U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology (OST-R)

Grant No. 69A3552348333

Transportation Infrastructure Precast Innovation Center (TRANS-IPIC)

Center Director: Bassem Andrawes, Ph.D., P.E., F.ASCE
Professor, Department of Civil and Environmental Engineering
University of Illinois at Urbana-Champaign
E-mail: andrawes@illinois.edu
Phone: (217)244-4178

Submission Date: May 2nd, 2024

DUNS Number: 04-154-4081 **EIN Number:** 37-6000511

Recipient Organization: University of Illinois at Urbana-Champaign
352 Henry Administration Building
506 S. Wright Street
Urbana, IL 61801-3620

Unique Entity Identifier (UEI): Y8CWNJRCNN91

Project/Grant Period: 6/1/2023 – 5/31/2024

Reporting Period End Date: March 31st, 2024

Report Term or Frequency: Semi-Annual

Signature of Submitting Official:

Bassem Andrawes, TRANS-IPIC UTC Director

1. ACCOMPLISHMENTS

1.1. Major Goals

The Transportation Infrastructure Precast Innovation Center (TRANS-IPIC) is a Tier 1 University Transportation Center (UTC) that focuses on improving the durability and extending the life of transportation infrastructure by advancing the technologies used in precast concrete (PC) construction and maintenance. The consortium is composed of the following five universities:

- University of Illinois at Urbana-Champaign (UIUC) – Lead Institution
- Purdue University (PU)
- University at Buffalo (UB)
- Louisiana State University (LSU)
- University of Texas, San Antonio (UTSA) – Minority Serving Institution

TRANS-IPIC's mission is to leverage research innovation and strong industry support to guide and provide leadership in the transportation domain's highly overlooked area of precast concrete technology. TRANS-IPIC's innovative research on PC-related technologies aims to develop short-term solutions for current infrastructure problems and revolutionize the development and performance of future infrastructure of various transportation modes, providing gains in durability, safety, and economy. The primary goals of TRANS-IPIC are:

1) Develop durable, climate-adaptable, and cost-effective advanced materials (concrete and reinforcement) for precast components.
2) Develop a new design framework for infrastructure PC elements based on innovative computational mechanics, topology optimization, and efficient manufacturing and accelerated construction processes.
3) Advance the field of building information modeling (BIM), automated manufacturing, repair, and inspection of precast infrastructure using new technologies like drones, satellite imaging, and 3D printing of forms and concrete.
4) Incorporate novel "built-in" quality control, self-assessment, and repair mechanisms in PC components.
5) Establish comprehensive economic plans for operating, managing, and processing off-site PC manufacturing, shipping, and installation.

1.2. Activities During This Period

During this period, the following activities have been completed:

1) Organizing the First Annual TRANS-IPIC Workshop: Among the important activities that took place during this period was the planning for the first Annual Workshop for the TRANS-IPIC UTC. The workshop is planned to be held in the Chicago Area (Rosemont, IL) on April 22nd, 2024. Information about the workshop was included on the TRANS-IPIC website (https://trans-ipic.illinois.edu/workshop). A total of eighteen (18) UTC projects are presented in the workshop program. The workshop is planned to engage participants from both academia and industry including stakeholders from State DOTs. The workshop offers 7.0 Professional Development Hours (PDHs) to the attendees.

2) UTC Directors/CUTC Meeting: Dr. Andrawes attended the UTC Directors and CUTC meetings that were held on January 7, 2024, in Washington, DC.

3) Connect with Transportation Committees: During the 2024 Transportation Research Board (TRB) Annual Meeting, the TRANS-IPIC Director and Associate Directors presented an overview of the center and its funded projects to the members of the *TRB Standing Committee on Concrete*

Bridges (AKB30). The goal was to engage committee members in the center's activities. Further, the TRANS-IPIC Director discussed with the American Concrete Institute (ACI) *Committee on Bridge Design (ACI-343)* offering a future session at the ACI Convention to highlight the work of the center.

4) K-12 Educational Outreach Activities: On March 20, 2024, TRANS-IPIC researchers at the University at Buffalo (UB) hosted local high school students in their structures laboratory as part of *Science Exploration Day*. The visiting students were noticeably excited to learn about advanced concrete materials and construction methods (such as 3D printing and precast concrete) and their role in improving the quality of our transportation infrastructure while saving time and money and protecting the environment. The students also observed the raw ingredients of strain-hardening cementitious composites (SHCC) and some of the 3D-printed SHCC specimens that are studied under one of the TRANS-IPIC projects at UB. The goal of these laboratory visits (and Science Exploration Day) was to motivate high school students toward pursuing STEM fields in college.

During this period also, we started putting together plans for the "*City Designers and Builders*" Summer Camp that will be held in July 2024 at the UIUC campus. The TRANS-IPIC UTC will host high school students and demonstrate to them several of the transportation-related technologies that are currently being studied through the UTC projects.

5) Organizing Monthly Webinars: In February 2024, TRANS-IPIC started holding monthly webinars where researchers and students get to share their research findings and discuss how to achieve the goals of the center. Each webinar includes two presentations related to the UTC projects. The recordings from the webinar are shared with the community through the TRANS-IPIC UTC website (https://trans-ipic.illinois.edu/news/webinars). The webinar offers 1.0 Professional Development Hour (PDH).

6) Quarterly Progress Reports: An online system was developed for the TRANS-IPIC researchers to share their projects' quarterly progress reports (QPRs). These reports are reviewed by the center's leadership team to ensure that the funded projects are on the right track. After reviewing the reports, the TRANS-IPIC management team provides the project Principal Investigators (PIs) with feedback about their progress. A copy of the QPRs is posted on the TRANS-IPIC's website (https://trans-ipic.illinois.edu/research).

7) Funding New Research Projects: Based on an internal request for proposals (RFP) that was issued for all researchers affiliated with TRANS-IPIC in September 2023, six (6) new projects were funded. The selection was based on an external review process by experts from academia and industry who are not affiliated with the UTC. **Table 1** shows the full list of projects funded to date by the TRANS-IPIC UTC including the six newly funded projects highlighted in blue. The starting date of the six newly funded projects was January 1st, 2024. The funded projects were posted on TRANS-IPIC's website (https://trans-ipic.illinois.edu) and reported to UTC Grant Manager, Ms. Denise Dunn. The funded projects were also posted on the Transportation Research Board's (TRB) Research in Progress (RIP) database.

Table 1. A List of TRANS-IPIC funded projects to date

Project Title	PI Institution & PI Name	Federal ($)	Match ($)
Evaluating Scanning Technology for Process Monitoring and Quality Control in Precast Concrete Fabrication	LSU: Isabelina Nahmens	$64,985.00	$37,008.00
Design, Manufacturing, and Characterization of Fiber Reinforced Shape Memory Polymer Rebars	LSU: Guoqiang Li	$96,787.00	$48,400.00
Holistic Quality Management of Precast Concrete Construction for Transportation Infrastructure	Purdue: Hubo Cai	$62,119.00	$39,865.00
Bio-Inspired Solutions for Jersey and Road Noise Barriers: Exploring 3DPrinting as Alternative Precast Technology	Purdue: Pablo Zavattieri	$67,576.00	$58,227.00
Unveiling synergistic effects of Nano-modification and CO2 curing on the durability and carbon footprint of precast elements	Purdue: Mirian Velay-Lizancos	$64,092.00	$40,132.00
3D Printed Advanced Materials to Mitigate Prestressed Concrete Girder End Cracks	UB: Ravi Ranade	$80,000.00	$40,000.00
Evaluating Prestressed Concrete Beams with Cracks using Machine Learning	UB: Pinar Okumus	$80,000.00	$40,000.00
Shape Memory Alloy Transverse Reinforcement for Solving End Region Problems in Precast Bridge Girders	UIUC: Bassem Andrawes	$100,000.00	$50,000.00
Innovative Precast Concrete Truss Using Adaptive Shape Memory Prestressing System	UIUC: Bassem Andrawes	$100,000.00	$50,000.00
Adaptive camber precast concrete girder for deflection mitigation of highway bridges	UIUC: Ann Sychterz	$65,000.00	$32,500.00
Design and Implementation of Digital Twin Models for Continuous Monitoring and Performance Prediction of Precast Concrete Bridges	UIUC: Volodymyr Kindratenko	$65,000.00	$32,500.00
Thermally Conductive Pre-cast Concrete Pavement for Urban Heat Island Mitigation	UTSA: Samer Dessouky	$80,000.00	$40,000.00
Exploring Fungal-Induced Carbonate Precipitation (FICP) for Healing Concrete Cracks	LSU: Hai Lin	$64,999.00	$32,503.00

Data-driven smart composite reinforcement for precast concrete	Purdue: Chengcheng Tao	$64,996.00	$325,04.00
Developing a cost-effective, reliable and sustainable PC supply system under price volatility and uncertain materials supply	LSU: Bhaba Sarker	$65,000.00	$32,508.00
Optimizing the Planning of Precast Concrete Bridge Construction Methods to Maximize Durability, Safety, and Sustainability	UIUC: Khaled El-Rayes	$64,961.00	$39,888.00
Photogrammetry and LiDAR-Based Precast Concrete Railroad Crossties Abrasion Damage Detections	PU: Shanyue Guan	$53,533.00	$32,000.00
Gaze-directed UAV-UGV Coordination Framework for On-site Quality Inspection of Precast	UTSA: Jiannan Cai	$65,000.00	$32,500.00

8) External Advisory Board Meeting: TRANS-IPIC Director, Dr. Andrawes held a meeting with the External Advisory Board (EAB) in late February 2024. The EAB is formed primarily from State DOT representatives from the States of Illinois, Texas, Indiana, and Louisiana and professional organizations including the American Concrete Institute (ACI), the Precast/Prestressed Concrete Institute (PCI), and the American Segmental Bridge Institute (ASBI). The EAB provided their input and feedback on the activities carried out to date by the UTC. They also offered suggestions related to the program of the workshop and the research projects that the UTC is currently funding, The EAB agreed to meet with the TRANS-IPIC UTC leadership every quarter.

1.3. Dissemination

1) Conferences and Meetings: The outcomes from the TRANS-IPIC UTC projects were highlighted at multiple events that are heavily attended by transportation professionals including the 2024 Transportation Research Board (TRB), the 2024 American Concrete Institute (ACI) Spring Convention, the 2024 Purdue Road School, the 2024 Joint Transportation Research Program, and the 2024 Infrastructure Collaborative Workshop (US Army Corp of Engineers). A total of three oral presentations, four poster presentations, and a journal paper were delivered (see **Fig. 1**).

Figure 1. TRANS-IPIC UTC students presenting their work at various transportation-related conferences and meetings.

2) Monthly Webinar Recordings: Recordings from the February and March monthly webinars are shared with the community through the center's website (see **Fig. 2**). These webinar recordings will help connect the center with the community and keep the community aware of the ongoing work by the center.

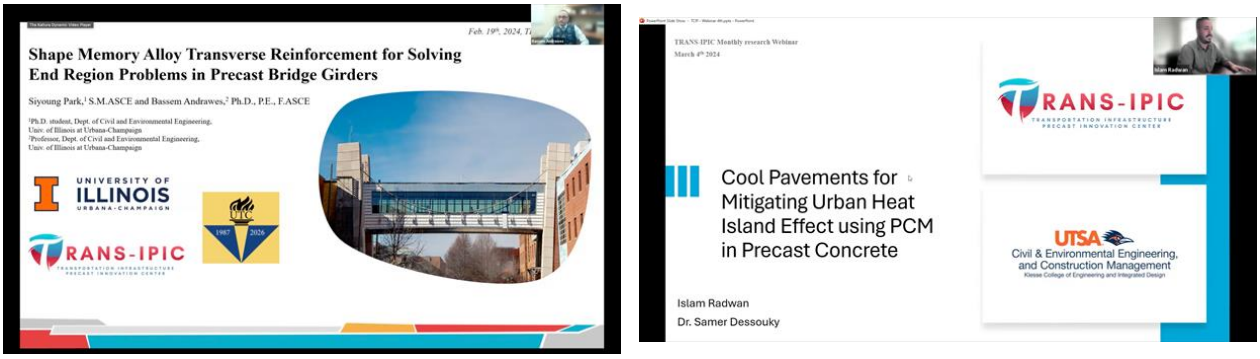


Figure 2. Snapshots from the recorded TRANS-IPIC UTC February and March webinars. Recordings are available on the center's website

1.4. Plans for the Next Reporting Period

The next reporting period will focus on:

1) Review and provide feedback on the quarterly progress reports for the quarters ending on March 31st and June 30th, 2024 for the 18 funded projects to ensure that TRANS-IPIC is on the right track to achieve its goals and objectives.

2) Promote and host the first Annual TRANS-IPIC workshop to be held in Chicago, IL, in April 2024 and invite researchers and transportation professionals from all over the U.S. to attend the workshop.

3) Participate with posters, a presentation, and a live demo in the 2024 Future of Transportation (FoT) summit that will be in August 2024 in Washington, DC.

4) Continue disseminating the knowledge created by TRANS-IPIC research projects through conference proceedings and journal papers. The TRANS-IPIC director discussed with the leadership team submitting a workshop proposal for the 2025 TRB Annual Meeting.

5) Leverage strong ties with the industry and partnership committees to promote collaborative projects between TRANS-IPIC and the transportation industry.

6) Host a summer camp in July at the UIUC for high school students.

7) Start a new series of Seminars/Webinars to be hosted by TRANS-IPIC and announced nationally.

2. PARTICIPANTS AND COLLABORATING ORGANIZATIONS

2.1. Partners

A list of the partners who indicated strong interest in contributing to TRANS-IPIC's activities can be found at (https://trans-ipic.illinois.edu/team/industry-partners). Among the organizations that are involved in the currently funded projects:

(1) Sherwin-Williams, Minneapolis, MN (In-kind material contribution)
(2) Illinois Department of Transportation, Springfield, IL (Field testing and data sharing)
(3) City of San Antonio, TX (Research partnership)
(4) Tindall Corp, Spartanburg, SC (Research partnership)
(5) FARO Technologies, Lake Mary, FL (Research partnership)
(6) Milestone Contractors, South Bend, In (Project advisory committee)
(7) Magnasoft Consulting, Bengaluru, India (Research partnership)
(8) Illinois Tollway (Research Partnership)

2.2. Other Collaborators

Several individuals from organizations and universities expressed strong interest in the mission of the UTC. They offered to collaborate with TRANS-IPIC in various forms, including reviewing research proposals and delivering training sessions and on-campus seminars to the UTC students. Many of these individuals participated in the first cycle of proposal reviewing which resulted in the funding of 19 projects.

3. OUTPUTS

3.1. Publications and Conference papers:

- Sung M. and Andrawes B. "Innovative Precast Concrete Truss System Using Shape Memory Alloys for Infrastructure Applications" *Intelligent Material Systems and Structures*. (https://doi.org/10.1177/1045389X241239701) (Federal Funds Acknowledgment: Yes)

- Park S. and Andrawes B. "Damage Mitigation of Prestressed Girders End Regions Using Shape Memory Alloys" *2024 Transportation Research Board Annual Meeting*. (Federal Funds Acknowledgment: Yes)

- Lasheen, M., Okumus, P., Elhami Khorasani, N. (2024). "Predicting Shear Strength of Prestressed Concrete Beams Using Machine Learning", poster presentation, Transportation Research Board Annual Meeting, presented at the reception by Institute of Bridge Engineering, University at Buffalo, January 7-11.

- Singh, P., Gadde, V.S., Zhou, C., Okumus, P., and Ranade, R. (2024) "3D printed advanced materials to mitigate prestressed concrete girder end cracks" poster presentation, Transportation Research Board Annual Meeting, presented at the reception by Institute of Bridge Engineering, University at Buffalo, January 7-11.

- Y. Wang, A. Douba, J. Olek, J. Youngblood, P. Zavattieri (2024) "Sustainable cementitious composite containing cellulose nanofibers and limestone filler for concrete 3D-Printing", American Concrete Institute (ACI) Spring 24 convention, New Orleans, LA

- Perez-Claros E. and Andrawes B. "Active Confinement of Precast Concrete Columns using FeMnSi Shape Memory Alloy Hoops" *18th World Conference on Earthquake Engineering*, July 2024, Milan, Italy

- P. Zavattieri, J. Youngblood, Nature-Inspired 3D Printing for Sustainable Infrastructure: From Design Concepts to Large-Scale Application, 3D Printing Natural Materials to Unlock Complex Nature-Inspired Infrastructure Collaborative Workshop: 7-8 Feb 2024, EWN, US Army Corp of Engineers (RDEC)

- Poster presentation in JTRP posters session on February 22, 2024 in Indiana Government Center South, Indianapolis, IN 46204

- Poster presentation in Purdue Road School 2024 poster session on March 12, 2024 in Purdue Memorial Union, West Lafayette, IN 47906

- Andrawes, B., Sung, M., and Park, S. (In Review) “Behavior of Hot-Rolled Annealed NiTiNb Bars under Full and Partial Heating for Concrete Prestressing Applications” Smart Materials and Structures. (Federal Funds Acknowledgment: Yes)

3.2. Technologies and Techniques:

- New End Region Reinforcement for Bridge Girders: A new technique was developed and validated numerically for mitigating the damage at the end regions of precast prestressed bridge girders. The technique uses a small number (2 or 3) of stirrups made of shape memory alloys at the end region of the girders. The stirrups can apply considerable internal recovery stress to mitigate the damage that is often observed at the end region due to the transfer of prestressing force in the longitudinal direction. Plans for validating this new technique experimentally are underway.

- Bio-inspired 3D Printed Road Barriers: We aim to utilize 3D printing technology and bio-inspired design principles to enhance the energy absorption capacity of concrete barriers (see **Fig. 3**), thereby improving their ability to protect drivers and passengers during roadside impacts. This innovative approach holds promise for advancing road safety and enhancing the efficiency of transportation infrastructure.

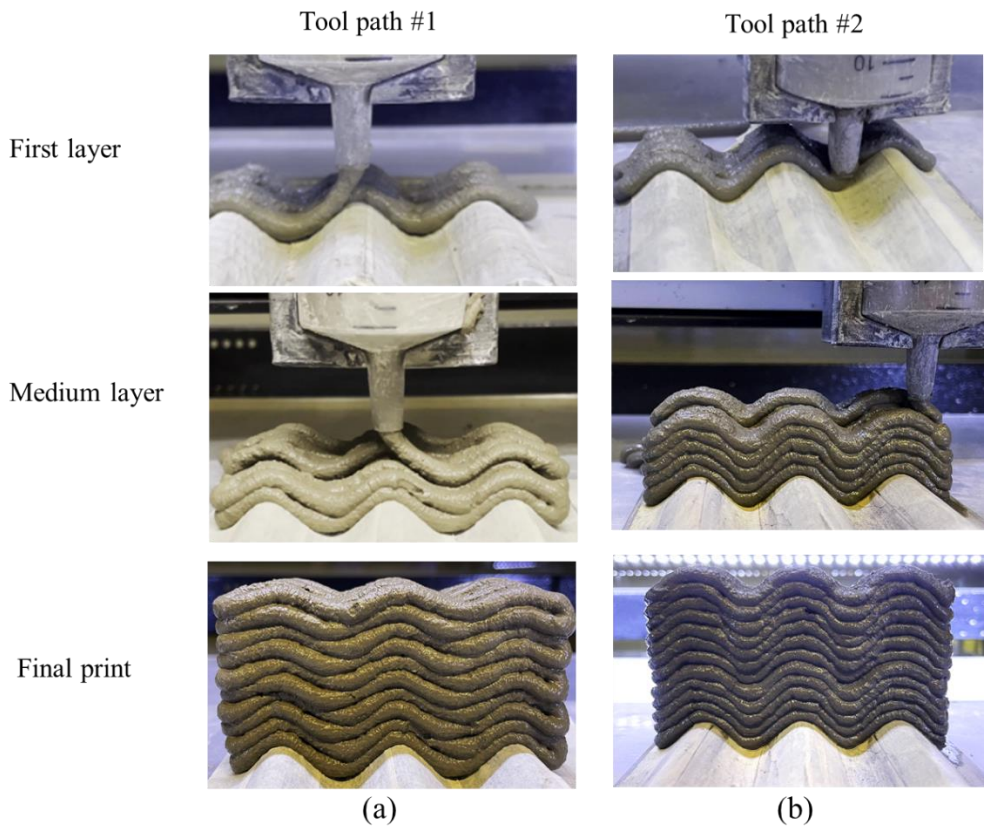


Figure 3. 3D concrete printing technology is used by TRANS-IPIC researchers to fabricate bio-inspired designs for precast road barriers.

4. OUTCOMES

The new reinforcement detailing technique for the end region (see TRB paper above) can impact the specifications and guidelines adopted in practice to reinforce precast bridge girders. The new detailing method (see **Fig. 4**) will help solve the problem associated with a prevalent type of damage at the girders' end regions, namely, end splitting cracking.

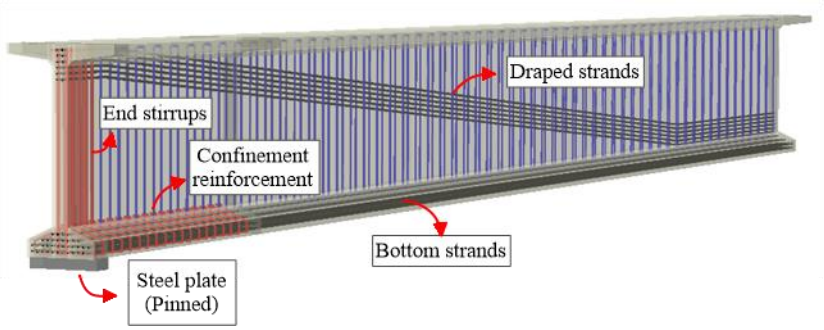


Figure 4. New detailing technique proposed by TRANS-IPIC researchers for PC bridge girders using shape memory alloys

5. IMPACTS

5.1. Effectiveness of the Transportation System and Scientific Knowledge

The twelve (18) funded TRANS-IPIC projects that started on September 1st, 2023 (see **Table 1**) address critical problems our transportation infrastructure faces. Over the next year, these projects (as well as the projects expected to be funded this fall from the second RFP cycle) will research innovative ideas and technologies that will help the transportation community improve the durability and sustainability of transportation systems. For example, one of the projects will develop digital twins for PC bridges. The project is expected to facilitate the exchange and analysis of data crucial for evaluating safety risks associated with transportation systems. Another project will develop thermally conductive precast concrete pavement that can reduce the Urban Heat Island effect, enhancing safety and livability for urban residents. One of the funded projects will provide the transportation industry with a novel Adaptive Prestressing System using smart materials to develop geometrically complex PC components with low embodied CO_2. Another project will develop a new method for reducing cracking in precast-prestressed concrete bridge girders using 3D-printable advanced concrete material. A team of researchers is funded through TRANS-IPIC to develop novel Building Information Models (BIM) to ensure the quality of precast components used in the transportation infrastructure. TRANS-IPIC researchers are also studying the adoption of 3D-printed Jersey barriers and acoustic metamaterials that will significantly improve road safety and infrastructure resilience. A project funded by TRANS-IPIC is also investigating the application of nanomaterials and CO_2 curing techniques that can enhance the sustainability and durability of precast elements used in transportation systems.

5.2. Transportation Workforce Development

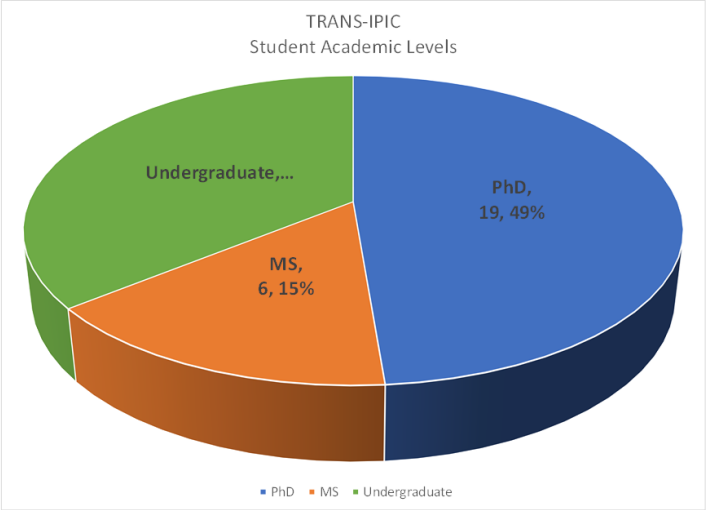
The 18 TRANS-IPIC-funded projects provide significant opportunities for students and young people in the transportation and related fields. Over the last eight months, a total of 39 students have been supported by TRANS-IPIC-funded projects (14, 6, and 19 undergraduate, MS, and Ph.D. students, respectively) (see **Fig. 5**). Among these students, 51% are from minority and under-represented groups.

6. CHANGES/PROBLEMS

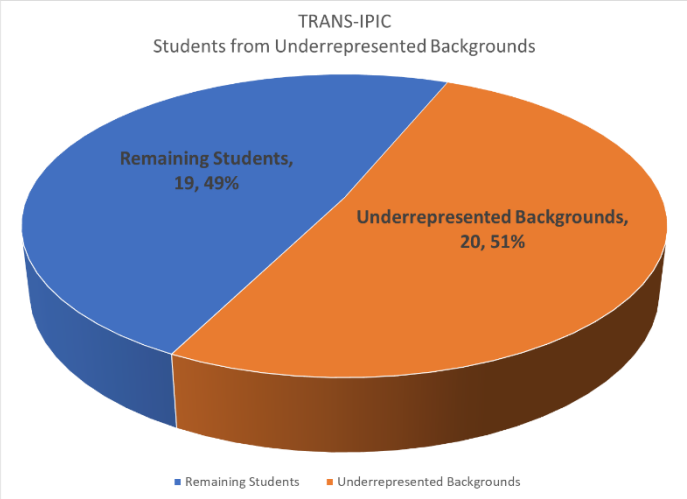
Nothing to Report.

7. SPECIAL REPORTING REQUIREMENTS

Nothing to Report.



(a) Academic level



(b) Minority students

Figure 5. Breakdown of TRANS-IPIC current students based on (a) academic level and (b) underrepresented and minority groups