Inclusion of Sustainability Evaluation/Assessment in National Airport Design Competition

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INTRODUCTION

Inclusion of sustainability plans, evaluations, and impacts is a critical element in long-term business strategy, yearly reports, and investor relations documents in many industries. Companies benefit from the integration of sustainability in their business models. Airports intend to implement sustainability into their day-to-day operations to reduce costs and environmental impacts, attract investors, and improve brand image, among other reasons. Many airports have developed long-term sustainability plan that are reported in their annual reports or sustainability reports. Integrating sustainability in graduate and undergraduate engineering, technology, and management courses as part of curriculum, lectures, and projects will prepare students to address sustainability challenges in industry.

Each year, students from universities across the United States (U.S.) compete in the Airport Cooperative Research Program (ACRP) Design Competition. The students form teams to prepare proposals to address airport challenges in one of the four competition categories: airport management and planning, airport operation and maintenance, airport environmental interactions, and runway safety/runway incursions/runway excursions. In this paper, first, second, and third-place winning design packages from 2021 to 2023 are analyzed for the inclusion of sustainability in terms of mentions, definitions, frameworks, evaluation metrics, and impacts. The winning design packages are publicly available on the Transportations Research Board ACRP Design Competition website. Quantitative and qualitative research methods are used to analyze the reports and graphical and statistical tests are used to answer the research question: *What is the extent of sustainability inclusion in terms of mentions, definitions, frameworks, evaluation metrics, and impacts, as reported in the 1st, 2nd, and 3rd place design proposals from 2021 to 2023?*

The ACRP airport design competition is an opportunity for engineering students to gain knowledge in project management, quantitative and qualitative research methods, technical writing, and interactions with team members and with industry experts. This paper may provide insights about the inclusion of sustainability in semester-long projects and winning design packages. Since engineering solutions will be at the core of solving global problems, it is crucial that students, especially STEM graduates, are equipped with the skills, knowledge, experience, and values to build a sustainable future. This paper may be useful for engineering educators to identify how they can incorporate sustainability in their courses, projects, or proposals. Future students who plan to participate in the ACRP competition may also learn about implementing sustainability into their projects to make their competition package stronger.

BACKGROUND

Inclusion of sustainability principles in engineering education is crucial. Since engineering solutions will be at the core of solving global problems, it is crucial that students, especially STEM graduates, are equipped with the skills, knowledge, experience, and values to build a sustainable future [1]. For instance, ABET explains engineering design as iterative, creative,

decision-making process to devise a system, component, or process to meet desired needs, specifications, problems, and convert resources into high-quality solutions under given circumstances or constraints; and sustainability is exampled as one such possible constraints [2]. As per ASEE Sustainable Development Education, "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" [3]. Engineering educators may use lectures, team projects, systems approach, case studies, and design competitions to include sustainability principles and assessment education in curriculum. One such example in aviation is the ACRP Design Competition where sustainability measures and assessments may be included as part of design proposals to solve airport related problems. This section presents an overview of common definitions of sustainability, airport sustainability, sustainability frameworks and metrics, the ACRP design competition, and highlights of prior research in the intersection of sustainability and ACRP competition winning design proposals.

Sustainability: Sustainability is a term that has been defined in various ways. A commonly accepted and used definition of sustainable development comes from the Brundtland Commission Report Our Common Future: "development that meets the needs of the present without compromising the ability of future generations to meet their needs" [4][5]. According to the U.S. Environmental Protection Agency [6], "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" [6]. In the European Union, 'green growth' is referred to something that "…entails developing integrated policies that promote a sustainable environmental framework" [7]. A concept known as Triple Bottom Line (TBL) focuses on the integration of sustainability principles in industry operations through the combined consideration of environmental protection, community needs, and economic vitality [8]. The United Nations has developed 17 sustainable development goals (SDGs) that are intended to "transform our world" [9]. In 2015, countries adopted a 2030 sustainable development agenda as a "plan of action for people, plant and prosperity" [10].

Airport Sustainability: The Airports Council International-North America (ACI-NA) has intentionally expanded the concept of the triple bottom line by adding the aspect of 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" [11]. The FAA Airport Sustainability web page describes four areas that impact sustainable airport development: economy, environment, operations, and community [12]. In addition to the FAA's noise and exhaust emissions programs, individual airports develop Sustainability Master Plans and Airport Sustainability Plans specific their long-range plans [12]. Also, operational sustainability for air transportation has long been considered as an expansion of the Triple Bottom Line (TBL) [13].

Sustainability Frameworks: Sustainability evaluation is multifaceted, encompassing environmental, social, economic, and governance dimensions. Various frameworks and metrics

have been developed to assess and measure sustainability in different contexts, such as organizations, projects, products, and communities. Commonly used sustainability evaluation frameworks include, but not limited to:

Triple Bottom Line (TBL): This framework evaluates sustainability based on three pillars: environmental, social, and economic. It encourages organizations to measure their impact on the planet (environment), people (social), and profit (economic) [8][14].

EONS Approach: The ACI-NA expanded the TBL approach to include operational efficiency as part of the assessing airport sustainability. The EONS approach of airport sustainability assessment considers the Economic Vitality, Operational efficiency, Natural Resource Conservation and Social responsibility (EONS) of the airport/project [11].

United Nations Sustainable Development Goals (SDGs): The SDGs are a universal call to action to end poverty, protect the planet, and ensure that all people enjoy peace and prosperity. There are 17 UN SDGs (Figure 1) that provide a comprehensive framework for assessing sustainability efforts across various sectors [9].

Figure 1. The 17 UN Sustainability Development Goals (SDGs) [9].

Global Reporting Initiative (GRI): GRI provides a comprehensive set of standards for sustainability reporting, helping organizations measure and communicate their economic, environmental, and social impacts [15].

ESG Criteria: Environmental, Social, and Governance (ESG) criteria are a set of standards for a company's operations that socially conscious investors use to screen potential investments [16].

Carbon Footprint Assessment: A measure of the total greenhouse gas emissions caused directly and indirectly by an individual, organization, event, or product. A commonly used reference for carbon footprint is the Greenhouse Gas Protocol, which provides widely used greenhouse gas accounting standards [17].

Life Cycle Assessment (LCA): LCA is a method used to assess the environmental impacts associated with all the stages of a product's life, from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal/recycling [18].

In addition to the frameworks and standards, some of the common metrics to measure sustainability include, but are not limited to, carbon footprint, water footprint, energy efficiency, waste reduction and recycling, sustainable procurement percentage, employee satisfaction and diversity metrics, economic performance indicators, ecosystem service values, etc.

ACRP National University Design Competition: The ACRP is a program of the Transportation Research Board (TRB) of the National Academies of Sciences, Engineering, and Medicine (NASEM), funded by the FAA, and managed by the Virginia Space Grant Consortium [19]. This competition invites individual participants and teams of undergraduate and/or graduate students, guided by faculty mentors from U.S. higher education institutions, to explore creative solutions to challenges faced by airports under four broad areas: (1) Airport Environmental Interactions, (2) Runway Safety/Runway Incursions/Runway Excursions, (3) Airport Operations and Maintenance, and (4) Airport Management and Planning [15]. Evaluation criteria categories include Introductory Material, Problem Statement and Background, Literature Review, Problem Solving Approach, Safety Risk Analysis, Practicality and Feasibility of the Design, Innovation, and the Overall Quality of Design [20]. More and more ACRP design proposals have started to incorporate some aspects of sustainability evaluation, sustainable development, and/or a wholistic impact of their design proposals. The winning design packages are publicly available on the TRB ACRP Design Competition website [21]. *Note.* In 2024, the four challenge areas have been modified to: (1) Airport Environmental Interactions, (2) Airport Safety, Operations, and Maintenance, (3) Passenger Experience and Innovations in Airport Terminal Design, and (4) Airport Management and Planning

Researchers have analyzed the ACRP national design competition winning packages for multiple insights. For example, a study analyzed 20 first place ACRP design packages from 2007 to 2017 and found that a majority (60%) of them mentioned sustainability; eight of these winning packages were awarded between 2013 and 2017 [22]. Another study identified the sustainability performance metrics and the motivations of including sustainability in eight 1st place ACRP winning design proposals between 2013 and 2017 [23]. One different study analyzed 1st, 2nd, and 3rd place winning design proposals for the value perceptions of the industry and expert interactions while developing the design proposals [24]. Another study highlighted the motivation and value of diverse student teams in graduate projects, including the ACRP design competition [25]. Following up on these studies [22][23][24][25], this paper aims to analyze the 1st, 2nd, and 3rd place winning design proposals for the inclusion of sustainability. Specifically, the research question in this paper is: *What is the extent of sustainability inclusion in terms of mentions, definitions, frameworks, evaluation metrics, and impacts, as reported in the 1st, 2nd, and 3rd place design proposals from 2021 to 2023?*

METHODOLOGY

Data Collection: The 1st, 2nd, and 3rd place winning design proposals for 2021 [26], 2022 [27], 2023 [28] are available on the ACRP Competition Winners website [21]. Typically, ACRP announces winners in each of the 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. However, each of these winning places may not necessarily be awarded every year and in each category. The design proposals that did not win 1st, 2nd, or 3rd place are not publicly available and not considered in this study.

Data Analysis Procedure: Each of the winning proposals from 2021 to 2023 were analyzed for mentions of sustainability, definitions of sustainability used, inclusion of sustainability assessment, frameworks used in sustainability evaluation, and metrics used to measure sustainability. Final results were tabulated.

RESULTS

This section presents the numbers and percentages of ACRP winning design proposals that included sustainability evaluation/assessments, definitions of sustainability found in the reports, and sustainability frameworks/metrics used in the evaluations. Table 1 presents a summary of number of ACRP winning reports from 2021, 2022, and 2023 and how many included sustainability. Table 2 presents the commonly used definitions of sustainability in ACRP winning proposals from 2021, 2022, and 2023. Table 3 presents the approach/frameworks used in sustainability assessments.

Table 1. ACRP Winning Design Proposals that Include Sustainability Evaluation/Assessment

		2021			2022			2023			TOTAL		
		Winning Proposals	Include Sustainability	Percentage	Winning Proposals	Include Sustainability	Percentage	Winning Proposals	Include Sustainability	Percentage	Winning Proposals	Include Sustainability	Percentage
By Place Awards	1st place	5	1	20%	4	1	25%	4	3	75%	13	5	38%
	2nd place	2	0	0%	3	0	0%	2	2	100%	7	2	29%
	3rd place	1	1	100%	4	3	75%	2	1	50%	7	5	71%
	TOTAL	8	2	25%	11	4	36%	8	6	75%	27	12	44%
By Challenge Areas	Airport Management and Planning	4	1	25%	3	2	66%	3	3	100%	10	6	60%
	Airport Environmental Interactions	1	0	0%	2	1	50%	3	2	66%	6	3	50%
	Airport Operation and Maintenance	2	1	50%	3	1	33%	1	0	0%	6	2	33%
	Runway Safety	1	0	0%	3	0	0%	1	1	100%	5	1	20%
	TOTAL	8	2	25%	11	4	36%	8	6	75%	27	12	44%

Note. In 2024, the challenge areas have been modified to: (1) Airport Environmental Interactions, (2) Airport Safety, Operations, and Maintenance, (3) Passenger Experience and Innovations in Airport Terminal Design, and (4) Airport Management and Planning

Table 2. Sustainability Definitions used in ACRP winning proposals in 2021, 2022, 2023.

Definition of Sustainability	Source	Number of winning proposals
"Meeting the needs of the present without compromising the ability of future generations to meet their own needs." [4]	United Nations Brundtland Commission	5
"Reduce environmental impacts. Help maintain high, stable levels of economic growth. Help achieve "social progress", a broad set of actions that ensure organizational goals are achieved in a way that's consistent with the needs and values of the local community." [12]	Airport Sustainability, FAA	2
"Enhances an airport's economic vitality, operational efficiency, natural resource conservation and social impact." [11][29]	North America Sustainability Policy Statement, ACI	2
"Create and maintain conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations." [6]	National Environmental Policy Act of 1969, U.S. Environmental Protection Agency	1
"Triple Bottom Line: people, planet and profits" [8]	John Elkington	1
"Continuous growth, contributing to a range of social-economic effects while simultaneously mitigating or even diminishing its negative impacts-costs on the environment and society in both relative and absolute terms." [30]	Milan Janić	1

Table 3. Sustainability approach/framework used in the ACRP winning proposals that included a sustainability evaluation/assessment of their project.

Area	Year	Place	Title	Sustainability Approach/ Framework	Metrics
Airport Management and Planning	2021	3rd	Modernization of Airport Cell Phone Lots: Reduce Landside Congestion and Increase Airport Sustainability	EONS	EONS impact analysis of airport cell phone lots
	2022	1st	Airport Unmanned Self-Driving Wheelchair (AUSW)	EONS	EONS impact analysis of AUSW
				UN SDGs	Highlighted relation to SDGs 9, 10, 11
		3rd	Increased Usage of Satellite Check-In: Reducing Landslide Congestion and Increasing Airport Sustainability	EONS	EONS impact analysis of Satellite Check-In
				UN SDGs	Highlighted relation to SDGs 3, 7, 11, 13
	2023	1st	Accessible Air Travel Information System (A2TIS)	EONS	EONS impact analysis of A2TIS
				UN SDGs	Highlighted relation to SDGs 9, 10, 11
		2nd	Automated Trolley Loop Assistance System (ATLAS)	FAA Airport Sustainability	Highlighted the Environment, Community, Economy, Operation impact of ATLAS
		3rd	Advanced Air Mobility Shuttle from GA Airports	EONS	EONS impact analysis of AAM Shuttle
				UN SDGs	Highlighted relation to SDGs 3, 7, 8, 9, 10, 13
Airport Env. Interactions	2022	3rd	Environmental Interactions Stormwater Management	Environmental Concerns	Included sustainability in multi-criteria decision matrix developed by the design team
	2023	1st	Implementing Airside Bioswales for Stormwater Management at the Airport	EONS	EONS impact of Stormwater Treatment Facility
				UN SDGs	Highlighted relation to SDGs 3, 9, 11, 13, 14, 15
		2nd	Integration of Piezoelectric Speed Bumps into Airport Roadways	EONS	EONS impact analysis of Piezoelectric Speed Bumps
				UN SDGs	Highlighted relation to SDGs 7, 9, 12
Airport Ops. & Maint.	2021	1st	Conceptual Design of Vertiport and UAM Corridor	FAA Airport Sustainability	Examined the Operational, Economic, Environmental, Social impact of vertiport design
	2022	3rd	A Systematic Decision-Making Approach for Developing and Maintaining a Plan for Airport Pavement	EONS	EONS impact analysis of Airport Pavement Plan
				UN SDGs	Highlighted relation to SDGs 8, 9, 11, 12, 13, 14, 15
Rwy Safety	2023	1st	Active Runway Indication System (ARIS)	EONS	EONS impact analysis of ARIS
				UN SDGs	Highlighted relation to SDGs 7, 9, 11

CONCLUSION

In this paper, a total of 27 ACRP airport design competition winning proposals from 2021, 2022, and 2023 were analyzed and 12/27 included a sustainability evaluation/assessment as part of the design package. The percentage of the wining proposals that include a sustainability analysis/assessment has increased from 25% (2021), 36% (2022), to 75% (2023). The sustainability definition proposed by the UN Brundtland Commission was used most frequently (5/12 proposals). Analyzing the sustainability impact using an EONS model (9/12 proposals) and highlighting a relationship to one or more of the17 UN SDGs (8/12 proposals) were most commonly used. Since engineering solutions will be at the core of solving global problems, it is crucial that STEM students are equipped with the skills, knowledge, experience, and values to build a sustainable future. Educators may choose to use lectures to introduce the principles of sustainability (for e.g., TBL, EONS model, UN SDGs, ESG metrics, GRI framework) and semester-long problem-solving projects such as the ACRP airport design competitions to provide hands-on experience of conducting a thorough sustainability assessment on a proposed solution.

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