.
City of San Antonio	Government	Discussed field implementation
CPS Energy	Government	Presented harvesting results on 9/13/2019
DOTD	Government	Shared data pertaining to FTA and DOTD support of existing and previous intercity services (i.e., LA Swift and regional Greyhound service)
ESPOL University	Academic institution	Process bagasse ash, prepare SCBA-ECC mixtures and evaluate its properties; Conduct research on zeolite-based EGC materials.
FHWA	Government	Discussed application of the vehicle classification software (Debbie Walker)
Frontiers Journal	Nonprofit	Trade organization
Greyhound	Industrial firm	Collaboration in in-person data collection for existing intercity passenger service customers
Institute of Engineering Mechanics (IEM) China	Nonprofit	Student to provide input on LiDAR for SHM of structures
Jonesboro High School (JHS)	Academic institution	The STEM Academy of JHS will select qualified students for the internship program
LaDOTD	Government	Help the PIs visit bridge construction sites
Megabus	Industrial firm	Collaboration in in-person data collection for existing intercity passenger service customers

3. Outputs

Performance metrics and targets for outputs, outcomes, and impacts of Tran-SET's research, T2, education, and workforce development programs are discussed below.

RESEARCH

Table 4 lists Tran-SET's performance metrics for research-related outputs. In total, **39** new technologies/techniques were developed. Selected technologies are summarized below.

Table 4. Research Performance Metrics: Outputs.

ID	Objective ID	Metric	Value[1]	Ann. Value[2]	Ann. Target[3]	Percent Compl.[4]
	R4, S1, IF2, IF3, IF4, IN1	**Number of projects specifically addressing regional challenges:**				
R-01		Metropolitan growth and congestion	5	5	5	100%
R-02		Future transportation challenges	12	12	15	80%
R-03		Declining public revenues	5	5	3	167%
R-04		Underserved communities	1	1	2	50%
R-05		Safety	8	8	5	160%
R-06	EC1	Number of collaborative (multi-institution) projects	8	8	11	73%
R-07	R1, R2, R3, R4, IN1	Number of new technologies or techniques developed	39	80	80	100%

[1]Metric value for reporting period; [2]Best estimate for annualized metric value; [3]Annual, per funding cycle, target; [4]Percent completion of annual target; same column definitions for Tables 4 – 13.

Discussion of Performance Metrics: Number of New Technologies or Techniques Developed

In this reporting period, various new technologies and methods were developed resulting from the successful research conducted during the third-cycle and fourth-cycle projects. Examples of developed technologies or techniques are presented below.

1. **Dr. Sahoo (PI)** and his research team in OSU developed two models (SOH inclusive battery model and Artificial Neural Network Model to learn the battery model), which can simultaneously estimate the state of charge, state of health, and internal parameters of lithium-ion (Li-ion) batteries to be used in electric vehicles.
2. **Dr.Chao Sun (PI)** and his research team in LSU developed a deep-learning based framework to identify concrete bridge cracking damage using UAV images.
3. **Dr. Hyun (PI)** and her research team in UTA developed network resilience assessment framework to understand equity impacts on network disruptions.
4. **Dr. Mena (PI)** and his research team in UTT implemented and validated a simple analysis method for determining the structural conditions of pavement sections at the network level.

TECHNOLOGY TRANSFER

Table 5 lists Tran-SET's performance metrics for T2-related outputs. Selected output examples are presented below.

Table 5. Technology Transfer Performance Metrics: Outputs.

ID	Objective ID	Metric	Value	Ann. Value	Ann. Target	Percent Compl.
	TT1, TT2, IN2	**Number of stakeholders identified, specifically[1]:**				
TT-01		Early potential adopters	46	46	30	153%
TT-02		Late potential adopters	26	26	30	87%
	TT1, TT2, IN2	**Number of times research products (technology) are disseminated via the following channels:**				
TT-03		Featured in Tran-SET newsletter	12	24	24	100%
TT-04		Featured on Tran-SET social media	32	62	50	124%
TT-05		Peer-reviewed publications and presentations	156	320	130	246%
TT-06		Webinars	2	6	5	120%
	TT1, IN2	**Tran-SET website traffic:**				
TT-07		Number of visitors to website	17k	34k	30k	113%
TT-08		Number of visits to website	122k	244k	250k	98%
	TT1, TT2, IN2	**Number of times disseminated research products have informed/been viewed:**				
TT-09		Social media engagement levels(s)	5.6/2.9	5.6/2.9	4.5[2]/2.5[3]	125/119%
TT-010		Number of times reports (or related) are downloaded	5,827	10,886	6,000	181%
TT-011		Number of citations from publications	274	425	120	354%
TT-012		Presentation attendees or views	5,624	10,760	10,000	108%
	TT1, TT2, IN2	**External funds:**				
TT-013		Industrial partners providing funds	5	5	4	125%
TT-014		Public agency partners providing funds	5	5	10	50%
TT-015		Total funds from industrial partners	$112k	$112k	$200k	56%
TT-016		Total funds from public agency partners	$301k	$301k	$300k	100%

[1]Individual stakeholders as specified in fifth-cycle, project-specific T2 plans; may contain multiple (but distinct) stakeholders within same agency; [2]Average "calculated as clicks/impressions" (LinkedIn); [3]Average "engagement rate" (Twitter).

Discussion of Performance Metrics: Building Audience

- **Number of Times Reports (or Related) are Downloaded (TT-010):** This metric has significantly increased in this reporting period from 5,059 to 5,827. Readers originated from 158 countries (with a strong majority from the US) and included educational institutions (52%), commercial entities (36%), and government agencies (12%).
- **Presentation Attendees or Views (TT-012):** The target for this metric was re-evaluated and was raised to 10,000 (from 9,500). The increase is due to successful outreach activities conducted during the third-and fourth-cycle projects' implementation and technical phases.

Peer-Reviewed Journal Publications (Selected)

1. Yuan, X., Smith, A., Sarlo, R., Lippitt, C. D., & Moreu, F. (2021). Automatic evaluation of rebar spacing using LiDAR data. *Automation in Construction*, 131, 103890.
2. AbuFarsakh R, Arce G, Hassan M, Huang O, Radovic M, Rupnow T, Mohammad LN, Sukhishvili S. Effect of Sand Type and PVA Fiber Content on the Properties of Metakaolin Based Engineered Geopolymer Composites. *Transportation Research Record*. 2021 Aug 10.

3. Billah, K., T.B. Le, and H. O. Sharif, 2021: Data- and Model-Based Discharge Hindcasting over a Subtropical River Basin. *Water 2021*, 13, 2560. DOI: 10.3390/w13182560.
4. Miah, M., Hyun, K., Mattingly S., Broach, J, McNeil N., Kothuri, S., (2021) Challenges and Opportunities of Emerging Data Sources to Estimate Network-Wide Bike Counts. *Journal of Transportation Engineering, Part A* : Systems, 2021.
5. Starr, J., Soliman, E., Matteo, E. N., Dewers, T., Stormont, J. C., Reda Taha, M. M., "Mechanical Characterization of Low Modulus Polymer-Modified Calcium-Silicate-Hydrate (C-S-H) Binder", *Cement & Concrete Composites*, 124, 104219, 2021.
6. Safapour, E., Kermanshachi, S., and Pamidimukkala, A. (2021). "Post-disaster recovery in urban and rural communities: Challenges and strategies," *Elsevier International Journal of Disaster Risk Reduction*, 64 (2021), PP. 102535. DOI: 10.1016/j.ijdrr.2021.102535

EDUCATION

Table 6 lists Tran-SET's performance metrics for education-related outputs. In total, Tran-SET supported **211** students and produced **38** educational modules. Selected modules are described below.

Table 6. Education Performance Metrics: Outputs.

ID	Objective ID	Metric	Value	Ann. Value	Ann. Target	Percent Compl.
	E1, E2, EL1, IF4, A2	**Number of students supported from Tran-SET research:**				
E-01		Undergraduate students	44	44	50	88%
E-02		Masters students	53	53	50	106%
E-03		Doctoral students	53	53	50	106%
	E1, E2, EL1, ED1, IF4, A2	**Number of research opportunities for under-representative groups:**				
E-04		Undergraduate students	47	47	15	313%
E-05		Graduate students	48	48	15	320%
E-06	E1, E2, EL1, ED1, IF4, A2	Total budgeted costs for women and minorities	$0.39M	$0.39M	$1.1M	35%
E-07	E1, E2, EL1, IF4, A2	Number of new transportation-related educational modules delivered	44	82	50	164%
E-08	E1, E2, EL1, IF4, A2	Number of STEM events sponsored by Tran-SET or that participated in	29	63	20	315%

Discussion of Performance Metrics

- **Number of research opportunities for under-representative groups-Undergraduate students (E-04):** This metric has significantly increased in this reporting period from 29 to 47. This reflects Tran-SET's recent success in engaging minorities in transportation-related research.

Educational Modules (Selected)

1. At UTA, an educational module was developed on gender-based health and safety of construction workforce in transportation infrastructure.
2. At LSU, an education module on pile downdrag was developed and incorporated into LSU course CEE 7700 (Advanced Foundation Engineering).

3. At UNM, an educational module was developed to train undergraduate cadets in cybersecurity of low-cost sensors for civil infrastructure safety.
4. At ASU, an educational module on powder active carbon in concrete was developed and incorporated into course "CE 5292: Advance Civil Engineering Materials."
5. At TAMU, an educational module was developed on corrosion protection in transportation assets.
6. At UTA, an educational module on efficient detection and monitoring sensing was developed for UTA course CE 5316 (Infrastructure Monitoring).

WORKFORCE DEVELOPMENT

Table 7 lists Tran-SET's performance metrics for workforce development-related outputs. During this reporting period, **94** revised courses and **26** seminars/workshops were delivered.

Table 7. Workforce Development Performance Metrics: Outputs.

ID	Objective ID	Metric	Value	Ann. Value	Ann. Target	Percent Compl.
WF-01	WF1, IF4, A2	Number of new or revised transportation-related courses	94	259	100	259%
WF-02	WF1, IF4, A2	Number of seminars/workshops presented	26	58	90	64%
WF-03	WF1, IF4, A2	Number of professional society-related events[1] sponsored or participated in	46	102	100	102%

[1]Events include local and regional meetings of various professional societies (e.g., AASHTO, ASCE, ITE, SAE, etc.); Tran-SET believes these local groups are a critical link in developing the transportation workforce.

Seminars/Workshops (Selected)

1. Kumar, A., Mishra, S. and Ngo, H.H. "Inductance-Based Charging Infrastructure Planning for Electric Vehicles Under Zonal Power Constraints, "Global Summit on Civil, Architectural and Environmental Engineering GSCAEE-2021, Barcelona, Spain, July 2021.
2. A. Sahoo, V. Narayanan, and Q. Zhao, "Adaptive gain observers for distributed state estimation of linear systems," American Control Conference, New Orleans, USA, May, 2021.
3. Nipa, T. and Kermanshachi, S. "Dimensions of Resilience Measurement in Critical Transportation Infrastructures," ASCE International Conference on Transportation & Development, Austin, TX, June 2021.
4. Kim, N., "Sensing Human Behaviors in a Virtual Reality Environment for Enhancing Safety in the Construction Industry," Punahou School, Honolulu, HI, August 2021.
5. Kim, N., "Reducing Risk Habituation to Struck-by Hazards in a Road Construction Environment Using Virtual Reality Behavioral Intervention," Emerging Technologies BIM Research Group, the Del E. Webb School of Construction, Arizona State University, Phoenix, AZ, April 2021.

4. Outcomes

While some of the outcomes will materialize in the long-term, the following subsections detail how current efforts are driving a number of outputs towards implementation and towards future and meaningful outcomes.

TECHNOLOGY TRANSFER

Table 8 lists Tran-SET's performance metrics for T2-related outcomes.

Table 8. Technology Transfer Performance Metrics: Outcomes.

ID	Objective ID	Metric	Value	Ann. Value	Ann. Target	Percent Compl.
	TT1, TT2, IN2	**External, derivative initiatives spurred by research products**				
TT-C1		Number of additional research projects	27	51	20	255%
TT-C2		Total funding of additional research projects	$9.4M	$13.7M	$8.0M	171%
TT-C3	TT1, TT2, IN2	Number of commercialized/patented/ licensed research products	1	5	6	83%
TT-C4	TT1, TT2, IN2	Number of stakeholders MOUs	5	7	6	117%
	TT1, TT2, IN2	**Number of stakeholders who have:**				
TT-C5		Committed to adopt research products	9	20	25	80%
TT-C6		Adopted research products	6	14	15	93%

Discussion of Performance Metrics: Further Development and Adoption of Research Products

- **Number of Additional Research Projects (TT-C1, TT-C2):** A total of **27** sponsored research projects (external to Tran-SET) were initiated as a direct result of research products developed from a Tran-SET-sponsored project. The funding agencies for these projects included but not limited to NCHRP, National Science Foundation (NSF), City of San Antonio, and Texas DOT.
- **Number of Stakeholders who have committed to Adopt Research Products (TT-C5):** A total of 9 stakeholders have committed to adopt research products resulting from Tran-SET-sponsored projects. As an example:
  (1) LaDOTD's CAV Technology Team are aware of the research results (Project No. 19ITSLSU06) and asked consultant preparing their "CAV Strategic Plan" to incorporate/utilize results as appropriate.
  (2) NMDOT and Structures Inc. committed to use the Ultra-High-Performance Concrete developed in NMSU (Project No. 19CNMS01) in bridge deck overlays.
  (3) A toolbox was developed in UNM to detect and assess bridge deck wearing surface and subsurface distresses for New Mexico Department of Transportation District 2.

New Policies, Regulations, Rulemaking, or Legislation (Selected)

- Dr. Chao Sun (PI) developed a deep learning-based framework to identify concrete bridge cracking damage using UAV images (Project No. 20STLSU12). Using this framework is expected to assist transportation agencies in the structural health monitoring of their transportation infrastructure.
- Dr. Hyun developed network resilience assessment framework to understand equity impacts on network disruptions (Project No 20PUTA28). Using this framework is expected to assist transportation agencies in determining the road network infrastructure criticality during extreme weather events by considering network topology, traffic flow and user characteristics of the transportation network.
- Dr. Momen Mousa (Project No. 20BLSU03) developed new cost-effective restriping strategies for district roads in Louisiana. These findings will result in a number of modifications towards reducing the potential for under-stripped or over-striped roads.

Adoption of New Technology, Techniques, or Practices (Selected)

- The research team in LSU (Project No. 21CLSU13) coordinated with the Louisiana Department of Transportation and Development to apply a low-cost Engineered Cementitious Composites (ECCs) in Rural Roads in the State of Louisiana.
- A system to monitor the flood water level was developed (Project No. 19SAUTA03), and the results of real-time data collection and processing technology were utilized by the state of Texas.
- The New Mexico DOT started using the wildlife monitoring techniques proposed by Tran-SET researchers to prevent wildlife-vehicle collisions (Project No. 19SAUNM03).

EDUCATION

Table 9 lists Tran-SET's performance metrics for education-related outcomes. In total, **211** students participated in Tran-SET-sponsored research.

Table 9. Education Performance Metrics: Outcomes.

ID	Objective ID	Metric	Value	Ann. Value	Ann. Target	Percent Compl.
	E1, E2, EL1, ED1, IN4, A2	Number of students participating in Tran-SET research:				
E-C1		Undergraduate students	44	44	75	59%
E-C2		Graduate students	106	106	100	106%
E-C3	E1, E2, EL1, IN4, A2	Number of times educational modules have been viewed	340	1,464	1,000	146%
E-C4	E1, E2, EL1, ED1, IN4, A2	Number of students attending sponsored or involved STEM events	559	1,596	1,300	123%

Increased Body of Scientific Knowledge (Selected)

- The developed High-Modulus Asphalt Concrete (HMAC) mixes in LSU will enhance the performance of asphalt pavements in Louisiana (Project No. 20BLSU02).
- The developed network resilience assessment framework in UTA will aid in advancing the state-of-the-art in determining the road network infrastructure criticality during extreme weather events (Project No 20PUTA28).
- Tran-SET engaged five high school students in transportation-related research in Louisiana State University in summer 2021. Such engagement provides information, exposure, and positive experiences at an influential stage in students' career trajectory.

WORKFORCE DEVELOPMENT

Table 10 lists Tran-SET's performance metrics for workforce development-related outcomes. In total, **3,823** attendees participated in new/updated transportation-related courses, seminars, or workshops.

Table 10. Workforce Development Performance Metrics: Outcomes.

ID	Objective ID	Metric	Value	Ann. Value	Ann. Target	Percent Compl.
WD-C1	WF1, IF4, A2	Number attending offered new or revised courses	2,898	5,513	4,000	138%

ID	Objective ID	Metric	Value	Ann. Value	Ann. Target	Percent Compl.
WD-C2	WF1, IF4, A2	Number attending presented seminars/workshops	925	2,366	4,000	59%
WD-C3	WF1, IF4, A2	Sponsorship: Number of stakeholders sponsoring seminars/workshops/conferences	9	24	20	120%
WD-C4		Total funds of sponsorship	$75k	$191k	$200k	96%

Enlargement of Trained Transportation Workforce (Selected)

- Dr. Momen Mousa (PI) from LSU coordinated with the American Traffic Safety Services Association (ATSSA) to provide a 1-hour educational session in the ATSSA's Annual CONVENTION & TRAFFIC EXPO 2022. This session will educate the attendees about optimizing the performance of pavement markings to enhance drivers' safety at night.
- Dr. Hossain (PI) conducted safety trainings for ready mix concrete operators in Jonesboro, Arkansas. These sessions educated the attendees on the safety protocols to be followed during concrete operations.
- Dr. Fernando Moreu (PI) developed an educational module in UNM to train undergraduate cadets in cybersecurity of low-cost sensors for civil infrastructure safety.

5. Impacts

As with the outcomes, the project impacts will be updated as they become available. The following subsections detail how select project outcomes are expected to impact the transportation system and workforce.

TECHNOLOGY TRANSFER

Table 11 lists Tran-SET's performance metrics for T2-related impacts. These metrics cover related products from third-cycle projects.

Table 11. Technology Transfer Performance Metrics: Impacts.

ID	Objective ID	Metric	Value	Ann. Value	Ann. Target	Percent Compl.
TT-I1	TT1, TT2, R1, IF2, IN1, IN2	Improve the durability and service life of transportation infrastructure[1]	36%	36%	20%	180%
TT-I2	TT1, TT2, IN2	Reduce costs associated with repair and upgrade of transportation infrastructure[2]	$203k	$203k	$100k	203%

[1]Represents the average percent improvement to service life estimated by third-cycle project PIs of their specific infrastructure component of study, assuming a full-scale implementation and all other factors constant; [2]Represents the average cost savings per lane-mile estimated by third-cycle PIs associated with repairs using their specific infrastructure component of study, assuming all other factors constant.

Discussion of Performance Metrics: Impact on Effectiveness of the Transportation System

- **Improve the Durability and Service Life of Transportation Infrastructure (TT-I1):** This metric encompasses **23** applicable products. For example:
  - The service life of the pavement structures constructed with Reclaimed Asphalt Pavement (RAP) and Warm Mix Asphalt (WMA) additives is expected to increase significantly. Based on the results of the WMA-RAP mixtures against rutting, the percentage increase in service life is expected to be 10-30% (Project No. 19BLSU01)

- The implementation of small unmanned aircraft system based airborne imaging techniques in bridge inspection will improve the durability and service life of the transportation infrastructure by about 50% (Project No. 19STUNM04)

- **Reduce Costs Associated with Repair and Upgrade of Transportation Infrastructure (TT-I2):** This metric encompasses **16** applicable products. For example:
  - The site-specific ground motion response analyses (SSGMRA) conducted at ASU will increase the resilience of the transportation infrastructure against catastrophic weather events with an expected cost reduction associated with repair and upgrade of the transportation infrastructure of about $25,000/lane-mile (Project No. 19GTASU01)
  - The implementation of Engineered Cementitious Composites (ECC) in the pavement structure is expected to result in cost reduction of about $11,000/lane-mile (Project No. 19CLSU03)

Impact on Adoption of New Practices and Commercialization (Selected)

- The developed Ultra-High-Performance Concrete (UHPC) from local materials in New Mexico is expected to provide an increase in service life of about 300% compared to normal strength concrete (Project No. 19CNMS01).
- The developed restriping strategy (Project No. 20BLSU03) for 4-inch wide markings is expected to save Louisiana about $20 million annually when restriping the whole network without jeopardizing user safety. The developed strategy for 6-inch wide markings is expected to save the State about $2 million annually when restriping the whole network in addition to enhancing the user safety. The research team secured additional funds from the NCHRP IDEA program to commercialize and adopt the developed strategy.

EDUCATION

Table 12 lists Tran-SET's performance metrics for education-related impacts. As shown, funded projects have led to the graduation of a large number of students that will effectively contribute to the transportation workforce.

Table 12. Education Performance Metrics: Impacts.

ID	Objective ID	Metric	Value	Ann. Value	Ann. Target	Percent Compl.
E-I1	EL1, EL2, IF4, A2	Number of graduated, supported students entering the transportation field	40	115	100	115%
E-I2	EL1, EL2, IF4, A2	Feedback[1] of graduated, supported students who've entered the transportation field[2]	4.4	4.4	5	88%

[1]Feedback solicited from students' advisors; [2]Scale: 0 to 5 (5 being perfect); same definitions for Table 13

Impact on Scientific Knowledge (Selected)

- Project No. 20PUTSA34 developed a simplified pavement health categorization chart utilizing Falling Weight Deflectometer (FWD)-simulated deflection bowls and deflection parameters. This has contributed to the body of knowledge in the field of pavement assets management at the network level.
- Project No. 20GTUNM31 developed a remote robot capable of recording data from the rock surface to identify unstable rocks prior to a rock fall. This has led to a better understanding of the rocks that are prone to fall in order to remove them.

WORKFORCE DEVELOPMENT

Table 13 lists Tran-SET's performance metrics for workforce development-related impacts.

Table 13. Workforce Development Metrics: Impacts.

ID	Objective ID	Metric	Value	Ann. Value	Ann. Target	Percent Compl.
	WF1, IF4, A2	Feedback of seminar/workshop/ Conference attendees:				
WD-I1		Related to skills gained	4.5	4.5	5	90%
WD-I2		Related to improved practices	4.5	4.5	5	90%

Impact on Transportation Workforce Development (Selected)

- Dr. Fernando Moreu was an invited speaker at the international webinar organized by IABMAS on July, 2021. In this webinar, Dr. Moreu educated the attendees about how augmented reality can enable new human-infrastructure interfaces. Over 100 researchers and industry leaders from many states and different countries attended this webinar. Interest from this webinar resulted in a collaboration between Dr. Moreu, NSF, and the Federal Railway Administration.
- The 13th and 14th Tran-SET webinars on the advancements in pedestrian and bicyclist safety engaged a diverse audience of designers, state DOTs personnel, contractors, industry suppliers, and researchers. More than 100 professionals attended this webinar. The webinar successfully transferred knowledge and educated the audience on enhancing the safety of pedestrians and bicyclists which is a critical challenge in Region 6. The number of attendees, positive feedback, and post-webinar engagement indicate its success.

6. Changes/Problems

Nothing to report

7. Special Reporting Requirements

Not applicable.

Appendix A

Table 14. Awarded Fifth-Cycle Projects.

Project No.	Title	Total Cost	Leading Institution	Research Objective	Topical Area
21GTASU02[1]	Seismic Hazard Analysis for the City of Jonesboro and Surrounding Counties within Northeast Arkansas (NEA)	$68,324	ASU	R3	Geotechnical
21GTASU01	Using of Rice Husk Ash (RHA) as Stabilizing Agent for Poor Subgrade Soils and Embankments	$80,691	ASU	R1	Geotechnical
21BLSU11[1]	Development of a Machine Learning-Based Model to Determine the Optimum and Safe Restriping Timing of Thermoplastic Pavement Markings in Hot and Humid Climates	$75,179	LSU	R1	Pavements
21CLSU12[2]	Resilient 3D-Printed Civil Infrastructure with Ultra-High Performance Engineered Cementitious Composites (UHPECCs)	$60,000	LSU	R1	Portland Cement Concrete Materials
21CLSU13[2]	Development and Implementation of Low-Cost Engineered Cementitious Composites (ECCs) in Rural Roads in the State of Louisiana	$217,822	LSU	R1	Portland Cement Concrete Materials
21PLSU15[2]	Development of Distress Index Prediction Models for Rehabilitation Treatments in Louisiana Using Advance Machine Learning Techniques	$95,179	LSU	R1	Pavements
21CLSU01	An Innovative Reinforcement Approach for Rebar-Free 3D Printing of Transportation Infrastructure	$90,000	LSU	R1	Structural
21STLSU04	Comparative Analysis of 3D Printed Bridge Construction in Louisiana	$60,000	LSU	R4	Structural
21GTLSU02	Development of Soil-Biochar Mixtures as a Sustainable and Multi-Functional Roadway Fill Material	$60,000	LSU	R2	Geotechnical
21COLSU14	A Deep Learning Tool for the Assessment of Pavement Smoothness and Aggregate Segregation during Construction	$60,000	LSU	R1	Construction
21ITSLSU16	Examining drivers' behaviors to connected and automated vehicles	$75,279	LSU	R4	ITS
21STLSU08	A Bridge Digital Twin for Enhancing Transportation Resilience and Asset Management	$60,000	LSU	R3	Structural
21BLSU03[2]	A New Generation of Dense-Graded Asphalt Mixtures with Superior Performance against Stripping and Moisture Damage	$135,000	LSU	R1	Asphalt Concrete Materials
21CLSU18	Development of Ultra-High Performance Engineered Geopolymer Composites (UHP-EGCs)	$285,000	LSU	R1	Portland Cement Concrete Materials
21CLSU19	Low-Cost Sustainable Engineered Geopolymer Composites (EGCs) for Repair and New Construction of Transportation	$300,000	LSU	R1	Portland Cement Concrete Materials
21CNMSU60	Alternative Supplementary Cementitious Materials in Ultra-High-Performance Concrete	$120,000	NMSU	R1	Portland Cement Concrete Materials
21ITSOSU01	Intelligent Incipient Fault Detection System for Electric Vehicle Battery: Fault Isolation Schemes and Prototype Development	$130,000	OSU	R4	ITS
21SAOSU02	Public Transportation Safety Performance Measurement Education and Training	$110,000	OSU	R3	Safety

Project No.	Title	Total Cost	Leading Institution	Research Objective	Topical Area
21HSPVAMU1	Potential Use of Renewable Diesel for Transportation in Texas and its Environmental Impacts under Uncertainties Caused by COVID-19	$60,000	PVAMU	R2	Mobility
21GTPVAMU2	Investigation of the Impact of Rainfall Patterns on Highway Slope Instability	$60,000	PVAMU	R3	Geotechnical
21GTLSU05	Resiliency of Transportation Infrastructure and the Environment after Hurricanes	$285,000	LSU	R2	Geotechnical
21COLSU06	Development of Robotics & Automation Roadmap for Road Construction/Maintenance Projects	$120,000	LSU	R4	Construction
21CTAMU01[1]	Characterizing corrosion control and prevention methods for RC elements based on hybrid protection mechanism	$230,000	TAMU	R1	Portland Cement Concrete Materials
21CUTA01	Integrate infrastructure performance monitoring using automatic crack evaluation system and convolutional neural network	$134,000	UTA	R3	Portland Cement Concrete Materials
21ITSUTA02	Effectiveness Assessment of E-Ticketing Technology Adopted to Mitigate Covid-19 Challenges for Inspectors and Field Engineers in Transportation Projects: Guidebook Development for E-Ticketing (Electronic Track of Material Delivery) Implementation	$108,000	UTA	R4	ITS
21ITSUTA03	Data Driven Identification of COVID-19 Impacts on E-Commerce and Freight Movement	$108,000	UTA	R4	ITS
21PUTSA01	Permeable Curb and Gutters for Storm Water Control	$90,000	UTSA	R2	Pavements
21SAUTSA01	Impact of Truck Drivers and Transportation Infrastructure Characteristics on Large Truck Crashes	$90,000	UTSA	R3	Safety
21SAUTSA02	Coupled Situational Awareness System to Improve Transportation Infrastructure Performance during Extreme Events	$117,763	UTSA	R4	Safety
21BLSU07	Monitoring Oxidation in Asphalt Pavements by Portable Infrared Spectroscopy (PIRS) to Establish Optimal Timing for Preservation Treatments	$60,709	LTU	R3	Pavements
21SAUNM03	Slowing COVID-19 Spread – Simulating Bus Seating Strategies	$100,000	UNM	R4	Safety
21SAUNM01	Field Evaluation of E-Ticketing Technologies for Efficient Asphalt Delivery Ticket Collection and Quantity Calculation	$130,000	UNM	R3	Safety
21SAUNM02	COVID-19 and Traffic Safety: Role of Infrastructure and Exposure	$100,000	UNM	R3	Safety
21CUNM05	Evaluation of Fresh and Hardened Properties of 3D-Printed Engineered Cementitious Composites (ECC) Designed for Sustainable and Resilient Infrastructure Systems	$100,000	UNM	R1	Portland Cement Concrete Materials
21STUNM04	Increasing Bridge Durability and Service Life with LIDAR Enhanced Unmanned Aerial Systems (UAS)	$100,000	UNM	R1	Structural

[1]Industrial firm providing matching funds (public-private partnership); [2]Government agency providing matching funds (public-public partnership); [3]Multi-institution project