Board 1: Aerospace: Inclusion of Sustainability Analysis in a National Airport Design Competition

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Abstract

Airports are including sustainability in their long-range planning and yearly reports. Environmental concerns have long been a part of air transportation planning, airports are also including social, economic, and sometimes operational concerns in their sustainability planning. In the United States of America (US), the Airport Cooperative Research Program (ACRP), a program of the Transportation Research Board (TRB) of the National Academies of Sciences, Engineering, and Medicine (NASEM), sponsors an airport design competition for university-level students each year funded by the Federal Aviation Administration. Students at U.S. colleges and universities compete by submitting design proposals to solve challenges facing airports, either as part of a course or as an independent project with faculty sponsors. In this paper, the first place design packages from 2007 to 2017 are examined for the inclusion of sustainability, and the departments of the faculty advisors. The data show that the trend has increased over these years. The educational value expressed by the winning teams and advisors was also explored. The educational value findings may encourage instructors to include the competition or sustainability in future design courses.

Introduction

Airports nationwide and globally are including sustainability in their long-range planning and yearly metrics. While there are environmental concerns, airports are also including social, economic, and sometimes operational concerns in their sustainability planning. The Federal Aviation Administration (FAA) and Sustainable Aviation Guidance Alliance (SAGA) are two organizations that include economic, operational, environmental, and social aspects in airport sustainability models. Technology, business, and engineering academic programs are including sustainability in their course offerings. Technology, business, and engineering professionals are seeking to apply the principles of sustainability to their respective areas of expertise. In the United States of America (US), the Airport Cooperative Research Program (ACRP), a program of the Transportation Research Board (TRB) of the National Academies of Sciences, Engineering, and Medicine (NASEM), sponsors an annual national airport design competition for university-level students using funding from the FAA. Students at U.S. colleges and universities prepare 40-page design packages that propose innovative designs to solve challenges facing airports, either as part of a course or as an independent project with faculty sponsors.

The online archive of winning design proposals includes first, second, and third place winners in each of the four challenges areas. In 2017, these four challenges were: (1) airport environmental interactions, (2) runway safety/runway incursions/runway excursions, (3) airport operations and maintenance, and (4) airport management and planning. The competition requires a full design package with a cost/benefit analysis and a risk analysis, but a sustainability analysis is not required. In 2017, three of the four first place teams included sustainability in their proposed designs. Past winning teams were comprised of students in a variety of disciplines such as civil

engineering, mechanical engineering, industrial engineering, computer science, human factors, psychology, and aviation technology. In this paper, the inclusion of sustainability in the first place design packages from 2007 to 2017 is examined.

This paper explores the topics of previous winning design packages, the departments of the faculty advisors, and the inclusion of sustainability. Insights from students and faculty of winning teams are highlighted. Statistics are used to analyze trends. The trends in the winning team proposals may reflect the level of importance of sustainability in industry and may support the need for explicitly including sustainability in courses in engineering and technology. The level and type of sustainability analyses may inform future competition teams and may be used by instructors as a tangible way to include sustainability in their engineering and technology courses.

Sustainability

Sustainability is a term that has more than one meaning. According to the US Environmental Protection Agency [1], sustainability is based on the principle that "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". In the European Union, the concept of 'green growth' is one that "…entails developing integrated policies that promote a sustainable environmental framework" [2]. The term sustainable is also used in non-academic areas. For instance, among other items in grocery stores, consumers may be familiar with canned tuna with labels that claim 'sustainably caught' [3] or coffee with labels claiming to be 'certified sustainable coffee' [4]. The authors of this paper focus on the United Nations' meaning of sustainable development as the basis of discussion. In the 300-page Brundtland Commission Report *Our Common Future*, sustainable development is introduced development that will "meet the needs of the present without compromising the ability of future generations to meet their own needs" [5]. In 2015, countries adopted a 2030 sustainable development agenda as a "plan of action for people, plant and prosperity" [6]. The United Nations has developed 17 sustainable development goals that are intended to "transform our world" [7]. The term *Triple Bottom Line* refers to sustainability in terms economic, environmental, and social aspects [8].

Airport Sustainability

As a part of the US Department of Transportation, the "Federal Aviation Administration (FAA) oversees the safety of civil aviation" and is responsible for certifying airports serving air carriers, among other responsibilities [9]. The FAA Airport Sustainability web page has four areas impacting sustainable airport development: environment, economy, operations and community [10]. While the FAA has noise and exhaust emissions programs, Sustainability Master Plans and Airport Sustainability Plans are specific to individual airports' long-range plans [10]. The Triple Bottom Line has long been expanded to include operational sustainability for air transportation [11]. The SAGA website presents answers to questions starting with "What is Sustainability?" The answer presented by SAGA explains that "The airport industry, in particular, has adopted

the "EONS" approach to sustainability (economic vitality, operational efficiency, natural resources, social responsibility), which expands the concept of the Triple Bottom Line by emphasizing operational efficiency" [12].

Airport Design Competition

This paper focuses on university-level airport design competitions that invite student teams to study problems and present solutions. For this paper, the "ACRP University Design Competition for Addressing Airport Needs" was selected for two reasons: (1) The winning design packages are available on line for free, and (2) The competition websites have winning 11 years of design packages (2007-2017).

The competition website contains guidelines, winning packages, evaluation criteria, submission files, and resources [13]. The competition was formerly known as the "FAA Design Competition for Universities" until August 2014 [14]. As quoted from the competition website [13],

> The Competition is managed for the ACRP by the Virginia Space Grant Consortium of Hampton, Va. This Competition challenges individuals and teams of undergraduate and/or graduate students working with faculty advisors at U.S. colleges and universities to consider innovative approaches related to airport issues. Students can win cash prizes for their winning innovative design solutions. First place winners present their work at a national award ceremony. Full details are provided in the competition guidelines.

The evaluation criteria on the website are organized by section of the report and contain scores within each category to aid the team in conducting their own evaluations prior to submittal, and also serve as the scoring sheets for use by the competition judges. The evaluation criteria do not contain the terms "sustain," "sustainable," "sustainability," or "environment." However, Airport Environmental Interactions is one of the four challenge areas and has a newly suggested project title containing the term "sustainability," and the Airport Operation and Maintenance challenge area has a newly suggested project title containing the term "sustainability" [13]. According to the Design Guidelines, the FAA funds the ACRP to conduct this competition [13].

Methodology

This section discussed the data sources, information selected, procedure of data selections, and analyses conducted in this study.

Data sources

Records published for winning designs between 2007 and 2017 are available online for the ACRP University Design Competition, formerly known as the FAA University Design Competition. Students from US universities were invited to address the airport issues in four technical challenges: (1) Airport Environmental Interactions, (2) Runway Safety/Runway Incursions/Runway Excursions, (3) Airport Operations and Maintenance, and (3) Airport Management and Planning. The archive of winning design proposals includes first, second, and

third place winners in the four challenges areas. The winning papers were posted on the official website of ACRP University Design Competition and the link to competition winners.

Data were derived from these online archives of winning design proposals and the information provided by the official website [13], [14]. The address of the webpage for the previous ACRP competition winners is *http://vsgc.odu.edu/ACRPDesignCompetition/Competition_Winners.html*. In this study, the focus in on the information provided by the first place winners.

Over the eleven-year time span of 2007-2017, there were 42 first place winners. In 2007 and 2008, there were only three challenge categories. The fourth category, Airport Management and Planning, was added in 2009. Moreover, while there were three challenge categories had first place winners in 2014, five teams won the first place in 2015, when Airport Operation and Maintenance challenge had two first place winners.

Procedure

To conduct the study, the research team collected seven types of information about the first place winning teams and their proposals. The types of information included project title, year, academic discipline, departments, University, sustainability approach, and educational experience evaluation. Most types of the information could be directly retrieved from the winning proposals and the webpage. To determine the types of inclusion of sustainability and the reason for participation required reading sections of the design proposals.

The research team divided the inclusion of sustainability. If a winning proposal did not mention sustainability or sustainability concepts, then this proposal would be marked with 0; else the proposals would be marked with 1. The researchers identified which sustainability approach(es) were used, if any. Commonly used sustainability concepts in the aviation industry include environmental concerns, Triple Bottom Line, and EONS.

To participate in the ACRP competition, every team has to submit an evaluation of educational experience as an appendix in the proposal. Both students and faculty are asked to answer the evaluation questions that are provided on the competition website and discuss the experience of the competition. In this section, the insights from students and their faculty could be explored.

Analysis

The data started with a summary on the departments, universities, and disciplines of the winning teams. The number of winning proposals and those that mentioned sustainability were counted by discipline categories, challenge categories, and years. The sustainability approach mentioned in the proposal was identified if applicable. According to the findings, the trend for inclusion of sustainability was investigated. The authors also explored the insights from the students and faculty advisors of winning teams. Finally, the inclusion of the ACRP competition in academic courses was discussed.

Results

In this section, the authors first summarized the numbers of first place winning proposals to ACRP Design Competition from 2007 to 2017 and categorized the disciplines and universities of the winning teams. Then, the numbers of winning proposals that mentioned sustainability, the sustainability approaches mentioned in these proposals, and the trend of inclusion of sustainability was determined. Finally, the insights from the winning teams and the course inclusion were discussed.

Disciplines and Universities

Table 1 shows the summary of winning teams' disciplines, departments, and universities of ACRP design competition from 2007 – 2017. The winning teams were from 21 departments of 16 universities in 12 States. The departments of the winning teams were determined according to the faculty advisors' departments which were listed in the Appendix D: Design Submission Form of each proposal. This form is mandatory to be submitted as an attachment to each design proposal.

The Center for Aviation Studies and Department of Aviation are units at Ohio State University. The School of Aviation and Transportation Technology is the former Department of Aviation Technology at Purdue University. Four winning teams from Embry-Riddle Aeronautical University, Daytona Beach had faculty advisors that were from two different departments; Human Factors Systems, and Applied Aviation Science. Those four teams in Table 1 are listed as a combination of the two departments.

By exploring the structure of departments shown on the respective university websites, the authors divided the 21 departments into eight discipline categories. The discipline of engineering covers ten departments at nine universities including civil engineering, environmental engineering, mechanical engineering, and industrial engineering. After exploring the structure of the School of Engineering, Computing and Construction Management of Roger Williams University and the School of Systems and Enterprises of Stevens Institute of Technology, the research team also includes these two schools in the engineering category.

As mentioned in the Data Sources section, the ACRP Design Competition has four challenge categories. Table 2 is a summary of the number of winning proposals in each discipline and each challenge category.

From 2007 to 2017, there were 42 teams that won the first place in four challenge categories, and 12 (27%) of them mentioned sustainability. During the 11-year time span, 11 teams won first place in Airport Environmental Interactions challenge, and five (45%) of the teams mentioned sustainability. All five teams were from engineering. In comparison, the other three categories had a relatively lower percentage of inclusion of sustainability. Although the disciplines of the competition winners were diverse, only the winning team from aviation, engineering, and computer science discipline categories mentioned sustainability in their proposals.

Table 1. *Summary of discipline, department, and university of winning teams from 2007 – 2017.*

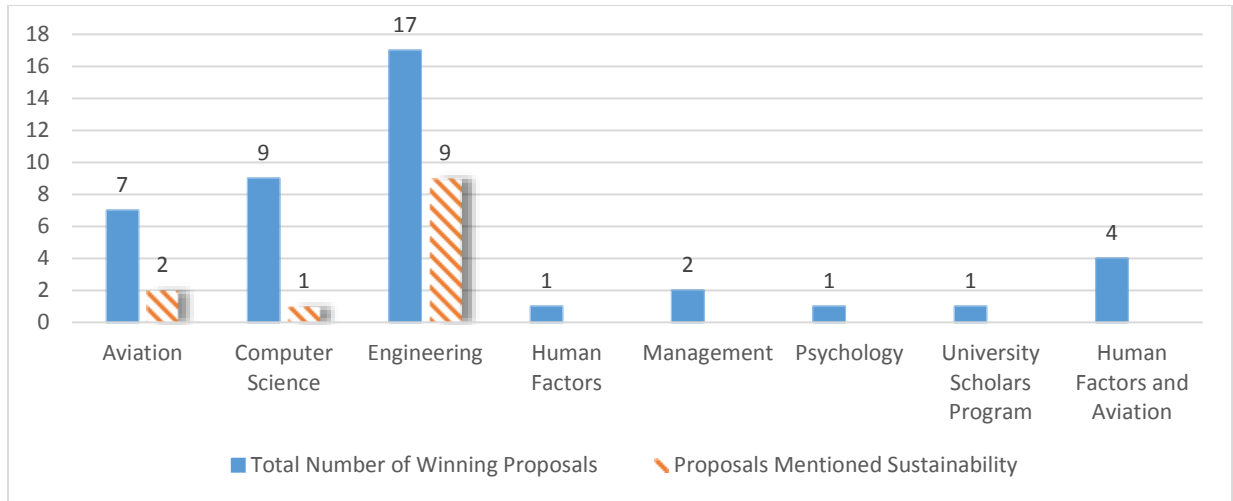| Discipline	Department	University
Aviation	Center for Aviation (Department of Aviation)	Ohio State University
		Ohio State University
	Aviation and Technology	San Jose State University
	School of Aviation and Transportation Technology (Aviation Technology)	Purdue University
Computer Science	Computer Science	Binghamton University - State University of New York
	Computer Science	University of Southern California
Engineering	Civil and Environmental Engineering	University of Massachusetts Amherst
	Civil, Environmental and Architectural Engineering	University of Colorado, Boulder
	Civil and Environmental Engineering	University of California, Berkeley
	Civil Engineering	University of Illinois, Urbana-Champaign
	Mechanical, Industrial and Systems Engineering	University of Rhode Island
	Environmental Engineering	University of Colorado, Boulder
	Mechanical Engineering	Tufts University
	School of Engineering, Computing and Construction Management	Roger Williams University
	School of Industrial Engineering	Purdue University
	School of Systems and Enterprises	Stevens Institute of Technology
Human Factors	Human Factors and Systems	Embry-Riddle Aeronautical University, Daytona Beach
Management	College of Business	Embry-Riddle Aeronautical University Daytona Beach
	Sky Harbor campus of the Worldwide Department of Business Administration	Embry-Riddle Aeronautical University in Phoenix, AR
Psychology	Psychology	George Mason University in Fairfax, VA
University Scholars Program	University Scholars Program	Binghamton University - State University of New York
Human Factors and Aviation	Human Factors and Systems Dept and Applied Aviation Science Dept	Embry-Riddle Aeronautical University Daytona Beach

Note. The information about the ACRP first place winners' disciplines, departments, and universities determined according to their winning proposals that are available on the official website of ACRP Design Competition: http://vsgc.odu.edu/ACRPDesignCompetition/Competition_Winners.html

Table 2. *Numbers of winning proposals by discipline category in four challenge categories.*

Challenge Category	Discipline Category		Winning Proposals	Mentioned Sustainability
	Aviation		1	0
	Computer Science		4	0
Airport Environmental Interactions	Engineering		5	5
	Management		1	0
		Subtotal	11	5 (45%)
	Aviation		4	1
Airport Management and Planning	Engineering		4	1
	Human Factors and Aviation		1	0
		Subtotal	9	2 (22%)
	Aviation		1	0
	Computer Science		4	1
Airport Operation and Maintenance	Engineering		5	1
	University Scholars Program		1	0
		Subtotal	11	2 (18%)
	Aviation		1	1
	Computer Science		1	0
	Engineering		3	2
Runway Safety/Runway Incursions/Runway Excursions	Human Factors		1	0
	Human Factors and Aviation		3	0
	Management		1	0
	Psychology		1	0
		Subtotal	11	3 (27%)
		Total	42	12 (29%)

Figure 1 shows the number of winning teams in eight discipline categories from 2007 to 2017. The blue bars represent the total number of winning proposals, while the orange bars represent the number of proposals that mentioned sustainability. The engineering categories had the highest number of winning proposals, which accounted for 40% of the total. For the proposals mentioned sustainability, engineering represented 75% of the total. The aviation and computer science categories contributed the other 25% of proposals.

Figure 1. Numbers of first place winning proposals to the ACRP Design Competition from 2007 to 2017 by discipline.

In a previous research study [15], the researchers explored the first, second, and third place winning proposals to the ACRP Design competition from 2013 to 2017, and found that in the past five years there were 55 winning teams and 21(38%) of the teams mentioned sustainability. Among the winning teams, 29 of them were from engineering, ten of them were from aviation, five were from human factors and systems department and applied aviation science department, and six were from the University Scholars Program at Binghamton University, the remaining five were from architecture, computer science, and management [15]. Seven out of ten (70%) of winning teams in aviation and 12/29 (41%) of winning teams in engineering mentioned sustainability, while there were only two teams that mentioned sustainability in the remaining teams [15]. The distribution of winning proposals that mentioned sustainability in the previous study is similar to the distribution in this study. The numbers of first, second, and third place winning proposals from 2013 to 2017 is shown in Figure 2.

Moreover, among the nice first place winning proposals from 2007 to 2017 that mentioned sustainability in the engineering category as shown in Figure 1, the civil engineering departments and environmental departments contributed four (44%) of them. In comparison to 1st, 2nd, or 3rd place winning proposals from 2013 to 2017, Gu and Johnson [15] found that the civil engineering departments and environmental departments contributed 10 out of the 12 (83%) that mentioned sustainability with teams mentored by the engineering discipline faculty as shown in Figure 2.
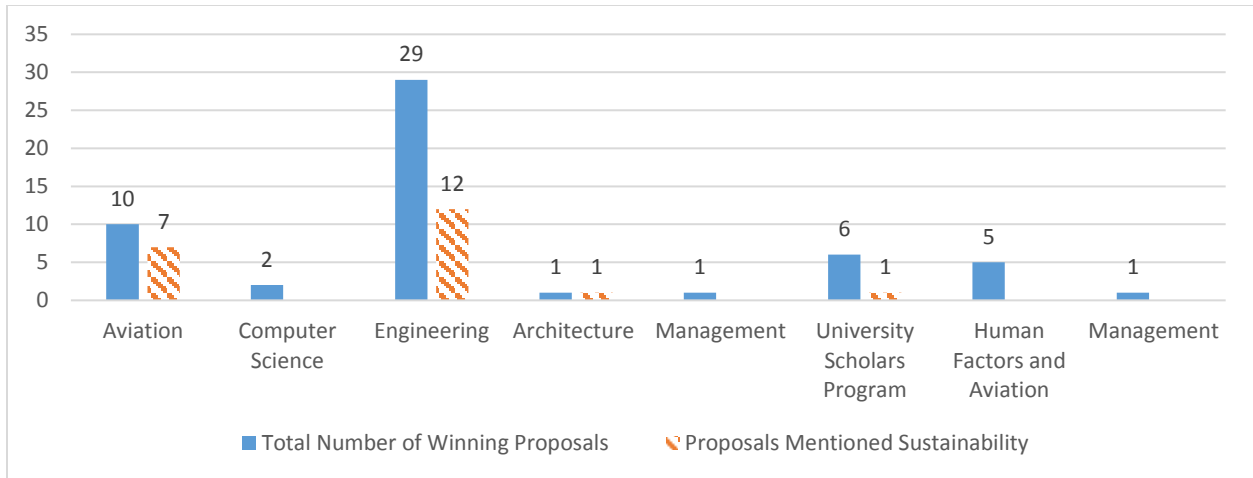
Figure 2. Sustainability in first, second, and third place winning proposals to the ACRP Design Competition from 2013 to 2017 by discipline.

Sustainability Approaches

The commonly used sustainability approaches in the aviation industry include environmental concerns, Triple Bottom Line, and EONS. Among the 12 first place proposals that mentioned sustainability, the environmental concerns is mentioned seven times, accounting for 58% of the 12 proposals. The principles of Triple Bottom Line were used in three proposals. These winning teams did not directly mention the TBL title but used the principles of TBL that take environmental, social and economic aspects of sustainability into measuring airport performance. The EONS approach was only mentioned by two winning teams from aviation departments. A probable reason that EONS was mentioned only by aviation teams is that these teams may be more familiar with the EONS model because it is mentioned on the FAA's website [10] and SAGA's website [12]. Figure 3 shows the percentages of three types of sustainability approaches mentioned in the winning proposals.
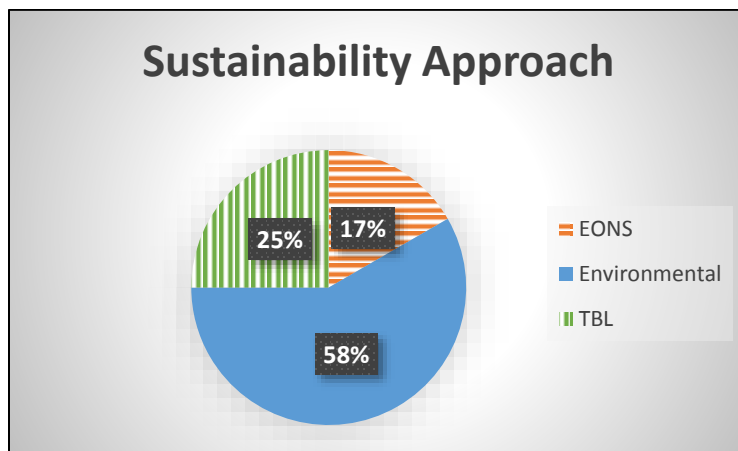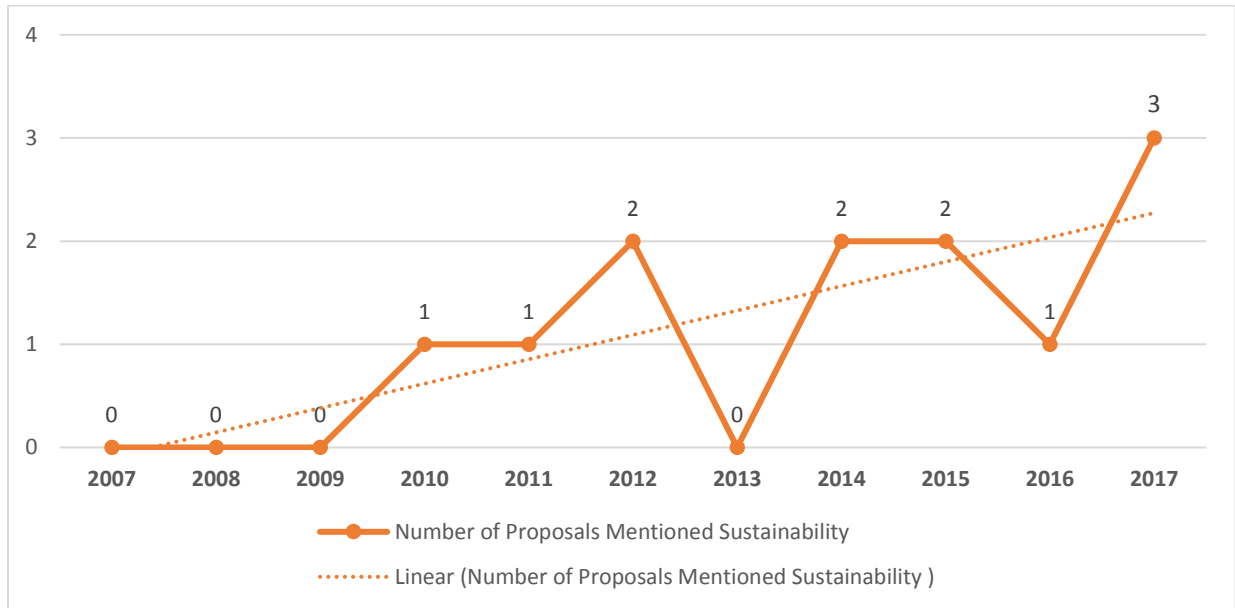

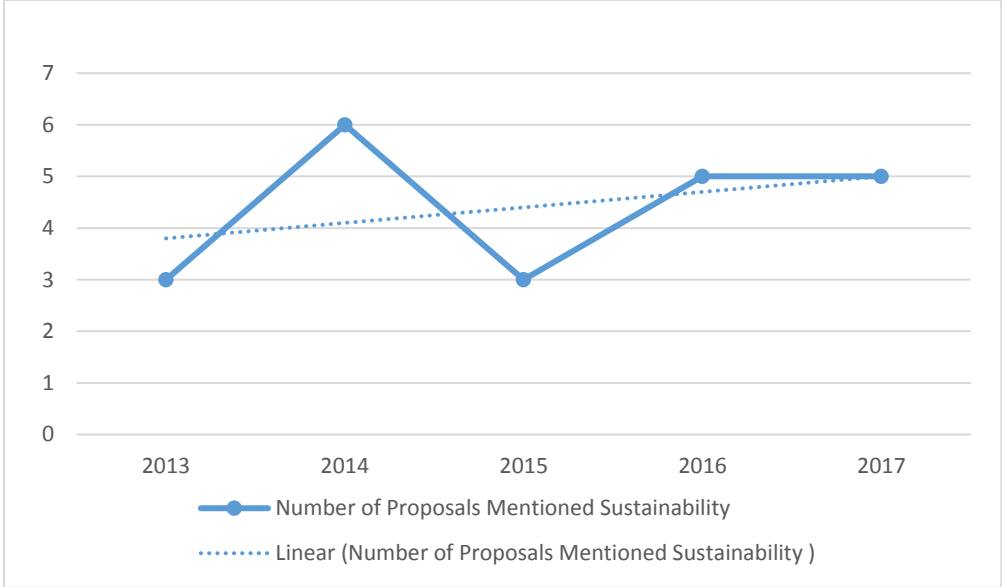*Figure 3*. Sustainability approaches used in ACRP Design Competition winning proposals.

Trend of Sustainability Inclusion

Figure 4 shows the number of first place winning proposals that mentioned sustainability in each year from 2007 to 2017. From 2007 to 2009, there were no winning teams that mentioned sustainability in their proposals. Since 2010, sustainability started to appear in the first place winning proposals with increased occurrences, except for 2013. In 2007, sustainability was mentioned in the three out of the four first-place winning proposals.
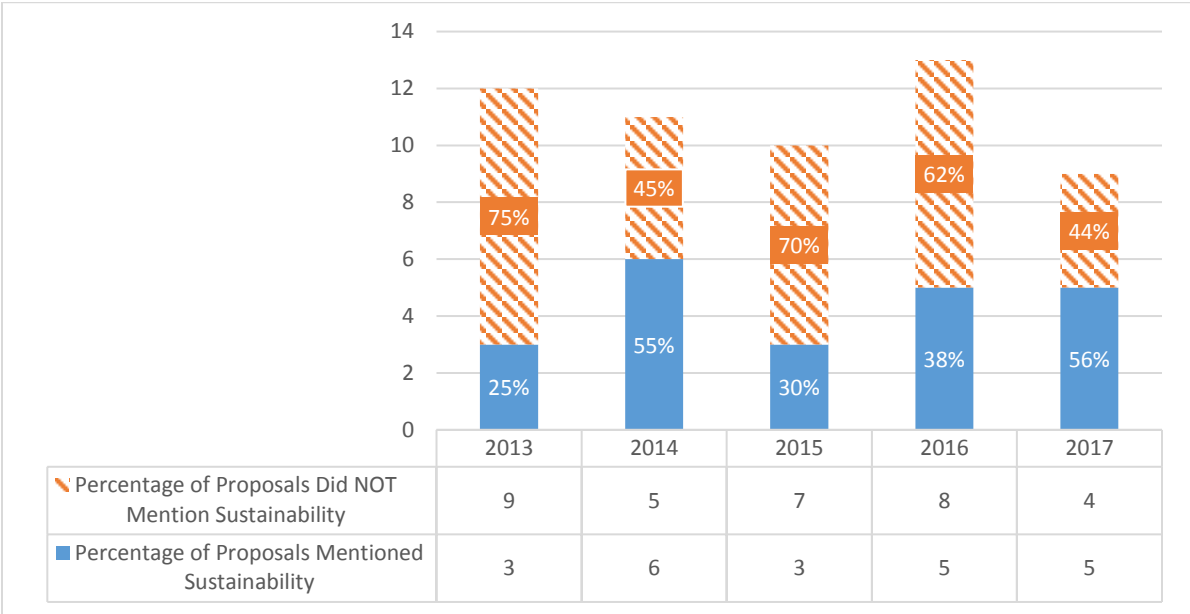

Figure 4. Trend of sustainability inclusion in the first place winning proposals to the ACRP Design Competition from 2007 to 2017.

Since the maximum number of first place winners of ACRP Design Competition in each year is four, the increase of proposals that mentioned sustainability may not be obvious. Figure 5 shows the numbers of first, second, and third place winning proposals that mentioned sustainability from 2013 to 2017. Figure 5 shows that from 2013 to 2017, at least three winning teams mentioned sustainability. In 2014, the number of winning proposals that mentioned sustainability reached six, the highest occurrences in the past five years. In 2016 and 2017, the number of winning proposals that mentioned sustainability remained at five. The level of inclusion of sustainability did not increase. The proportion of winning teams that mentioned sustainability out of the total winnings team increased. As shown in Figure 6, except 2014, the percentage of the winning proposals that mentioned sustainability gradually increased in the past five years. According to the findings of this research and Gu and Johnson [15], the number of winning teams that chose to include sustainability increased year by year. The authors made three assumptions based on the findings that may explain this trend: (1) The ACRP Design Competition participants recognized the importance of sustainability. (2) The ACRP Design Competition was becoming to prefer the designs that applied sustainability. (3) The airport industry has internal and external demands to include sustainability principles.

Figure 5. Trend of sustainability inclusion in the first, second, and third place winning proposals to the ACRP Design Competition from 2013 to 2017.
Note. This figure is based on data from [15].

	2013	2014	2015	2016	2017
Percentage of Proposals Did NOT Mention Sustainability	9	5	7	8	4
Percentage of Proposals Mentioned Sustainability	3	6	3	5	5

Figure 6. Percentages of sustainability inclusion in the first, second, and third place winning proposals to the ACRP Design Competition from 2013 to 2017.
Note. This figure is based on data from [15].

Insights from the Winning Teams and Their Faculty Advisors

The ACRP Design Competition requires every team and their faculty advisors to answer a series of questions in order to provide an evaluation of the educational experience of participating in the competition. The responses to these questions are included in the team's proposal.

One question for students is "Did the FAA Airport Design Competition provide a meaningful learning experience for you? Why or why not" [13]. By reading the answers of this question, the authors summarized six insights from the students:

- Gain valuable experience in teamwork
- Expand knowledge, skills, and learn industry standards
- Have opportunities to interact with industry professionals and experts
- Exposure to real-world problems
- Improve problem-solving skills
- Improve technical writing and communication skills

A similar question for the faculty advisors is "Describe the value of the educational experience for your student(s) participating in this competition submission" (ACRP, 2017). The five insights extracted from the answers of advisors are:

- Receive educational experience beyond normal classroom curricula
- Improve communication skills
- Learn importance of persistence and follow-up
- Improve the ability to define and solve problems
- Explore the applicability of sustainability

The real-world experience and the opportunity to interact with industry professionals were mentioned frequently by the students. Correspondingly, all faculty advisors mentioned the importance of receiving educational experience beyond normal classroom curricula. The improvement of communication skills is another meaningful value that was recognized by both the students and their faculty advisors. In addition, the advisors emphasized problem-solving skills. These skills not only include finding practical solutions, but also include identifying the problem, setting up implementation plans, and conducting measurements.

Course Inclusion

The ACRP competition is open to university students at the undergraduate and graduate level with a faculty mentor, either as part of a course or a club activity. On the Notice of Intent form on the website [13], the drop-down menu contains four options to characterize how the project will be done: as a part of a design class, independent study, student society chapter project, or other (explain). The competition may be completed over one or two semesters between August and April each year, but all packages are due no later than a specific date in April (e.g. April 28, 2018). The 40-page package plus appendices are specified in the guidelines and referred to in the evaluation criteria [13]. In addition to the challenges presented in the guidelines coming from real airport issues, these specifications are conducive for use in design or capstone courses

because they mimic the real world of preparing proposals. In the guidelines, the teams are encouraged to document their interactions with aviation experts from professional organizations and the evaluation criteria have scores for those interactions.

In the 2017 winning packages available online, two teams did their projects as part of an undergraduate capstone design experience and two teams did their projects as one part of a graduate aviation sustainability course [13]. In the Resources tab at the ACRP website [13], there are video tutorials, links to documents and reports, list of expert advisors for the teams to contact, tips from past winners and evaluators, and a style sheet for references and citations. These items may be used by professors wishing to include the ACRP Design Competition in their courses. One tip is for advisors to work with students to develop a schedule with intermediate milestones with the final due date ahead of the competition due date.

Conclusion

Sustainability in airport designs is an increasing concern, and is also growing in other industries. By examining the design packages from 42 first place proposals in a national design competition, the research shows that there is an increase in including sustainability. Therefore, in design courses, sustainability analysis should be a consideration for instructors. One way to include sustainability in design courses is to use established approaches such as environmental, Triple Bottom Line, and EONS. These approaches should also mimic the competition that requires a full design package with a cost/benefit analysis and a risk analysis. In 2017, three of the four first place teams included sustainability in their proposed designs. Including sustainability in designs goes across many disciplines as evidenced by past winning teams disciplines such as civil engineering, mechanical engineering, industrial engineering, computer science, human factors, psychology, and aviation technology.

This paper explored the topics of previous winning design packages, the departments of the faculty advisors, and the inclusion of sustainability. Insights from students and faculty of winning teams focused on the value of the educational experience. These insights focus on soft skills and problem-solving skills. The trends in the winning team proposals may reflect the level of importance of sustainability in industry and may support the need for explicitly including sustainability in courses in engineering and technology. Future analysis of the winning proposals of the ACRP design competition and other national competitions may be conducted to better understand the level and type of sustainability analyses used by instructors as a tangible way to include sustainability in their engineering and technology courses.

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