

## **Motivations for Including Sustainability in a National Airport Design Competition**

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# Motivations for Including Sustainability in A National Airport Design Competition

## Abstract

More and more airports are trying to integrate sustainability into their long-range planning and day-to-day operations to gain both short-term and long-term benefits. This trend also is reflected in the Airport Cooperative Research Program (ACRP) University Design Competition for Addressing Airport Needs, a national competition for United States university-level students. This competition is sponsored by ACRP a program of the Transportation Research Board (TRB) of the National Academies of Sciences, Engineering, and Medicine (NASEM) with funding from the U.S. Federal Aviation Administration (FAA). A recent study found that from 2007 to 2017, sustainability was mentioned in more than 50% of the first-place design packages (12 of the 20 first-place design packages), and eight of these winning proposals were awarded between 2013 and 2017. This paper identifies sustainability performance metrics used in these eight winning designs and explores the motivations of these eight winning teams for including sustainability in their design. As there is no single, definitive standard for airport sustainability, the team selected their own metrics. The sustainability resources listed in the paper may be helpful to students and faculty interested in competing in future competitions or wanting to include sustainability metrics in other design projects. Faculty may use the sustainability sources listed in the paper, along with sustainability metrics and team motivations, during course design in engineering and technology programs.

## Introduction

Airport Sustainability is a business strategy with both short-term and long-term benefits. More and more airports are trying to integrate sustainability into their long-range planning and day-to-day operations. Although the Federal Aviation Administration (FAA) does not require airports to develop sustainability programs, the FAA has encouraged airports to incorporate sustainability concepts into their planning process and daily operations [1]. The FAA funded 44 U.S. airports to develop their own airport sustainability plans via Airport Improvement Program (AIP) grants [1]; however, the FAA did not issue a definitive standard for the initiatives, goals, or metrics to be used to plan and measure airport sustainability. Airports that commit to enhancing sustainability need to track and measure the performance made toward achieving their sustainable goals. However, it is a challenge to convert sustainability concepts into quantitative measuring tools, and to select appropriate performance metrics [2].

The ASEE Board of Directors issued a statement on sustainable development education that states in part “Engineering students should learn about sustainable development and sustainability in the general education component of the curriculum as they are preparing for the major design experience” and that “...faculty should ask their students to consider the impacts of design upon U.S. society, and upon other nations and cultures” [3]. Some engineering programs have used a national airport design competition in their education programs [4, 5]. Between 2007 and 2017, over 40% of winning teams in the *Airport Cooperative Research Program (ACRP) University Design Competition for Addressing Airport Needs* were comprised of students

enrolled in undergraduate and graduate level degree programs in engineering programs [5]. This competition is an annual national competition for university-level students. The competition has four challenge categories, airport environmental interactions, runway safety/runway incursions/runway excursions, airport operations and maintenance, and airport management and planning. Each of the four challenges categories could potentially have 1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup> place winners. The submitted design packages are judged by panels of airport industry experts using a published evaluation scoresheet. The 1<sup>st</sup> place teams are invited to Washington, DC to present their designs to airport industry experts. The past winning proposals are available in online archives on the competition's official website [4].

This competition is sponsored by ACRP, with funding from the FAA. The ACRP was established by the FAA in 2005 to coordinate airport cooperative research programs that help airports address real world problems, <http://www.trb.org/ACRP/ACRP.aspx>. The ACRP is part of the Transportation Research Board (TRB) of the National Academies of Sciences, Engineering, and Medicine (NASEM). Separate from the competition for university students, the ACRP funds numerous research projects to address airport challenges.

The evaluation criteria for the design competition is divided into eight sections and totals 122 possible points [4]. While sustainability is not explicitly mentioned in the criteria, student teams are choosing to include sustainability in the winning submissions. A recent study found that from 2007 to 2017, sustainability was mentioned in 12 first-place design packages over these 11 years, and eight (75%) of these first-place design packages were awarded in the most recent five years (2013 to 2017) [5]. The frequency of including sustainability in the winning proposals has increased [5].

On the competition website, there are many resources for student teams to use such as design guidelines with suggested topics for each challenge area, suggested risk analysis techniques, and suggestion for conducting benefit and cost analysis. Along with the increase in inclusion of sustainability in the winning proposals, the competition design guidelines have changed. In the ACRP airport competition design guidelines for the 2017-2018 academic year, ACRP newly included enhancing sustainability and resilience of airports as a topic in the challenge area of airport operations and maintenance, and in the challenge area of airport environmental interactions [4]. The 2018-2019 design guidelines include these two topics as well [4]. However, the motivations for 2013 to 2017 winning teams to include sustainability in their design proposals have not been investigated. Because one of the evaluation criteria for this competition is interaction with industry (12 out of 122 points), these motivations may reflect the demand of airport industry for including sustainability or may reflect the inclusion of sustainability into design courses as recommended by ASEE.

Student teams at U.S. colleges and universities may participate in the competition either as part of an academic course or as an out-of-class project, with a faculty advisor. Each student team submits a design package that proposes an innovative design to solve a real-world problem that airports are facing and a self-assessment of the educational experience of participating in the competition. The self-assessment includes both student and faculty inputs.

This study aimed to address two research questions:

1. What are the metrics were used by student teams to measure sustainability in the 2013 – 2017 1<sup>st</sup> place winning proposals of ACRP airport design competition?
2. What are the motivations for the 2013 – 2017 1<sup>st</sup> place winning teams to include sustainability into their designs?

To answer research question 1, the 1st place winning proposals from 2013 – 2017 that mentioned sustainability were explored to identify the sustainability metrics used by the student teams. To answer research question 2, the motivations provided by the winning teams were analyzed. The outcomes of this study are a set of measurement metrics for sustainability and a list of motivations for including sustainability into the designs. As there is no single, definitive standard for airport sustainability. The metrics identified in this study may be helpful to the students and faculty interested in competing in future competitions or wanting to include sustainability metrics in design projects. Faculty may use the sustainability sources listed in the paper, along with sustainability metrics and team motivations, during course design in engineering and technology programs.

### **Airport Sustainability**

Sustainability has been defined in various ways. The Brundtland Commission report's definition of sustainable development is a commonly accepted version as "development that meets the needs of the present without compromising the ability of future generations to meet their needs" [6]. The US Environmental Protection Agency explains that:

"Sustainability is based on a simple principle: Everything that we need for our survival and well-being depends, either directly or indirectly, on our natural environment. To pursue sustainability is to create and maintain the conditions under which humans and nature can exist in productive harmony to support present and future generations" [7].

Sustainability principles have been integrated by diverse industries into their operations through the combined consideration of environmental protection, community needs, and economic vitality, known as Triple Bottom Line (TBL), for both current and future generations [8]. Airports Council International-North America (ACI-NA) has purposefully broadened the triple bottom line to include operational efficiency. According to ACI-NA,

"Airport sustainability, in effect is a holistic approach to managing an airport so as to ensure the integrity of the Economic viability, Operational efficiency, Natural Resource Conservation and Social responsibility (EONS) of the airport" [9].

ACI-NA explained that including operational efficiency is particularly important for managing an airport "because while not all airports can or need to build new facilities, all have opportunities within the construct of their business model to leverage their O&M (operations and maintenance) dollars in ways that promote sustainability" [9]. Airports are encouraged to use an existing definition of sustainability or develop their definitions based on their unique circumstances and roles within their community and environment [10].

### ***Metrics for measuring airport sustainability***

Sustainable solutions need to have a business case that presents a return on investment [10]. Sustainability performance metrics are the indicators of performance for sustainability activities and can help the airport to measure and track performance over time. To measure the return on investment of sustainable solutions, metrics must be appropriately selected for the associated sustainability goals and initiatives. The Sustainable Aviation Guidance Alliance (SAGA) describes their organization as “a broad volunteer coalition of aviation interests that formed in 2008 to assist airport operators of all sizes in planning, implementing, and maintaining a sustainability program” and provides access to information “intended to supplement, not replace, existing guidance” [11]. SAGA suggests some sources of commonly used key performance indicators (metrics) for sustainability:

- Global Reporting Initiative (GRI) Reporting Guidelines
- The GRI Airport Sector Supplement
- ISO 26000: 2010 Guidance on Social Responsibility
- Envision™ Infrastructure Sustainability Rating System
- LEED™
- The CDP (formerly Carbon Disclosure Project)
- The Global 100 [12].

According to SAGA, metrics used to measure sustainability should be specific to the airport [12]. The GRI airport operator sector supplement, guidance is available for airports to select sector specific metrics for economic, social, and environmental aspects. Airport management teams may select the metrics from these sources or develop their own metrics based on the sustainable goals and targets created.

### ***Motivation for including sustainability***

Airports are under budgetary pressure and are expected to provide safe and secure connectivity between communities, boost area employment, and reduce the impact on the environment. FAA guidance encourages airports to incorporate sustainability concepts into their planning and decision-making process and initiated a Sustainable Master Plan Pilot Program to fund the U. S. to develop their airport sustainability plans [13]. A study focused on the sustainability practices in the airport industry explored the motivators for airports to improve their sustainability performance. The result showed that the top 5 motivators for implementing sustainability practices were “state/regional regulations airport policy, federal regulations, corporate responsibility, and stakeholder concerns/relations” [14]. A similar study explored the motivators for small airports to implement sustainable initiatives. The result of this study showed that the most common motivators were “cost reductions, desire for improved sustainability performance, compliance concerns, and addressing global concerns” [15].

### **Airport Design Competition**

ACRP is a program managed by TRB of NASEM and sponsored by the FAA. ACRP is “an industry-driven, applied research program that develops practical solutions to problems faced by airport operators” [16]. The *ACRP University Design Competition for Addressing Airport Needs*, formerly known as the FAA Design Competition for Universities, is an annual national competition for university-level students. Student teams and individuals are invited to study

problems and present solutions under the four broad challenge areas. The Virginia Space Grant Consortium based in Hampton, Virginia is managing this competition for ACRP. According to the competition guidelines, the competition is intended to

1. “Raise awareness of the benefits of the Airport Cooperative Research Program and the importance of airports to the National Airspace System infrastructure.
2. Increase the involvement of the academic community in ACRP and addressing airport operations and infrastructure issues and needs.
3. Engage students at U.S. colleges and universities in the conceptualization of applications, systems and equipment capable of addressing related challenges in a robust, reliable and comprehensive manner.
4. Encourage undergraduate and graduate students at U.S. colleges and universities to contribute innovative ideas and solutions to issues facing airports and the National Airspace System.
5. Provide a framework and incentives for quality educational experiences for university students.
6. Develop an awareness of and an interest in airports as vital and interesting areas for engineering and technology careers.” [4]

Past winning teams have been comprised of students from engineering and technology programs [5]. From 2007 to 2017, sustainability was mentioned in twelve of the first-place design packages of the ACRP competition, and eight of these winning proposals were awarded from 2013 to 2017 [5]. Before the 2017-2018 academic year, sustainability was not a challenge topic of the ACRP airport competition. Sustainability is not an explicit criterion for selecting winning proposals. However, the frequency of mentioning sustainability in the first-place design packages of ACRP Airport design competition has increased [5]. There is a gap in investigating the motivations of the first-place winning team for including sustainability in the ACRP university design competitions.

## **Methodology**

This section describes the data sources, data selections procedure, and analysis processes conducted in this study.

## **Data Sources**

The ACRP University Design Competition has four broad challenge areas: (1) Airport Environmental Interactions, (2) Runway Safety/Runway Incursions/Runway Excursions, (3) Airport Operations and Maintenance, and (4) Airport Management and Planning [4]. Student teams and individuals working with faculty advisors at U.S. colleges and universities compete to potentially win first, second, and third place in each challenge area. The archive of winning design proposals of first, second, and third place winners in the four challenges areas are posted on the official website of ACRP University Design Competition. The address of the webpage for the previous winning design proposals is [http://vsgc.odu.edu/ACRPDesignCompetition/Competition\\_Winners.html](http://vsgc.odu.edu/ACRPDesignCompetition/Competition_Winners.html). This study focused on the information provided by the first-place winners from 2013 to 2017.

From 2013-2017, there were 20 first-place winners in these five years. In 2014, only three challenge areas had first-place winners. In 2015, two student teams shared the first-place of Airport Operations and Maintenance Challenge area. Eight first-place winning teams mentioned sustainability in their proposals among those 20 first-place winners [5]. The sustainability approaches used in the winning design are environmental concerns, Triple Bottom Line, and EONS (Economic Viability, Operational Efficiency, Natural Resource, and Social Responsibility). Table 1 lists the titles, year, challenge category, and the sustainability approaches used for the eight first-place winning proposals.

Table 1. *First-place ACRP Design Competition winning proposals that mentioned sustainability from 2013 – 2017*

Title	Year	Challenge Area	Sustainability Approach
Twice Repurposed Crumb Rubber as a Jet Fuel Solidifier	2014	Airport Environmental Interactions	Environmental concerns
PAWS-Design of a Low Level, Affordable Wind Shear Detection System for GA Airports.	2014	Runway Safety/Runway Incursions/Runway Excursions	Environmental concerns
Eye in the Sky – Drone Detection and Tracking System	2015	Runway Safety/Runway Incursions/Runway Excursions	Environmental concerns
Piezoelectric Carpet System (PECS) - Design of a Self-Sustaining Affordable Energy Generating System for Airports.	2015	Airport Environmental Interactions	Environmental concerns
Mycoremediation Applications for Stormwater Management	2016	Airport Environmental Interactions	TBL
Control of Deicing Chemicals at Airports Using Subterranean Aerated Gravel Beds	2017	Airport Environmental Interactions	TBL
Innovative Revenue Generation Strategies for GA Airports	2017	Airport Management and Planning	EONS
Airport Runway Ice and Snow Monitoring System with Remote Sensing Technology	2017	Runway Safety/Runway Incursions/Runway Excursions	EONS

Note. This table is created based on the findings of [5].

Among the eight first-place proposals that mentioned sustainability, four of the winning teams used environmental concerns as their sustainability approach. As airports are large consumers of energy to power lighting, signage, and HVAC, energy consumption is commonly considered an element within the environmental concerns. The Triple Bottom Line as the sustainability approach were used in two winning proposals. These two winning teams did not directly mention the TBL title in their proposals instead used the principles of TBL that take environmental, economic and social aspects of sustainability into measuring airport performance. The EONS approach was directly mentioned and used by two winning teams [5].

### ***Data collection procedure***

Six types of information about the first-place winning teams and their proposals were collected and used to answer the two research questions of this study. The types of information included project title, year, sustainability approach, sustainability measuring metrics, academic discipline of the team, and motivation of including sustainability into the designs. The information about project title, year, and academic discipline of student team could be collected directly from the winning proposals and the webpage. Investigating the sustainability approach, sustainability measuring metrics, and the motivation of including sustainability requires thoroughly reading the design proposals and creating lists.

### ***Data analysis process***

Research question 1: What are the metrics were used by student teams to measure sustainability in the 2013 – 2017 1st place winning proposals of ACRP airport design competition?  
Based on the sustainability approaches mentioned in the proposals, the metrics that used to measuring sustainability performance of the proposed design were identified if applicable.

Research question 2: What are the motivations for the 2013 – 2017 1st place winning teams to include sustainability into their designs?

The research team identified motivations for including sustainability that were stated by the teams in the eight first-place winning proposals that mentioned sustainability. By comparing and summarizing the findings, the research team created a list of motivations.

## **Results**

The metrics used by the student teams in the first-place winning proposals to ACRP Design Competition from 2013 to 2017 are presented. Next, the motivations for including sustainability in the winning designs are discussed and summarized into six types.

### ***Sustainability performance metrics***

Table 2 lists the types of sustainability performance metrics used by each winning team. Among eight first-place winning teams, three did not use any metrics to measure the sustainability performance of the designs. These three winning teams are the 2014 first-place winning team of Airport Environmental Interactions challenge area, the 2014 first-place winning team of Runway Safety/Runway Incursions/Runway Excursions challenge area, and the 2014 first-place winning team of Airport Environmental Interactions challenge area. All three winning teams consider environmental concerns as their sustainability approach.



Table 2. *Metrics were used in measuring sustainability in the first-place winning proposals of the ACRP Design Competition from 2013 – 2017*

Title	Year	Sustainability Approach	Metrics
Twice Repurposed Crumb Rubber as a Jet Fuel Solidifier [17]	2014	Environmental concerns	Not Mentioned
PAWS-Design of a Low Level, Affordable Wind Shear Detection System for GA Airports. [18]	2014	Environmental concerns	Not Mentioned
Eye in the Sky – Drone Detection and Tracking System [19]	2015	Environmental concerns	Percentage of power supplied by renewable energy source
Piezoelectric Carpet System (PECS) - Design of a Self-Sustaining Affordable Energy Generating System for Airports. [20]	2015	Environmental concerns	Not Mentioned
Mycoremediation Applications for Stormwater Management [21]	2016	TBL	A Multi-criteria decision matrix developed by the design team
Control of Deicing Chemicals at Airports Using Subterranean Aerated Gravel Beds [22]	2017	TBL	A Multi-criteria decision matrix developed by the design team
Airport Runway Ice and Snow Monitoring System with Remote Sensing Technology [23]	2017	EONS	Metrics for measure the impact of projects
Innovative Revenue Generation Strategies for GA Airports [24]	2017	EONS	A Pugh decision matrix developed by the design team

Note. The metrics are from [17], [18], [19], [20], [21], [22] [23] & [24].

The 2015 first-place winning team of Airport Environmental Interactions challenge area also used environmental concerns as its sustainability approach and used the “percentage of power supplied by renewable energy source” as the metric to measure the sustainability performance of their design [19]. Please see Table 1 for the challenge areas for each winning proposal.

The design of “Mycoremediation Applications for Stormwater Management” was the 2016 first-place winning proposals of Airport Environmental Interactions challenge area. The winning team was from the Environmental Engineering department of University of Colorado, Boulder. This winning team used TBL as its sustainability approach and developed a Multi-criteria decision matrix to select the best alternative for their solution. This decision matrix contained three categories with relevant criteria. The sustainability categories and criteria used are:

- “Technological
  - Technical Maturity,
  - Operational Impact/Safety, and
  - Lifespan/Maintenance
- Environmental
  - ENVISION Score/Local Ecosystem Impact
- Social
  - Social Acceptability” [21].

The design team selected a list of questions from the ENVISION checklist to evaluate the criterion within the environmental category, but did not describe the questions selected [21]. The ENVISION checklist is a free-standing sustainability assessment tool developed by the Zofnass Program for Sustainable Infrastructure at the Harvard University Graduate School of Design and the Institute for Sustainable Infrastructure. The ENVISION checklist can be used “for comparing sustainability alternatives or to prepare for a more detailed sustainability assessment” [25].

The design of “Control of Deicing Chemicals at Airports Using Subterranean Aerated Gravel Beds” was the 2017 first-place winning proposal of Airport Environmental Interactions challenge area [22]. The winning team was from the Environmental Engineering department of University of Colorado, Boulder. This team also used TBL as its sustainability approach and developed a Multi-criteria decision matrix to select the best alternative for their solution, but the new matrix has different categories and criteria than the matrix used in the design in 2016. The sustainability categories and criteria used are:

- “Economic:
  - Capital Costs,
  - Operations Personnel Costs, and
  - Recurring Energy Costs
- Environmental
  - Biochemical Oxygen Demand (BOD) Reduction
- Social/Logistical
  - Spatial Requirements
  - Maintenance Requirements
  - Adaptability and Feasibility” [22].

The design of “Airport Runway Ice and Snow Monitoring System with Remote Sensing Technology” was the 2017 first-place winning proposals of Runway Safety/Runway Incursions/Runway Excursions challenge area. The winning team was from the School of Aviation and Transportation Technology of Purdue University. This winning team conducted a sustainability analysis for the potential impact of its design under the framework of EONS sustainability approach. The team divided the metrics used into four EONS sustainable categories. The categories and metrics are:

- “Economic Impact
  - Prevent runway/taxiway excursion in dollars
  - Improve snow removal efficiency in dollars
  - Prevent taxiway excursion in dollars
  - Reduce tarmac deicing chemical usage in dollars
  - Reduce human injury or fatality in dollars
- Operation Impact
  - Real-time knowledge of runway/taxiway snow/ice coverage
  - Improve deicing/snow removal operation schedule
  - Improve runway condition forecast/prediction
  - Eliminate runway shutdown for runway condition measuring
  - Reduce change of runway/taxiway excursion incident/accident
- Environmental Impact
  - Reduce usage of ground vehicle fuel
  - Reduce usage of pollutive deicing chemicals
  - More data source for climate/weather forecast research
- Social Impact
  - More employment in product design/development/manufacturing
  - Reduce worker on-call rate; Improve worker happiness
  - Benefit community/public by reducing chances of incident/accident” [23].

In order to analyze the economic impact of the design, the winning team estimated the potential dollar savings from airport operational expenses and the dollar savings from preventing the occurrences of incidents and accidents after implementing the proposed design. Therefore, the unit of the economic impact metrics was dollars.

The design of “Innovative Revenue Generation Strategies for GA Airports” was the 2017 first-place winning proposals of Airport Management and Planning challenge area [24]. The winning team was from the School of Aviation and Transportation Technology of Purdue University. This winning team incorporated sustainability principles into the airport decision-making process for selecting best-fit innovative revenue generation strategies for general aviation airports. This team developed a Pugh Decision-Making Matrix using EONS sustainability approach. The 14 criteria and metrics used in the Pugh Matrix are shown in Table 3.

### ***Motivations for including sustainability***

Table 4 lists quotes that are related to team motivations for including sustainability that were found in the design proposals. The motivations for the design of “Airport Runway Ice and Snow Monitoring System with Remote Sensing Technology” were found in a section describing the educational experience provided by the projects [23]. The motivations for the design of “Innovative Revenue Generation Strategies for GA Airports” were found in both the main body and the section on educational experience [24]. The other six winning teams mentioned their motivations in the main body of the proposals.

The motivations found in this study are summarized into six types, shown in Table 5. The motivations for including sustainability in the design proposals may be summarized as

- Required by the targeted airport
- Required by the course
- Sustainable and green solution
- Required by federal regulations
- Reduce operating cost
- Prevalence in the airport industry.\

Table 3. *EONS Criteria Metrics were used in the design of “Innovative Revenue Generation Strategies for GA Airports”.*

EONS Pillars	Criteria	Metrics
Economic	Revenue Generation	Amount of additional revenue to be generated by the new strategy
	Start-up Costs	Cost of purchase and installation of equipment and facilities
	Operating Costs	Cost to operate day to day including labor, taxes, and energy costs
	Maintenance Costs	Any cost to maintain, repair or upgrade facilities, tools or equipment
	Facilities/Land Available	Is there space that can be used for the strategy including offices, hangars, and land
Operational	Improve Infrastructure and Operations	Does the strategy help the airport operate more efficiently
	Encourage Alternative Fuel or Energy Usage	Does the strategy improve the use of alternative power sources on the airport
Natural Resource	Air Quality	Does the strategy increase or decrease the air pollution in the surrounding area
	Land Pollution	Does the strategy create additional pollution to surrounding land
	Reduce Energy Usage	Reduce the amount of power that must be purchased from the power companies in the area
Social	Legally Permitted	Is it legislation that prevents you from using the strategy for any reason
	Safety	Does the technology increase or decrease safety of all operation occurring at and around the airport
	Community Service Opportunity	Is there a benefit for the surrounding community
	Noise Pollution	Does the strategy create additional noise or reduce the noise in the surrounding area

*Note.* The criteria and metrics listed are from [24]

Table 4. *Motivations for including sustainability in the first-place winning team of the ACRP Design Competition from 2013 – 2017.*

Title	Team Motivations found in Design Competition Packages
Twice Repurposed Crumb Rubber as a Jet Fuel Solidifier [17]	<ul style="list-style-type: none"> <li>• The Targeted Airport “expressed interest in implementing a more sustainable process while maintaining the speed and effectiveness of the current practice” [17].</li> <li>• The Targeted Airport “expressed interest in a solution that provides improvements to remediation time, sustainability, and cost” [17].</li> <li>• “The FAA works to enforce pertinent safety and environmental regulations at airports across the county” [18].</li> </ul>
PAWS-Design of a Low Level, Affordable Wind Shear Detection System for GA Airports [18]	<ul style="list-style-type: none"> <li>• “PAWS is an affordable and sustainable concept addressing society’s need for “green,” next generation technology” [18].</li> </ul>
Eye in the Sky – Drone Detection and Tracking System [19]	<ul style="list-style-type: none"> <li>• “RIAC developed a set of design specifications for both the Drone Detection and Tracking System and the Drone Operator Notification System” [19].</li> <li>• One of the requirements was “Sustainable, green device” [19].</li> </ul>
Piezoelectric Carpet System (PECS) - Design of a Self-Sustaining Affordable Energy Generating System for Airports [20]	<ul style="list-style-type: none"> <li>• “The motivation for designing this system results from the need to design a completely new technology that has a positive impact on both the environment and airport operating costs” [20].</li> <li>• “PECS is an affordable and sustainable concept addressing society’s need for a sustainable future with next generation technology” [20].</li> <li>• “As airports begin to implement PECS, they will be able to lower airport operating costs while simultaneously supporting a “green” environment” [20].</li> </ul>
Mycoremediation Applications for Stormwater Management [21]	<ul style="list-style-type: none"> <li>• “The low cost, easy implementation, and easy maintenance of mycoremediation solutions act as indicators that mycoremediation may be a new, environmentally sustainable, and economically feasible solution for many remediation applications at airports around the world” [21].</li> </ul>
Control of Deicing Chemicals at Airports Using Subterranean Aerated Gravel Beds [22]	<ul style="list-style-type: none"> <li>• “The one priority of this project was helping to make sure DIA could maintain their environmentally sustainable reputation. In order to lead airports across the nation in environmental stewardship, capturing or diverting deicing waste from state waters draining from the airport is critical” [22].</li> </ul>
Airport Runway Ice and Snow Monitoring System with Remote Sensing Technology [23]	<ul style="list-style-type: none"> <li>• “This competition is a valuable educational experience for the students in my graduate level aviation sustainability course because it provides a vehicle for the students to explore the applicability of sustainability to real-world airport design challenges” [23].</li> <li>• “Because airport sustainability has been adopted by the FAA and more and more aviation organizations” [23].</li> </ul>
Innovative Revenue Generation Strategies for GA Airports [24]	<ul style="list-style-type: none"> <li>• “Some airports struggle due to money, while others face different challenges” [24].</li> <li>• “There are many ways for a GA airport to generate revenue using strategies and technologies that benefit the community and have little to no harmful impact on the planet. These ideas are becoming more popular across all airports in the U.S. Airport operators must choose the best fit for their airport” [24].</li> </ul>

*Note.* The motivations found in the proposal of “Airport Runway Ice and Snow Monitoring System with Remote Sensing Technology” were also stated in the proposal of “Innovative Revenue Generation Strategies for GA Airports”.

Table 5. *Types of team motivations for including sustainability and the first-place ACRP winning proposals that mentioned associated types of motivations from 2013 to 2017*

Type of Motivations	Mentioned in (proposals)
Required by the Targeted Airport •	[17], [19], [22]
Required by the Course	[23], [24]
Sustainable and green solution	[18], [20], [21], [22], [24]
Required by Federal Regulations.	[17], [22]
Reduce operating cost	[17], [20], [21], [23], [24]
Prevalence in the Aviation Industry	[23], [24]

## Discussion

There were eight first-place winning teams of the ACRP university design competition that mentioned sustainability in their design proposals between 2013 and 2017, but none of 2013 first-place winning teams mentioned sustainability. In 2014 and 2015, the sustainability approach used in the first-place winning design was only environmental concerns, and only one metric “percentage of power supplied by renewable energy source” was used [17]. Since 2016, the sustainability approaches used in the winning proposal designs have started to go beyond the environmental concerns and has included economic, social, and operational aspects. Even though not explicitly required by the scoring criteria, the role of sustainability became a part of the decision-making process of the designs. These findings show that the inclusion of sustainability has increased, and that sustainability is being used by student teams to select among design alternatives. It should be noted that in 2017 three of the four winning teams chose to use sustainability metrics. It is not clear whether or not sustainability is an influence on the judges or if this is just a coincidence. The research also indicates that the winning teams used specific sustainability performance metrics based on the unique purposes of the design.

The teams’ motivations for including sustainability in the first-place winning design were summarized into six types: required by the targeted airport, required by the course, sustainable and green solution, required by federal regulations, reduce operating cost and prevalence in the airport industry. Besides the two motivations of required by the course and prevalence in the aviation industry, the other four motivations are matched with motivators of “state/regional regulations airport policy, federal regulations, stakeholder concerns/relations, cost reductions, and desire for improved sustainability performance”, from two airport studies [12] [14]. This finding again reflects the internal and external demands of the airport industry to include sustainability practices.

## Conclusion

Sustainability principles are being incorporated into design, planning, and operations by many airports. Sustainability metrics should be used in a proper way to track and evaluate the performance of the sustainability activities of the airport. The paper explored the metrics used in the eight first-place winning designs that mentioned sustainability in the ACRP university design competitions from 2013 to 2017. Among the eight first-place winning proposals that mentioned sustainability, four of these proposals did not provide any metrics. The other four winning designs used metrics either to measure the sustainability impacts of the design or to aid in the decision-making for select the best solution. The metrics used were not the same in all designs. The metrics were selected based on the different sustainability approaches and the different goals of the designs.

As there is no single, definitive standard for airport sustainability. The metrics identified in this study may be helpful to the students and faculty interested in competing in future competitions and wanting to include sustainability metrics. The motivation for including sustainability varied within these eight first-place winning proposals. Consistent with findings from other studies, the authors found six types of motivations which are required by the targeted airport, required by the course, sustainable and green solution, required by federal regulations, reduce operating cost and prevalence in the airport industry.

As there is no single, definitive standard for airport sustainability, the team selected their own metrics. The sustainability resources listed in the paper may be helpful to students and faculty interested in competing in future competitions or wanting to include sustainability metrics in other design projects. Faculty may use the sustainability sources listed in the paper, along with sustainability metrics and team motivations, during course design in engineering and technology programs.

In 2013, none of the first-place proposals mentioned sustainability. In 2017, three of the four winning proposals mentioned sustainability. In 2017, sustainability was mentioned for the first time in the suggested topics listed in the competition guidelines. It is difficult to conclude that this is a trend or if it is a reflection of the needs of the airport community as expressed to the teams, the concerns of the student teams, the preferences of the judges, the requirements of the course associated with the design proposal preparation, or some combination of these and other factors. Future research may seek to understand the extent of sustainability metrics in all of the competition submittals and to understand if inclusion of sustainability has become an apparent advantage to winning the competition, and if sustainability should be suggested as an explicit criterion.

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