DEFINING AIRPORT OPERATIONAL SUSTAINABILITY FOR THE U.S. GENERAL AVIATION AIRPORTS

by

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This dissertation is dedicated to my mother for her endless love, support, and encouragement throughout my entire life. This dissertation is also dedicated to my father for his love and support.

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1G3	Kent State University Airport
1V6	Fremont County AirportG
ACI	Airports Council International
ACI-NA	Airports Council International - North America
ACRP	Airport Cooperative Research Program
AIP	Airport Improvement Program
ARFF	Aircraft Rescue and Firefighting
atm	Air Transport Movements
BOCC	Board of County Commissioners
BOS	Boston Logan International Airport
CDOT	Colorado Department of Transportation
CDP	Carbon Disclosure Project
COE	Coeur d'Alene Airport
CSR	Corporate Sustainability Reports
DFW	Dallas-Fort Worth International Airport
DOAV	Virginia Department of Aviation
EONS	Economic viability, Operational efficiency, Natural resource conservation, and Social responsibility
EWR	Newark Liberty International Airport
FAA	Federal Aviation Administration
FDOT	Florida Department of Transportation
GA	General Aviation
GCR	GCR Inc.
GRI	Global Reporting Initiative
HNL	Honolulu International Airport
ISO	International Organization for Standardization
LEED	Leadership in Energy & Environmental Design
MSL	Mean Sea Level
NAS	National Airspace System

NOAA	National Oceanic and Atmospheric Administration
NPIAS	National Plan of Integrated Airport Systems
ODOT	Ohio Department of Transportation
PAPIs	Precision Approach Path Indicators
RIL	Rifle Garfield County Airport
SAGA	Sustainable Aviation Guidance Alliance
SLC	Salt Lake City International Airport
SLCgreen	Salt Lake City Green
SLCDA	Salt Lake City Department of Airports
SMP	Sustainability Management Plan
TBL	Triple Bottom Line
TRB	Transportation Research Board
VRB	Vero Beach Regional Airport

ABSTRACT

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While the general public may be familiar with commercial airports, there are thousands of small General Aviation (GA) airports serving communities across the United States. Many of these airports are under pressure to survive and to bring in more revenue without impinging on the community and environment. Many organizations and governmental agencies such as the Federal Aviation Administration (FAA), now recognize the value of sustainable development and importance of operation to airport sustainability. Achieving operational sustainability is a means that may help airports on sustainable development and has positive impacts on airports' economic viability, natural resource conservation, and social responsibility. However, airport operational sustainability is rarely defined in a consistent, measurable manner (Johnson & Gu, 2017).

This study explored the understanding of airport operational sustainability among five GA Regional and Local airports. Based on the findings, a new definition of airport operational sustainability for U.S Regional and Local GA airports was proposed. A set of performance metrics for airport operational sustainability was developed. The outcomes of the study may help airport shareholders contribute to airport sustainability planning through a better understanding of sustainability principles. A set of performance metrics for airport operational sustainability may be used to quantify the sustainability achievements of airports and help airports measure their performance.

CHAPTER 1. INTRODUCTION

While the general public may be familiar with commercial airports such as Chicago O'Hare or Dulles, there are thousands of smaller airports serving communities across the United States. There are 2,564 public General Aviation (GA) airports in the United States and 1,495 of these airports are classified as Regional or Local (FAA, 2016). Many of these airports are under pressure to survive and to bring in more revenue without impinging on the community and environment. Sustainability has become important for airport operators and policy-makers. The U.S. Federal Aviation Administration (FAA) is encouraging U.S. airports to develop comprehensive sustainability planning by providing Airport Improvement Program (AIP) grant funds (FAA, 2017).

The FAA and the Sustainable Aviation Guidance Alliance (SAGA) recommend starting the airport sustainability planning with defining sustainability for airports (FAA, 2012b & SAGA n.d.d). Many airports chose EONS (Economic viability, Operational efficiency, Natural resource conservation, and Social responsibility) as their airport sustainability model or developed their own models based on the EONS model (Martin-Nagle & Klauber, 2015). This EONS model adds operational sustainability to the Triple Bottom Line (TBL). The TBL contains economic, environmental, and social sustainability pillars (Elkington, 1999). The Airports Council International - North America (ACI-NA) considers operational efficiency as one of four pillars in its definition of airport sustainability (ACI-NA, n.d.). The FAA includes operational sustainability in its airport sustainability model (FAA, 2017).

Operational sustainability is a concept that may help airports achieve sustainability and has potential impacts on the other three pillars according to the EONS model. However, airport

operational sustainability is rarely defined in a consistent, measurable manner (Johnson & Gu, 2017). The assessment of operational sustainability is a challenge for airport management. A definition for airport operational sustainability for U.S. GA Regional and Local airports will help airport stakeholders contribute to airport sustainability planning through a better understanding of sustainability principles. A set of performance metrics for airport operational sustainability may be used to measure the sustainability achievements of airports and help airports improve their performance.

1.1 Scope

This study uses the EONS model for airport sustainability. A definition of airport operational sustainability is developed in this study to meet the operational goals, functions, requirements, and regulations for U. S. GA Regional and Local airports. The performance metrics that are identified and developed in this study focus on GA Regional and Local airport operational sustainability.

1.2 Significance

Fundamentally, the contribution and significance of the research is the development of a definition and a set of performance metrics for airport operational sustainability for U.S. GA Regional and Local airports.

While much research exists in the economic, environmental sustainability or holistic sustainability of airports, few studies focus on operational sustainability (Adler, Ülkü,& Yazhemsky 2013, Gu & Johnson, 2018, Johnson & Gu, 2017 & Upham & Mills, 2005). There is not an agreed upon and explicit definition of airport operational sustainability used by airports, aviation organizations, and aviation policy-makers, let alone a way to assess it. The definition

and performance metrics can help airport shareholders understand and assess operational sustainability, and improve operational sustainability.

Compared with large commercial airports that may afford external consultants to develop their sustainability program, the thousands of general aviation airports "lack the expertise and resources, both financial and labor, to develop and implement sustainability programs" (Martin-Nagle & Klauber, 2015, p. 7). The outcomes of this study are intended to: 1) enable GA airports to better understand airport operational sustainability as a part of their planning efforts, 2) be useful in expanding the sustainability perspectives of other airports, and 3) lead to future research on the effectiveness and impacts of airport sustainability efforts.

1.3 Research Questions

The purpose of this study is to develop a definition of airport operational sustainability and associated performance metrics for U.S. Regional and Local GA airports based on the current understanding of airport operational sustainability and existing metrics.

Research Question 1. What are the current understandings of airport operational sustainability among U.S. GA Regional and Local airports and what would be a synthesized definition of airport operational sustainability for U.S. GA Regional and Local airports?

Research Question 2. What are performance metrics for airport operational sustainability among U.S. GA Regional and Local airports?

1.4 Assumptions

There are assumptions inherent to the multiple-case study research designs. The assumptions used in this study are:

- There is a need to define airport operational sustainability and a set of performance metrics for U.S. GA Regional and Local airports.
- There are documents that represent the understandings and performance metrics for airport operational sustainability already used by U.S GA Regional and Local airports.
- The information contained in the airport sustainability documents and other databases used in this study was accurate.
- The method used by the researcher was suitable and correctly applied.
- General aviation airports are considered as small airports.

1.5 Limitations

This research uses case-study research and qualitative analysis. These two research methods have limitations. The limitations for this study are:

- The number of cases in this research was restricted to the total number of U.S. GA Regional and Local airports that have airport sustainability planning as reported on the FAA Airport Sustainability website and available during this study.
- The information in the literature review was limited to the materials that can be found through online access, Purdue libraries, and Purdue Inter-library loans.
- The researcher may have a potential bias in analyzing data and selecting emerging themes due to his experiences at airports.

1.6 Delimitations

The delimitations identified for this research are:

- This study did not investigate why GA airports have the current published understandings of airport operational sustainability and how they assess it.
- This study focused on the five GA Regional and Local airports that have developed and published a sustainability plan.

1.7 Definitions

Airport Sustainability: "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" (ACI-NA, n.d., para.1).

EONS Framework: "A four-component framework of sustainability defined by the Environmental Committee of ACI–NA as consisting of Economic viability, Operational efficiency, Natural resource conservation, and Social responsibility" (Lurie, Humblet, Steuer, & Lemaster, 2014, p. 81).

General Aviation Airports: "Civilian airports that do not serve scheduled passenger service are typically known as general aviation airports. These airports usually serve private aircraft and small aircraft charter operations" (FAA, 2015a, para.1).

Performance Action: "An effort taken to improve sustainability that, when evaluated alongside other Performance Actions, serves as a good indicator of sustainability performance" (Lurie, Humblet, Steuer, & Lemaster, 2014, p. 81).

Performance Metric: "An indicator of performance within a sustainability activity that allows the airport to measure and track performance over time" (Lurie, Humblet, Steuer, & Lemaster, 2014, p. 81).

Sustainability Activity: “High-level undertakings that have a strong potential to improve the sustainability of an airport” (Lurie, Humblet, Steuer, & Lemaster, 2014, p. 82).

1.8 Summary

This chapter introduces the foundation of this research, including scope, significance, problem statement, research questions, and definitions for key terms used in this study. This chapter also presents the assumptions, limitations, and delimitations that providing the direction and constraints for the research.

CHAPTER 2. LITERATURE REVIEW

This chapter starts with an introduction to General Aviation (GA) airports. Then, sustainability and airport sustainability are discussed followed by introducing airport sustainability program planning and assessment. This chapter also introduces the operational sustainability programs at four U.S. large commercial airports and explains previous studies on airport operational sustainability.

2.1 General Aviation Airports

The FAA Modernization and Reform Act (2012) defined a general aviation airport as "a public airport that is located in a State and that, as determined by the Secretary does not have scheduled service or has scheduled service with less than 2,500 passenger boardings each year" (p. 26). In the report of *General Aviation Airports: A National Asset*, the FAA divided U.S. GA airports into four categories in the *National Plan of Integrated Airport Systems* (NPIAS): National, Regional, Local, and Basic GA airport. (FAA, 2012a). NPIAS identifies 3,328 existing and proposed commercial and GA airports as the national aviation infrastructure that are critical to the U.S. national air transportation system (FAA, 2018). Airports in NPIAS are qualified to receive federal funding assistance, such as the FAA's Airport Improvement Program (AIP) grants.

The criteria for each airport category in NPIAS are the number of based airport, the types of the based aircraft, the levels of operations at each airport. In 2014, the FAA revised the categories and added another unclassified category to include the airports cannot be categorized into the four existing categories (FAA, 2014). According to the latest version of NPIAS report,

there are 2,554 GA airports in the United States, and 1,472 of these are GA Regional or Local airports (FAA, 2016). The GA airports categories and associated criteria are shown in Table 1.

Non-airline operators at GA airports spent over $12 billion flew and an estimated 27 million flights in 2009 (FAA, 2012). The operations at GA airport include emergency medical services, aerial firefighting, law enforcement, and border control, agricultural functions, flight training, time-sensitive air cargo services, business travel, and critical community access (FAA, 2012). From 2000 to 2012, approximately 170 airports were closed due to economic or other types of issues, such as increasing construction costs, decreases in available funding, and periodic downturns in the aviation industry; many of these airports are GA airports (Epstein, 2012). The FAA is encouraging U.S. airports to develop sustainability planning to help them sustain operations (FAA, 2017b).

Table 1. NPIAS General aviation airport categories

Airport Category	Criteria		Number of Airports
	Based Aircraft	Level of Activity	
National	"Averaging about 200 total based aircraft, including 30 jets" (p. 3)	Very High	22
Regional	"Averaging about 90 total based aircraft, including three jets" (p. 3)	High	296
Local	"Averaging about 33 based propeller-driven aircraft and no jets" (p. 3)	Moderate	1,176
Basic	"Averaging about ten propeller-driven aircraft and no jets" (p. 3)	Moderate - Low	840
Unclassified			220

Note. The airport categories and their criteria are from the FAA (2012a). The numbers of airports are from FAA (2018).

2.2 Sustainability

Sustainability has various definitions. The Brundtland Commission report provided commonly accepted definition of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their needs" (World Commission on Environment and Development, 1987, p. 8). Since the concept of sustainable development was presented in 1987, it has been introduced in many industrial sectors, one of which is aviation. These diverse sectors integrate sustainability into their operations through the combined consideration of environmental protection, community needs, and economic vitality for both current and future generations. These three concepts are linked, as the natural and physical systems of the earth (e.g., clean air and water, and a stable climate) provide the critical support for healthy, functioning social systems (e.g., sanitation, energy systems, and safe transportation networks), which in turn enable our economic systems to be productive and thrive. In the context of businesses such as airports, sustainability means not only looking at the traditional economic bottom line, but what is known as the triple bottom line: people, planet, and profit (Elkington, 1999).

Since 1987, the role of business entities in the promotion of sustainability and sustainable development changed dramatically. The *King Report on Governance* (2009) states that "sustainability is the primary moral and economic imperative of the 21st century" (p. 8). The Governance & Accountability Institute (G&A Institute) published a finding that 82% of the S&P 500 Companies released their Corporate Sustainability Reports (CSR). The number of S&P 500 Companies that had CSRs increased by 62% from 2011 to 2016 (G&A Institute, 2017).

Sustainability requires the creation and maintenance of a productive harmony between social, economic, and environmental requirements. In 1999, Elkington published *Cannibals with Forks: The triple bottom line of 21st Century Business*. This book introduced the Triple Bottom

Line (TBL) as an accounting model used to explain the relationship between the three pillars, environmental, social and economic, of sustainability (Elkington, 1999). Elkington (1999) urged corporations to make efforts on sustainable business strategy to achieve a sustainable corporation.

2.3 Airport Sustainability

Airports Council International - North America (ACI-NA) broadened the definition of airport sustainability by expanding the concept of the triple bottom line a as "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" (ACI-NA, n.d., para.1). The inclusion of operational efficiency addresses operational aspects of airport business including:

- "Operating Costs (Airport Infrastructure, IT, Fleet Management, etc.)
- Maintenance Costs
- Component Renewal Costs
- Life-cycle Costs (e.g., debt service, component renewal, and O&M)
- Ability to holistically trade-off priorities in life-cycle" (ACI-NA, n.d., para. 5).

ACI-NA explained that including operational aspects is essential for managing airport because all airports have "opportunities within the construct of their business model to leverage their O&M (operations and maintenance) dollars in ways that promote sustainability" (ACI-NA, n.d., para. 6).

The FAA considered airport sustainability as the sustainable actions that "reduce environmental impacts, help maintain high, stable levels of economic growth, and 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" (FAA, 2017b, para. 1). The FAA created an airport sustainability model that includes operations in addition to economy, environment, and community.

In 2008, a board of volunteers with aviation interests united together and formed the Sustainable Aviation Guidance Alliance (SAGA). This group supports airport operators, to plan, implement, and maintain their sustainability programs (SAGA, n.d.a). SAGA states that "every sustainability effort is unique and, often, organizations will adopt varying definitions of what sustainability means to them" (SAGA n.d.b, para. 2). Most definitions of sustainability are based on the Triple Bottom Line (SAGA n.d.b). In the airport industry, the EONS approach is also a commonly used sustainability model (SAGA, n.d.b). SAGA identifies the targeted topics of each pillar of the TBL and EONS, as shown in Table 2. TBL and EONS have the same targeted topics in economic, environmental and social pillars, while EONS has additional topics in the operational pillar.

Economic viability is the fundamental requirement for achieving the holistic sustainability of airports. Martin-Nagle & Klauber (2015) identifed that the lack of financial resources is the most common barrier for airports to implement their sustainability program. Airports can enhance economic viability by increasing revenue generation, decreasing costs, and investing long-term projects with "a return on capital expenditure" (Martin-Nagle & Klauber, 2015, p. 18).

Table 2. Targeted topics in each pillar of the TBL and EONS

	Triple Bottom Line	EONS
Economic	Job creation Local purchasing Advancing new markets Increasing GDP Total cost of ownership Initial costs Life cycle costs Staff training Revenue generation FAA funding eligibility	As same as the TBL's
Environmental	Air quality and climate change Water quality and conservation Wildlife hazards and management Landscape and vegetation management Solid waste and recycling Hazardous materials and chemical management Natural resources conservation	As same as the TBL's
Social	Land use compatibility Community benefits Quality of life Employee welfare Diversity and environmental justice Education public outreach Public relations Innovation and industry leadership Transparency and information sharing Regional economic benefits Noise abatement	As same as the TBL's
Operational		Roadway congestion Intermodal transportation access Air travel delay customer service APU's, gates, GSE equipment efficiency Energy conservation

Note. The targeted topics are from SAGA (n.d. b.).

The FAA stated that the aims of operational efficiency is to efficiently use ‘existing resources and facilities” and to “minimizes waste” (FAA, 2012c, p. 4). However, there is not an explicit explanation of operational efficiency and an agreed upon set of metrics. In airport sustainability plans, airports create goals and initiatives to achieve operational efficiency. Martin-Nagle and Klauber (2015) pointed out that the measurement of airport operational sustainability should integrate with “a wide variety of related operations,” an included both airside and facility operations (p. 20). Also, Martin-Nagle and Klauber (2015) found that operational sustainability activities may relate to energy saving and climate resiliency.

The natural resource conservation is another pillar of the EONS model of airport sustainability. Martin-Nagle and Klauber (2015) identified the subject areas that are related to natural resource conservation are widely implemented in airport sustainability programs. The strategies that typically retated to this pillar are air quality enhancement, energy saving, noise abatement, water quality protection, and waste reduction, renewable energy, many other environmental protecting strategies.

Airports may have a broad social responsibility that not only provides safely and efficiently facilitates for the movement of passengers and cargos, but also supports local and regional economy by providing jobs and making purchases that promote local businesses (Martin-Nagle & Klauber, 2015). Martin-Nagle and Klauber (2015) regarded airports as "forums in which employees, tenants, aircraft owners, operators, passengers, service providers, and others can interact socially" because airports gather people for pleasure and commerce (p. 24).

Airport Cooperative Research Program (ACRP) is an “industry-driven, applied research program that develops practical solutions to problems faced by airport operators” (FAA, 2017a, 2017, para.1). ACRP is a program of Transportation Research Board (TRB) of the National

Academies of Sciences, Engineering, and Medicine and is sponsored by the FAA to address the airport issues that other Federal research programs do not. This program funds more than 20 projects every year and has created “more than 400 practical resources and tools for airport practitioners” (FAA, 2017a, 2017, para.1) Many of these projects are focusing on airports sustainability.

The ACRP Project A11-03 explored the drivers, aids, and barriers to sustainability programs at U.S. commercial hub airports (Berry, Gillhespy & Rogers, 2008). The top 5 drivers identified in this study for implementing sustainability practices are “state/regional regulations airport policy, federal regulations, corporate responsibility, and stakeholder concerns/relations” (Berry, Gillhespy & Rogers, 2008, p. 9). A similar study explored the drivers that motivating small commercial and GA airports to implement sustainability practices shows that “cost reductions, desire for improved sustainability performance, compliance concerns, and addressing global concerns” are most common drivers for small airports (Prather, 2016, p. 2).

2.4 Airport Sustainability Planning

At the beginning of the planning process, both the FAA and SAGA suggest that every airport develop a definition of airport sustainabilitly based on a sustainability model, such as the Triple Bottom Line and EONS (FAA, 2012b & SAGA n.d.d). Also, identifying stakeholders allows airports to “gain buy-in, identify potential practices, obtain guidance and lessons-learned, and make the stakeholders involve in related activities” (SAGA, .n.d.d., para. 5). This strategy helps airports to recognize what and how the stakeholders contribute to their sustainability programs. The FAA has a set of requirements for the contents of the sustainable master plan or sustainability management plan for the airports which participated airport sustainability planning pilot program (FAA, 2010):

1. The airports should write a sustainability policy or mission statement of the airport, define the roles of airports, and describe how it related to “the airport employees, tenants, and the community” (FAA, 2010, p. 3).
2. The airports should “define sustainability categories at the airport” (FAA, 2010, p. 3). FAA (2012b) lists the ten most common categories that are used by airports, which are “energy reduction, planned development, construction methods, waste management and recycling, water quality and conservation, air quality, emissions reduction, airport connectivity, land use, and natural resources management” (p. 5).
3. The airports should analyze the baseline inventory and assess each defined sustainability category.
4. The airports should define the measurable goals that they want to achieve for sustainability categories. Those goals help the airports to measure how successful are the programs contribute to reducing environmental impact.
5. The airports should identify a group of sustainability initiatives (also called activities or practices) that can help airport achieve the sustainability goals.
6. At last, the airports should have a plan to encourage the public and their communities to participate in the program (FAA, 2010).

SAGA (n.d.d) included steps of a process for planning a sustainability program and describes a procedure for refining the sustainability goals during the implementation. The process starts with assessing the conditions of the sustainability program to define the new gaps in sustainability. According to assessment, airports can update the sustainability categories, goals, and relevant key performance indicators (KPIs). Then, airports can select and implement new initiatives or existing initiatives that can achieve new goals. For monitoring the progress,

airports should determine the streamline resources, roles, and responsibilities for each initiative and include them into a plan (SAGA, n.d.d). SAGA (n.d.d) argues that the process should be an endless cycle and identifies effective communication, stakeholder involvement, and continuous improvement as the three critical factors for planning sustainability programs.

Many tangible and intangible benefits can be obtained from airport sustainability planning, such as reducing energy consumption, reducing carbon footprint, improving water quality, improving community relations, and saving operational expenses.

In 2009, the FAA initiated an Airport Sustainable Master Plan Pilot Program. The primary purpose of the pilot program is to accumulate experience and knowledge that can demonstrate how to achieve "an airport's forecasted demand while achieving aviation standards, and reducing an airport's environmental impact" (FAA, 2010, p. 1). The pilot program may also provide helpful information to the FAA and to airports in developing program guidance to meet the growing interest of airports. The Airport Planning and Environmental Division (APP-400) asked all regions in the United States to provide the FAA with recommendations of airports that are interested in sustainabbility planning (FAA, 2010).

Interested airports could investigate sustainable initiatives specific to their airport and plan their sustainability documents in one of two ways:

1. Sustainable Master Plan that applies to "an airport sponsor who is about to prepare or update its Master Plan and who has the desire to include sustainability in its proposed development" (FAA,2010, p. 2). In this type of document, sustainable initiatives are addressed as a new chapter within the Master Plan.

2. A stand-alone Sustainable Management Plan that is appropriate to "an airport sponsor who is not updating its Master Plan, but who is interested in looking at sustainability at its airport" (FAA, 2010, p. 2).

For choosing which plan to prepare, FAA (2012b) recommended that airports develop a sustainable master plan. When preparing sustainable master plans, airports can integrate the concepts of sustainability into the process of planning and may discover more opportunities to improve airport sustainability. A sustainable master plan, however, is more challenging than a sustainable management plan, since airports should balance the sustainability objectives and the aviation needs. This requirement limits the attention that airports can devote to sustainability. Therefore, a stand-alone sustainable management plan may be used in the early stage of airport sustainability planning as the airport matures toward a sustainable master plan (FAA, 2012b). For the airports which decide to prepare a sustainable master plan, the FAA (2012b) suggested that airports to "intersperse sustainability throughout the document" (p. 2) instead of a single chapter of sustainability.

According to FAA (2012b) preparing a sustainable plan starts with a reasonable schedule and timeline. SAGA (n.d.d) suggested airports analyze the needs for their sustainability program and define the "specific action items, personnel, key meetings, and an overall schedule" (para. 3). FAA (2012b) developed guidance of recommended timelines for each type of airports. FAA (2012b) advised GA airports to complete their plan in 12 months, reliever airports in 12 months, non-hub primary airport in 12-18 months, hub airports to finish the planning process in 18-24 months. The FAA does not recommend that an airport to create plan too quickly because the FAA reviewers found that the rapidly developed plan, in one case, was not robust and was not reviewed insufficiently.

The Colorado Department of Transportation Division (CDOT) of Aeronautics established a Colorado Airport Sustainability Program to provide tools and guidance for general aviation airports in Colorado to develop their airport sustainability plans (CDOT, 2016). This program intends to assist Colorado GA airports in remaining viable now and in the future by improving economic, social, operational, and environmental sustainability. The Fremont County Airport and Rifle Garfield County Airport voluntarily participated in this program as case studies to show how airports with different available resources can benefit from sustainability (CDOT, 2016).

CDOT adopts a "broad and adaptable" definition of sustainability for the general aviation airports in Colorado:

> "Sustainability is to maintain and enhance the long-term viability of Colorado's general aviation airports in a way that properly balances economic, social, and environmental pressures while still meeting the operational needs of an airport" (CDOT, 2016, p. 3)

Each airport may define airport sustainability differently because different airports may have different needs and unique operational environments (CDOT, 2016). In its promotional flyer of the Colorado Airport Sustainability Program, CDOT addresses the potential benefits for incorporating sustainability for an airport, as shown in Table 3.

In the GA Airport Sustainability Kit, CDOT created three focus categories within the operational element which are Operations and Maintenance, Asset Management, and Business Operations. In the user's manual of the Tool Kit, CDOT described the broad goals for these focus categories, as shown in Table 4.

Table 3. Potential benefits for incorporating sustainability for airport

Element	Potential Benefit
Economic	"Adapt to a changing financial environment by creating initiatives to identify new revenue sources and cut costs" (p. 2).
Operational	"Improve your airport's effectiveness and performance by maximizing efficiency in maintenance and operations" (p. 2).
Natural Resources	"Manage your airport's environmental stewardship and impact on natural resources" (p. 2).
Social	"Demonstrate your value to airport users and enhance relationships with your community" (p. 2).

Note. The potential benefits are from CDOT (n.d.)

Table 4. Sustainability focus categories within operational efficiency and associated goals

Category	Goal
Operations and Maintenance	"Sustainable operation and maintenance of airport facilities and infrastructure support long-term growth and resiliency" (p. 14).
Asset Management	"Sustainable construction and investment in land, capital, and human resources contribute to a thriving airport and community" (p. 14).
Business Operations	"Incorporating sustainability principles within the operations of an airport maximizes efficiency and allows for multiple elements to be factored into decision-making" (p. 14).

Note. The goals for the focus categories are from CDOT (2016).

The Virginia Department of Aviation (DOAV) developed a statewide sustainability management plan (SMP) for the 66 public-use airports in Virginia (DOAV, 2016a). This statewide sustainability management plan contains a statewide framework and three SMP supplements for each of the three airport categories the defined by the DOVA. The three airport categories are:

- Commercial Service airports "conduct regularly scheduled commercial flights and typically employ 30–200 or more individuals" (DOAV, 2016a, p. 5).

- Reliever and GA Regional airports "are typically without scheduled airline service and generally have fewer than 10 full-time employees" (DOAV, 2016a, p. 5).
- GA Community and Local Service airports that "provide access to rural communities and areas in the Commonwealth not served by larger airports, and typically employ between zero and three full-time staff" (DOAV, 2016a, p. 5).

The three categories of airports are using one overall definition of airport sustainability, which is "a strategic approach to airport planning, development, asset management, and resource protection – including financial, environmental, community-relations, and other factors – that prioritizes current operational needs while best preparing Virginia's airports for continued success in the future" (DOAV, 2016c, p. 27). The SMP framework presents the overall sustainable mission for airports in Virginia and identifies sustainable focuses and associated sub-areas. The SMP supplements provide user-friendly and practical resources for each of the three airport categories (DOAV, 2016c).

2.5 Assessment of Airport Sustainability

FAA (2012b) used the sequencing baseline assessment as the method to evaluate airport sustainability. This assessment method requires airports to first set a baseline year and collect the relevant data in that year. Airports identify baselines for different objectives, based on the existing data or the baselines of benchmarking airports. The appropriate performance indicators/metrics are determined to measure and track performance over time. Based on this requirement, multiple performance indicators may be selected to track progress for the same goal. As mentioned in the FAA requirements for the contents of sustainable plans, airports should conduct baseline assessments before developing their sustainability goals. This strategy will help airports "set realistic and accurate targets" (FAA, 2012b, p. 6).

For collecting appropriate data, FAA (2012b) recommended that airports have a collection leader, such as an expert, to "coordinate inflow and maintain common data" (p. 6). This approach can minimize the duplicated data and reduce the confusion about what data have been collected (FAA, 2012b). Also, a standardized list of data needs and checklists will contribute to the data collection process.

Measuring sustainability requires quantifying the performance of airports. Appropriate KPIs and associated metrics can aid the process (FAA, 2012b). SAGA (n.d.c) mentioned that sometimes suitable KPIs and metrics have been used by airports. In these cases, it is easy to use and modify the existing KPIs and metrics for quantifying achievements of airport sustainability. For instance, airports are normally tracking their electricity usage which can be used as the KPI for assessing energy reduction (SAGA, n.d.c).

SAGA (n.d.c) listd the sources of commonly-used KPIs and metrics, including ACRP Report 119, Global Reporting Initiative (GRI) Reporting Guidelines, GRI Airport Sector Supplement, International Organization for Standardization (ISO) 26000: 2010 Guidance on Social Responsibility, Envision™ Infrastructure Sustainability Rating System, Leadership in Energy & Environmental Design (LEED)™, Carbon Disclosure Project (CDP), and Global 100.

ACI (2012) presentd airport performance indicators and metrics for airport operation, such as environment, safety, and service quality. Airports can search these sources and select KPIs and associated metrics that are sensible for their sustainability goals.

After identifying the KPIs and metrics for sustainability goals, airports should have a plan and tools to monitor the progress of programs (SAGA, n.d.c). According to SAGA (n.d.c), the monitoring plans should identify "the people who are accountable for implementation and monitoring, the schedule, the milestones, and the resource need" (para. 5). The Colorado

Department of Transportation (CDOT) Division of Aeronautics developed an airport sustainability tool kit to help the GA airports in Colorado to develop and implement sustainability plan, and track and report the progress of plans (CDOT, 2016). The Virginia Department of Aviation (DOAV) developed a Utility Performance Tracker Tool (DOAV, 2016).

Airport Sustainability Rating and Report Systems.

ACRP Report 119. The ACRP Report 119 is the summary of the ACRP Project 02-28. The report presented a prototype airport sustainability rating system (Lurie et al., 2014). Lurie et al. (2014) identified eight different categories that have strong potential impacts on airport sustainability, and divides fifty existing sustainability activities into these eight sustainability categories. Airports can evaluate achievement of each sustainability activity, based on the levels of performance within this activity and give a score from one to four. The sum of the points earned in each sustainability category can be compared to the possible total points of the categories. Based on this mechanism, airport sustainability performance is evaluated (Lurie et al., 2014).

GRI Standards and airport operators sector disclosures. GRI is an international independent standards organization dedicated to helping "businesses, governments, and other organizations understand and communicate the impact of business on critical sustainability issues" (GRI, n.d., para. 1). GRI developed a set of the reporting standards and guidelines to help businesses in different industries report their sustainability performance in economic, environmental, and social aspects. Per GRI, among 250 largest global corporations, 92% report their sustainability performance, and 74% of these corporations use GRI Standards (GRI, n.d.). Currently, the GRI's reporting guidelines are GRI Standards, which are used to supersede G4 Guidelines, the old version of reporting guidelines of GRI. However, the G4 Sector Disclosures

that provide specific guidance for sustainability reporting for certain sectors are still using the supplements of the GRI Standards (GRI, n.d.). The Airport industry is one of the sectors that has its sector disclosure. In addition to the general standard disclosures applicable to every industry, the G4 Airport Operators Sector Disclosures contain many specific standard disclosures for airport operators and divides these disclosures into economic, environmental, and social categories (GRI, 2014). The operational aspects of sustainability are not found in this document. The disclosures that are specific for airport operators are:

- "Inter-modality – Environmental
- Noise – Environmental
- Business Continuity and Emergency Preparedness – Social
- Service Quality – Social
- Provision of Services or Facilities for Persons with Special Needs – Social" (GRI, 2014, p.11).

2.6 Operational Sustainability Program at U.S. Large Commercial Airports

Since the program was initiated in 2009, the FAA Airport Sustainable Master Plan Pilot Program has funded more than 40 U.S. airports to develop their sustainability plans (FAA, 2017b). Among the participants, there are 12 large hub commercial airports. Ten of those large hub airports' sustainability documents can be accessed online. Among those ten large hub airports, six airports adopted EONS as their sustainability model, or developed their models based on the principle of EONS. Thus, the sustainability program of these airports has contents related to operational sustainability. These airports are Dallas-Fort Worth International Airport (DFW), Honolulu International Airport (HNL), Salt Lake City International Airport (SCL), Newark Liberty International Airport (EWR), Denver International Airport (DEN), and Boston

Logan International Airport (BOS). The airports are located in four different FAA Airports Regional and District Offices. The sustainability programs of DFW, EWR, HNL, and SCL airports are discussed in this literature review.

Dallas/Fort Worth International Airport. DFW has focused on enhancing its sustainability at the airport for over a decade (DFW, 2014). During this period, DFW had published diverse types of sustainability documents that describe the progress and situations of sustainability at the airport. The publications contain an airport sustainability management plan and several sustainability reports issued in different years. In the early stage of DFW's sustainability program, they identified the Triple Bottom Line to be their sustainability model as stated in their 2012 airport sustainability report (DFW, 2012). In the 2014 airport sustainability management plan, the airport included operational efficiency into its goals for airport sustainability for the first time. DFW created this management plan as a participant of the FAA's Airport Sustainable Master Plan Pilot Program (DFW, 2014). DFW then identified its four pillars of sustainability: cost competitiveness, customer satisfaction, operational excellence, and employee engagement. The management plan, however, did not explain their definition of operational excellence.

DFW identified eleven focus areas and associated goals based on "the best practices in the aviation industry", as well as and DFW's sustainability activities and analysis of the airport's "commitments, industry standards, and leading trends in sustainability and social responsibility" (DFW, 2014, p. 35). Two of these focus areas are procurement and sustainable infrastructure and resiliency under the pillar of operational excellence (DFW, 2014). DFW selected key performance indicators (KPIs) and metrics to track and measure progress of these sustainability goals. DFW used the results of baseline assessment of the sustainability program, KPIs, and

metrics, as the foundation, for setting reasonable targets and selecting sustainable practices for its short, medium, and long-term planning. Table 5 shows the DFW's sustainability goals and their associated KPIs, metrics, and targets for the focus area of procurement.

DFW listed four ongoing sustainable practices toward achieving the goals of procurement and sustainable infrastructure and resiliency. These practices are "green procurement team, identification of warehouse products with sustainability attributes, an educational module for green procurement, and green building standards" (DFW, 2014, pp.45-48). DFW divided these practices into several sub-practices throughout the three stages of implementation (DFW, 2014).

Table 5. DFW's sustainability focus area of procurement

Procurement: "Enhance DFW's green procurement program and evaluate the supply chain for opportunities to reduce environmental, social and economic impacts" (p. 44).			
Goal	KPI	Metric(s)	Target
"Measure the sustainable materials and services procured to minimize upstream and downstream impacts" (p. 43).	"Value of materials purchased that have sustainability attributes" (p. 43).	"% of products purchased with sustainability attributes (based on dollar value)" (p. 43).	"Identification of sustainability attributes and measurement of the baseline by 2016" (p. 43).
	"Number of new suppliers screened using sustainability criteria" (p. 43).	"% of suppliers screened for sustainability criteria % of suppliers that meet sustainability criteria" (p. 43).	"Identification of sustainability attributes and measurement of the baseline by 2016" (p. 43).
"Measure the purchase of goods and services from North Central Texas" (p. 44).	"Proportion of spending on North Central Texas-based suppliers" (p. 44).	"% of product purchases made locally (based on dollar value)" (p. 44).	"Definition of 'local products' and measurement of the baseline by 2016" (p. 44).
		"of service contract awards to local companies (based on dollar value)" (p. 44).	"Definition of 'local services' and measurement of the baseline by 2016" (p. 44).

Note. The sustainability goals and associated KPIs, metrics, and targets are from DFW (2014).

In the 2016-2020 Airport Strategic Plan, the DFW defined operational excellence as "planning for the Airports' future infrastructure needs, and implementing those plans in an environmentally sustainable way within budget and on schedule" and finally "continuously improving" the "processes to drive better business performance, enhance the customer experience, and make the airport more safe and secure" (DFW, 2016, p. 18). DFW (2016) discussed operational excellence with a holistic viewpoint rather than emphasizing a few focus areas. Green procurement and sustainable infrastructure and resiliency are not mentioned in this airport strategic plan. Instead, DFW stated that their new strategic objectives would focus on improving airport airside performance, applying innovative technologies and practices to measure and forecast enterprise operational efficiencies, developing and implementing a "ten-year Capital Improvement Program," and incorporating sustainability (DFW, 2016, p. 19).

Newark-Liberty International Airport. EWR is a large critical hub for the New York / New Jersey metropolitan area which is operated by the Port Authority of New York and New Jersey (EWR, 2012). The Port Authority is dedicated to "integrating sustainability principles and practices into the Airport's long-term business strategy and day-to-day operations" (EWR, 2012, p. 4). The Port Authority has developed a sustainable building guideline for green building and infrastructure and implemented many sustainability practices at EWR (EWR, 2012).

In 2010, EWR was selected as one of the ten initial participants of the FAA's Sustainable Master Plan Pilot Program. Based on the sustainability projects at EWR, the Port Authority developed EWR's sustainable management plan with the help of airlines, concessionaires, and the airport's tenants. EWR defined its sustainability vision and principles based on the two sustainability approaches, TBL and EONS. One of these principles about operational efficiency shows that the airport wants to "improve operational efficiency of the airport and airspace by

working with the airlines and Federal Aviation Administration to reduce aircraft delay and associated environmental impacts, by implementing infrastructure improvements and technologies to support airport, aircraft, and airspace operational enhancement" (EWR, 2012, p. 4). In the EWR Sustainable Management Plan 2012, nine focus areas of EWR's sustainability program are addressed: "operational efficiency, climate change adaptation, water management, air quality and greenhouse gases, solid waste management and recycling, ground transportation, community outreach, contract and lease management, and health and welfare of employees" (EWR, 2012, p. 7). Only one focus area that highly complies with the definition of EWR's operational efficiency. The goals of the focus area of operational efficiency are to "incorporate sustainability principles into the long-term business strategy and day-to-day operations, building on existing systems and standard operating procedures" (EWR, 2012, p. 7). The targets and initiatives that underlie the focus area of Operational efficiency are shown in Table 6.

Table 6. EWR's initiatives

Initiative	Target
• "Implement full airside ground management program" (p. 8). • "Modify approaches using ground-Based Augmentation System (gBAS) and Required Navigation performance (RNp)" (p. 8). • "Support additional Nextgen activities while advocating that new procedures support environmental goals of organization" (p. 8).	"Implement full airside ground management program" (p. 8).
• "Establish more extensive teleconference/Webex/shared documents systems for intra- and inter-facility communication" (p. 8). • "Establish default double-sided printing procedures" (p. 8). • "Investigate potential to streamline data logging, to report and to inspect" (p. 8). • "Develop paperless systems for day-to-day port Authority processes" (p. 8).	"Reduce airport paper purchases by 5% by 2015" (p. 8).

Note. The EWR's initiatives and associated targets are from EWR (2012).

The metrics that are used to measure the performance of operational efficiency are "average taxi-out times" and "paper purchased" (EWR, 2012, p. 45). The cost of the EWR sustainability program is not discussed by EWR.

Honolulu International Airport. As the international gateway for the Pacific Region Honolulu International Airport (HNL) has expressed their goal to be a world leader in airport sustainability and to "instill a sense of pride among customers, employees, industry, and the community." (HNL, 2016 b, p. 1). The Hawaii Department of Transportation—Airport's Division has a sustainableDOT-A's (sDOT-A) airport system sustainability program. The SustainableHNL (sHNL) is the first initiative and a pilot test for the sDOT-A program (HNL, 2016).

In 2014, the FAA's Airport Sustainable Master Plan Pilot Program funded the Hawaii DOT-A to help the HNL airport incorporate sustainability into the airport planning. According to HNL, the Hawaii DOT-A spent about $600,000 to create the HNL sustainability management plan (HNL, 2016 a). As a required outcome of this program, a stand-alone HNL sustainability management plan (SMP) is developed by HNL (HNL, 2016 b). HNL's SMP was created based on the EONS framework and defined HNL's airport sustainability as "leveraging design, construction, operations, and maintenance dollars through proven business practices that pay benefits to the customers, employees, industry, and community" (HNL, 2016 b, p. 5).

Before developing the SMP, the Hawaii DOT-A performed a successful measurement on HNL's sustainability and identified opportunities for improving the airport's sustainable performance. Therefore, DOT-A received grants from the FAA and designed a management plan to guide the sustainable program for HNL (HNL, 2016). HNL identified thirteen focus areas and ranked them in order of importance: "energy, carbon, water, waste, stormwater, financial

sustainability, day-to-day operations, design and construction, ground transportation, climate resiliency, community, food and beverage, sociocultural" (HNL, 2016, p. 8). The focus areas of energy, carbon, water, waste, stormwater are the top 5 strategic priorities identified by the airport (HNL, 2016). HNL, however, did not align these focus areas to the pillars of EONS model. By analyzing the description, goal statement, and objectives of each focus area, five focus areas are determined to be related to operational efficiency (sustainability). The selected focus areas are listed in Table 7.

Table 7. HNL's focus areas that related to operational efficiency

Focus Areas	Goal Statements	OBJECTIVES
Energy: Electricity consumption and cost	"Maximize efficiency and increase renewable energy" (p. 4)	• "Reduce energy consumption through efficiency. • Harness renewable energy resources." (p. 4)
Day-to-Day Operations: Sustainable operation requires airport spaces that are operated based on best practices	"Incorporate sustainable principles and practices into airport governance" (p. 4)	• "Measure the purchase of goods and services from locally owned businesses. • Reduce overall life cycle cost for capital investments. • Provide commitment around sustainability implementation." (p. 4)
Design and Construction: Airport spaces based on integrated sustainability approaches	"Incorporate sustainability planning, design, and construction best practices into airport projects." (p. 4)	• "Meet 3rd party certification and achieve certification where possible for airport projects. • Incorporate the Sustainable high-performance guidelines for projects." (p. 4)
Ground Transportation: Promotes alternative transportation for passenger & employee travel	"Provide public transportation infrastructure to achieve district-wide sustainability." (p. 4)	• "Plan for future ways to reduce congestion on the roadways by supporting public transportation. • Embrace hybrid and electric vehicle infrastructure for DOT-A, tenant and public vehicles." (p. 4)

Note. The focus areas and their associated goals, and objectives are from HNL (2016).

HNL summarized its lessons learned when developing and implementing the airport sustainability program. According to HNL's experience, they choose 4 to 5 focus areas that focused on the internal operation to start. When communicating with stakeholders, HNL believes that using their language would enhance understanding, so keeping data in one place with SMP tools would be helpful for tracking the process of the program. In addition, implementing initiatives requires a long time to plan (HNL, 2016a).

Salt Lake City International Airport. Salt Lake City has a long-lasting commitment to sustainability. Salt Lake City established a city sustainability program called Salt Lake City Green (SLCgreen) which is a compilation of the city's environmental programs and policies designed for achieving "conservation of resources, reduction of pollution, and deceleration of climate change to ensure a healthy and sustainable future for Salt Lake City" (SLC, 2015, p. 119). As a key component of SLCgreen, Sustainable Salt Lake—Plan 2015 is developed. The Salt Lake City Department of Airports (SLCDA) received a grant from the FAA's Airport Sustainable Master Plan Pilot Program and created an Airport Sustainability Management Plan that leads current governance and operations at SLC. This SMP used the concept of Triple Bottom Line and EONS as the framework for its baseline assessment and sets the airport's sustainability categories (equivalent to focus areas mentioned at DFW and HNL section), objectives, and performance targets. SLC states SLC's primary sustainability goal is to be "a leader in the community and airport industry by preserving and enhancing Salt Lake City Department of Airport's financial, human, natural, and energy resources" (SLC, 2015, p. 119).

To demonstrate the consistency among goals between the airport and the city, SLCDA adopted five appropriate categories from the Sustainable Salt Lake—Plan 2015 and adds an additional category according to its operating environment. These categories identified by SLC

are: “Air Quality and Climate Change, Water Resources, Energy, Recycling and Materials Management Community Health and Safety, and Planning and Building” (SLC, 2015, p. 123). SLC (2015) did not mention the relationship between the categories and EONS model. Energy and Planning and Building are identified to underline the operational efficiency according to the SAGA standards. The Sustainability category of Energy and its associated goals, objectives, metrics, and performance targets are shown in Table 8.

Table 8. SLC’s sustainability category of energy

Goal: “Reduce the total energy use and demand of the airport and increase renewable energy generation on airport property” (p. 124).		
Objective	Metrics	Targets
“Complete energy efficiency projects to reduce energy use in airport facilities” (p. 124).	• “Total energy use (MMBTu/year) • Total Electricity use per passenger • Total Electricity demand per passenger • Total Natural gas use per passenger • Total energy use by cost center • Utility Costs (Electricity and Natural Gas)” (p. 124).	“Decrease energy use in buildings and operations by 10% over a rolling 10-year average (2020 reduction from 2000-2010 average, then 2030 reduction from 2010-2020 average)” (p. 124).
	• “Rate of energy use in De-icing Fluid Reclamation Facility” (p. 124).	“Decrease rate of energy use in Deicing Fluid Reclamation Facility by 5% in five years” (p. 124).
“Increase renewable energy generation on airport property” (p. 124).	• “Renewable energy generated on property” (p. 124). • “Percent of total electricity purchased from renewable sources” (p. 124).	
“Leverage people (energy users) to promote energy efficiency” (p. 124).	NA	“Develop, incorporate, and distribute a comprehensive employee education and engagement program for energy conservation on a quarterly basis.” (p. 124).
	NA	“Develop passenger education information through Wi-Fi dashboard or lobby dashboards” (p. 124).

Note. The sustainability category, goals, objectives, metrics, and performance targets are from SLC (2015).

SLC (2015) identified sustainability initiatives toward achieving the goals of each sustainability category. The identification process has three levels. SLC first determines the feasibility of initiatives based on regulatory obstacles to implementation, compatibility of relevant categories, and challenges for implementation (SLC, 2015). SLC next conducted cost/effect analysis to identify the initiatives that require low cost, have great quick effects. In the final level, SLC defined the sequence of implementation of selected initiatives according to the scores determined during the first levels (SLC, 2015). The identified initiatives for sustainability categories are shown in Table 9. Nevertheless, the associated costs of initiatives are not mentioned in any documents published by the SLCDA online.

Table 9. SLC sustainable initiatives of energy and planning and building

Energy • "Incorporate any new air handler systems into the Building Automation System (BAS) • Implement monitoring-based commissioning software in the BAS control scheme to monitor airport equipment and systems in near-real time. • Continually evaluate maintenance schedules to ensure peak efficiency • Continue to upgrade to high efficiency light fixtures (i.e., light-emitting diode (LED) • Utilize direct/indirect evaporative cooling from HVAC • Continue to convert to LED airfield lighting • Improve efficiency of deicing fluid reclamation plant process flow" (p.152).
Planning and Building • "Design spaces to appropriate sizes to avoid increasing building footprint and initial resource use and energy and maintenance burden • Encourage use of local materials airport-wide" (p.152).

Note. The sustainable initiatives are from SLC (2015).

2.7 Previous Research on Airport Operational Sustainability

Janic (2010) considered operational performance a dimension of airport sustainablitly. Janic (2010) divided the indicators of airport operational performance into categories of demand, capacity, quality of service, and integrated intermodal service. Assessment metrics for the demand indicator, which reflects the scale of the airport operations, sush as the number of air transport movements (atm), the number of passengers, and the volume of freight shipments. The capability of an airport operation “accommodated to a certain volume of demand under given conditions” (Janic, 2010, p. 219). Two metrics can be used for assessing the airside and landside capacity of airports. The metrics for measuring airside capacity is the maximum number of atm, while the ‘maximum number of WLUs assesses the landside capacity accommodated over a given period” (Janic, 2010, p. 219). The assessment metric for measuring the quality of service should reflect the relationship between airport demand and capacity. For example, while the airport demand exceeds the capacity, the delay happens. Therefore, the average delay per atm or WLU is selected as the metric for the indicator of the quality of service. The integrated intermodal service indicator is designed for the airports to provide the connection between regional, national and international transport networks. These airports may improve their capacity by replacing some the short-haul flights with long-haul flights or other types of transportation, such as high-speed trains. Therefore, the metric for measuring the integrated intermodal service indicator is the ratio between the number of substituted flights or other types of transportation and the total number of viable substitution of short-haul flights in a given period (Janic, 2010).

A set of operational and environmental indicators and associated metrics was developed in Upham and Mills (2005). These indicators include "number of surface access vehicles, aircraft movements, static power consumption, gaseous pollutant emission, aircraft noise emissions,

terminal passengers, surface access passengers, water consumption and wastewater emission, solid waste, and land take and biodiversity" (Upham & Mills, 2005, pp. 174-175). These indicators were selected to inform the airport operators of what they need to know when they make decisions and enable better understanding on the interrelationship between airport environmental and operational indicators (Upham & Mills, 2005).

Johnson and Gu (2017) combined and harmonized the different viewpoints of airports, aviation organizations, and researchers into a definition of airport operational sustainability as "the ability to operate an airport in the most effective and efficient manner to safely move people and cargo while providing improved levels of service and function without increasing the impacts on the environment or compromising the needs and values of the local community" (p. 6). However, the viewpoints used to create this definition of airport operational sustainability are from large commercial airports (Johnson & Gu, 2017).

Johnson and Gu (2017) reviewed the assessment metrics used by two sustainability assessment organizations and the eight largest airports which had sustainability documents in eight National Oceanic and Atmospheric Administration (NOAA) regions. According to Johnson and Gu (2017), the assessment metrics used by the eight airports differ from each other. One fundamental reason for this phenomenon is that the definitions of operational sustainability and sustainable goals are different among the airports studied (Johnson & Gu, 2017).

Johnson and Gu (2017) also developed a framework for assessing airport operational sustainability. Airports should first develop its own operational sustainability definition according to the airport's conditions, such as airport capacity and function followed by developing sustainability goals, identifying KPIs and associated assessment metrics. By comparing airport data to each metric with the baseline values, an airport can conduct a

reasonable assessment of the airport operational sustainability. According to the results, airports may choose to update new sustainability goals or adjust and implement more sustainable activities to accomplish the original goals. This framework is fitting to the airports which do not have an existing sustainability program or only implement sustainable initiatives without a sustainable plan (Johnson & Gu, 2017).

Gu and Johnson (2018) explored operational goals and metrics suggested in the DOAV guidance for airport sustainability management plan. Gu and Johnson (2018) found that airports in different categories may use different metrics to measure the performance in the same area based on their operational context. A new categorization of metrics for airport operational sustainability is developed in this research (Gu & Johnson, 2018).

To conclude, the previous studies about airport operational sustainability primarily focused on commercial airports. Since the definitions of airport operational sustainability are defined variously, it is difficult for airports to develop their own definitions by using or modifying existing definitions of other airports. It is a challenge for airports to convert sustainability concepts into the quantitative measuring tools, and to select appropriate performance metrics Small airports include GA airport have disadvantages on their resources and expertise for developing airport sustainability programs. There is a demand to conduct studies on airport operational sustainability for U.S GA airports.

2.8 Summary

In the literature review, the researcher explains why this study is necessary. Firstly, the researcher introduces the U.S. GA airports, demonstrates their importance to U.S. national transportation, and claims the need for airport sustainability planning for GA airports. Then, the researcher briefly overviews the historical development of sustainability and present situations of

sustainability in the airport industry. The sections of airports sustainability planning and assessment for airports sustainability emphasizes the significance of defining airport sustainability and developing performance metrics. The operational sustainability programs of four large hub U.S. airports presents the diversity of understandings of airport operational sustainability at different airports. The previous review of research on airport operational sustainability identifies the gap of research on airports operational sustainability for GA airports.

CHAPTER 3. METHODOLOGY

To answer the two research questions of this study, the researcher used the exploratory multiple-case study method. This chapter first introduces the research model and framework of the research. Next, the data source, data collection, and data analysis processes are presented. Finally, the validity and reliability of the study are discussed.

3.1 Research Questions

The two research questions of this study are: (1**)** What are the current understandings of airport operational sustainability among U.S. GA Regional and Local airports and what would be a synthesized definition of airport operational sustainability for U.S. GA Regional and Local airports? (2**)** What are performance metrics for airport operational sustainability among U.S. GA Regional and Local airports?

3.2 Research Model and Framework

The criteria for selecting appropriate research methods in every study include the purpose objectives, research question, the current body of knowledge in the area of the research, and the accessibility of the data required by the research (Wynekoop and Russo, 2011). According to the research goals and needed data of this study, the qualitative research method was selected over the quantitative and mixed research methods. The quantitative research methods usually examine hypotheses, whereas qualitative research methods describe, investigate, explain, or interpret theories in a particular situation (Venkatesh, Brown, & Bala, 2013). Furthermore, quantitative research with hypotheses, based on numerical data, while qualitative research answers research questions based on interpreting non-numerical data (Christensen et al., 2011). In this study, the

researcher explored the current understandings and performance metrics for airport operational sustainability for U.S. GA airports, by using non-numerical data. Therefore, qualitative research methods should be appropriate.

In the book *A case for the case study*, Feagin defined a case study as "an in-depth, multifaceted investigation" of a case (or cases) or situation(s) using "several data sources" (Feagin, 1991, p.2). Yin (2014) stated that the goal of a case study is to "to expand and generalize theories (analytic generalization)" (p. 44). Yin (2014) also claimed that the purpose of analytic generalization as an investigation of theory in a particular case might also be widely applied to other cases. This research explores the existing definitions, understandings, and performance metrics for operational sustainability used by GA Regional and Local airports, and then generalizes a theory (definition) of airport operational sustainability and develops a set of performance metrics for assessing operational sustainability. Hence, a case study method is the most suitable for this study.

Both Tellis (1997) and Yin (2014) mentioned three general types of case study work, which are descriptive, explanatory, and exploratory case studies. The definitions of three types of study are described in Table 10. According to Neuman (2006), the primary purpose of exploratory research is "to examine a little-understood issue or phenomenon to develop preliminary ideas and move toward refined research questions by focusing on the 'what' question" (p. 33). The airport operational sustainability for GA airports is rarely defined (Johnson & Gu, 2017). The outcomes of this study may inspire the researcher and facilitate further research in this area. For example, further research under this area may be conducted on how to assess the operational sustainability for U.S. GA airports. Thus, the exploratory case study design is selected for this research.

Table 10. Types of case study

Type of Case study	Definition
Descriptive case study	"a case study whose purpose is to describe a phenomenon"
Explanatory case study	"a case study whose purpose is to explain how or why some condition came to be"
Exploratory case study	"a case study whose purpose is to identify the research questions or procedures to be used in a subsequent research study, which might or might not be a case study."

Note. The definitions of three types of the case study are from Yin (2014, p. 238).

In addition to the case study, there are four other types of qualitative research designs: narrative study, ethnographic method, phenomenological research, and grounded theory. The narrative study is used for creating cohesive stories for individuals. The ethnographic design intends to describe and discover a kind of culture of a group of individuals. The phenomenological method focuses on examining the experience of participants. The grounded theory allows researchers to develop theories that are grounded in specific situations. (Christensen et al., 2011). The researcher considered these four types of qualitative research methods; however, they were not chosen, because their characteristics are not aligned with the purpose of this research.

Figure 1 displays the structure of this study. The researcher first answered the research question (1) and defined the operational sustainability for U.S. GA Regional and Local airport, based on the data selected. Then, the researcher used the new definition as the criterion to develop a set of performance metrics for assessing the airport operational sustainability of U.S. GA Regional and Local airports.

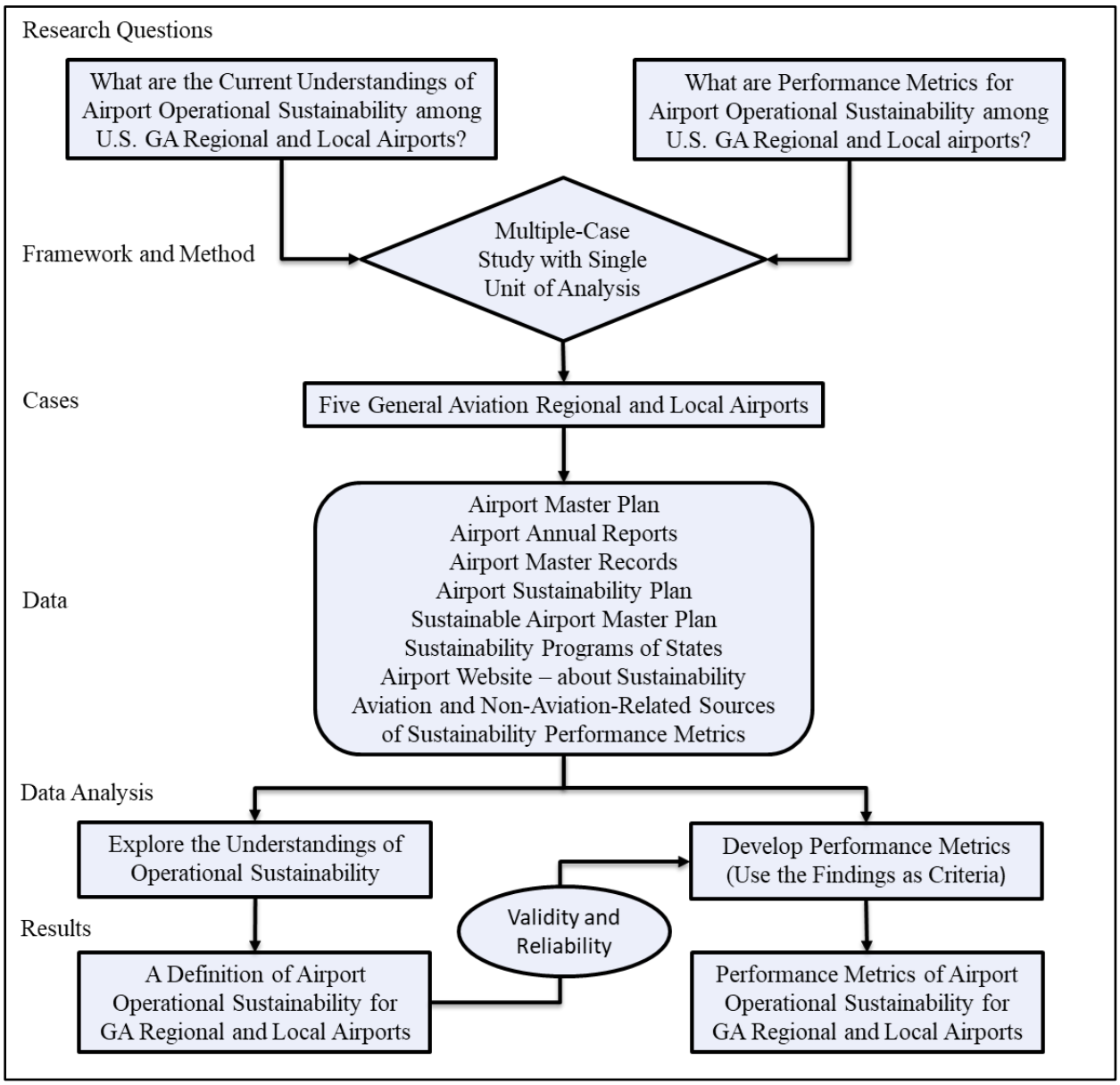

Figure 1. Research model used in this study

3.3 Multiple-Case Study-Research

This study is a multiple-case study, with a single unit of interest focused on airport operational sustainability. According to Yin (2014), there are four types of research designs in case study work, as shown in Table 11. Yin (2014) considered that single-case and multiple-case design are the two variants under the framework of the case study. Yin (2014) argued that single-case designs are appropriate where a "critical, unusual, common, revelatory, or longitudinal case" (p. 51) exists, while multiple-case study work is essential "to consider multiple cases as one would consider multiple experiments" (p. 57). A multiple-case design could conduct either a single unit of analysis or multiple units of analysis (Yin, 2014). Multiple cases are analogous to the replications in multiple experiments, rather than the multiple subjects in a single experiment. These multiple cases should be selected by following the same replication logic and should be considered as one "whole" study. In this study, each replication is a U.S. GA Regional or Local airport that has developed and published a sustainability plan. The airport operational sustainability is a single unit of analysis.

Table 11. Types of case study designs

	Single unit	Multiple units
Single-case	A single case with one unit of analysis	A single case with multiple units of analyses
Multiple-case	Multiple cases with one unit of analysis	Multiple cases with multiple units of analyses

Note. Types of the case study are from Yin (2014).

3.4 Advantages and Disadvantages of Case Study Research

Advantages. Eriksson and Kovalainen (2008) mentioned that case study research could represent complex, high context situations of contemporary events. Compared to other research methods; case study methods allow researchers to use thick description to explore and explain a

phenomenon or a couple of phenomena. Dul and Hak (2008) summarized several opinions of other researchers and recognized that case study research is beneficial “when the topic is broad and highly complex when there is not a lot of theory available, and when ‘context’ is very important" (p. 24).

According to Johnston, Leach, and Liu (1999), case study research has an advantage in validating studies, since it allows researchers to use multiple data sources in research. Therefore, multiple strategies, such as triangulation can be used. The bias of the researcher is also isolated from the study (Johnston, Leach & Liu, 1999). For instance, company documents, such as airport reports, that are developed without the influences of the case study research are more objective. Yin (2014) argued that the multiple-case study methods have more robust results by providing the researcher an opportunity to analyze the units in the replication of cases.

Disadvantages. In contrast, the researcher should expend more effort and time to conduct multiple-case studies. Also, Johnston, Leach, and Liu (1999) argued that multiple-case study research is detected by a lack of well supported and defined procedures and methods. This disadvantage may reduce the reliability of studies.

3.5 Data Sources and Collection

Tellis (1997) argued that case study research could use both quantitative and qualitative data sources and classified these data sources into six categories, as shown in Table 12. For this research, the data from documents is used extensively. The types of documents include, but are not limited to, the GA airports’ sustainable master plans, sustainable management plans, and sustainability reports, the States’ sustainability plans for GA airports, the journal articles about airport operational sustainability and associated performance metrics, airport master records,

Airport Cooperative Research Program (ACRP) publications about airport sustainability, and the U.S. airport regulations.

Table 12. Data sources used in case study research

Data sources	Description
Documents	Reports, administrative documents, articles, and memoranda
Archival records	Service records, organizational records, and survey data
Interviews	Open-ended, focused, and structured interviews or survey
Direct observation	Observe subjects without altering their environment.
Participant-observation	Researcher actively participant in events investigated
Physical artifacts	Tools, instruments, and other physical evidence

Note. The types of data sources are from Tellis (1997).

3.5.1 Data Sources

As discussed in Chapter 2, Literature Review, the FAA initiated an Airport Sustainable Master Plan Pilot Program in 2009. This program funded U.S. airports to develop their airport sustainability plans in order to accumulate experience and knowledge that can demonstrate how to achieve "an airport's forecasted demand while achieving aviation standards, and reducing an airport's environmental impact" (FAA, 2010, p. 1). Since 2009, the FAA has funded 44 U.S. airports to develop their sustainability plans and listed airports' names and links of their airport sustainability planning documents on the FAA webpage (FAA, 2017b). Colorado is on the list but chose to develop a sustainability management plan program that provides the information and tools for GA airports in Colorado to create sustainability plans for their own facilities (CDOT, 2016).

On the FAA's list of participants of the Airport Sustainable Master Plan Pilot Program, there are three GA airports (FAA, 2017). Two of these airports are GA Regional airports, while one of them is a GA Local airport. Under the Colorado sustainability management plan program, two GA airports have developed their sustainability plans using statewide guidelines (CDOT, n.d.). Therefore, the multiple cases are the five known GA airports with sustainability plans recognized by the FAA. Table 13 lists five cases of this research and data collected.

Table 13. Five cases of this study and data collected

Airport Name and Location	Data Collected Between September 2018 and January 2019
Coeur D´Alene Airport (COE) at Idaho	• Airport Website – Sustainability – 10/2018 • Airport Master Record – 12/31/2016 • Airport Master Plan – 2018 • Airport Sustainability Plan – 2016 • Airport Sustainable Business Plan – 5/2016 • Airport Sustainability Stakeholder Meeting Presentation 4/22/2015
Kent State University Airport (1G3) at Ohio	• Airport Master Record – 12/31/2017 • Airport Sustainability Plan – 5/16/2016 • Colorado Department of Transportation (CDOT) General Aviation Airport Sustainability Tool Kit Guidance Manual – 2016 • CDOT GA Airport Sustainability Program Flyer
Fremont County Airport (1V6) at Colorado	• Airport Master Record – 12/31/2015 • Airport Sustainability Plan – 6/8/2016 • CDOT GA Airport Sustainability Tool Kit Guidance Manual – 2016 • CDOT GA Airport Sustainability Program Flyer
Rifle Garfield County Airport (RIL) at Colorado	• Airport Master Record – 8/2018 • Airport Master Plan – 5/2016 • Airport Master Plan – Appendix H Sustainability – 5/2016 • Airport Master Plan – Executive Summary Fact Sheet– Summer 2016 • Airport Master Plan – Fact Sheet 2 – Summer 2014 • Airport Master Plan – Fact Sheet 3– Fall 2014
Vero Beach Regional Airport (VRB) at Florida	• Airport Master Record – 12/31/2017 • Sustainable Airport Master Plan: Executive Summary – 6/2016 • Airport Annual Reports 2015, 2016, and 2017

Note. The airport's name and associated States are from FAA (2017b) and CDOT (n.d.).

Sources for investigating and selecting the performance metrics. The performance metrics for this study were selected from existing metrics that are being measured and that can apply to the sustainability goals or practices. For example, if the sustainability goal of an airport is to reduce energy use, the electricity consumption measured in kWh would be a reasonable metric for this goal. The metrics are selected from the sources, such as airport sustainability documents, SAGA Resource Guide, ACRP publications, and airport industry or non-airport industry rating and certification programs. Please see Appendix B, List of Sources of Sustainability Performance Metrics.

3.6 Data Analysis

The data analysis of this research has two main parts. In the first part, the understanding of airport operational sustainability among the five airports were explored. A coding process developed by the researcher was used to analyze data thematically as shown in Figure 2.

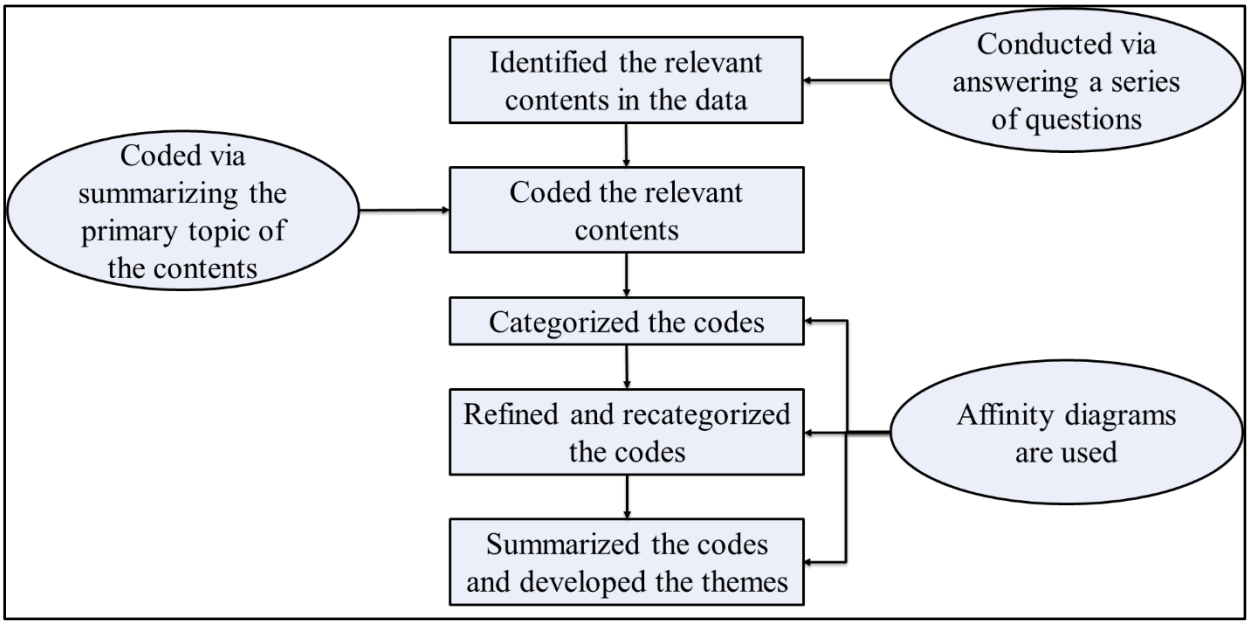

Figure 2. Coding scheme of this study

The coding process started with identifying the relevant contents in the collected data. A series of questions were used to help the researcher identify the relevant contents, as shown in Table 14. The section of *Airport Understanding of Operational Sustainability* in the case summary of each airport is the summary of the answers for these five questions. Then, the codes were developed by summarizing the primary topics of the contents identified. Affinity diagrams were used to categorize and summarize the codes. This coding process is performed by the researcher to analyze the data of each case and to develop the thematic areas of each airport. In the cross-case summary, the thematic areas of each case were combined and harmonized to define the themes that cross the five cases.

Affinity diagrams are tools that are used to gather large amounts of qualitative data (e.g., idea, language, and opinions) and organize them into groupings based on subjective similarity. Affinity diagrams can be used for "identifying patterns and establish related groups that exist in qualitative datasets" (Shafer, Smith & Linder, 2005, p. 200). The outcomes of the first part of the analysis are a definition of airport operational sustainability for U.S. GA Regional and Local airport and three emerging themes and associated subcategories.

Table 14. Questions used to identify the relevant contents

#	Questions
1	How do the airports define and describe operational sustainability /efficiency?
2	What are the sustainable areas/categories defined by the airports related to airport operation?
3	What are the sustainable goals of those operation related areas set by the airports?
4	What are activities that airports are conducting or planning to do to improve their operational sustainability/efficiency?
5	What are the metrics that airports are using to measure the performance on sustainable goals?

The second part of the data analysis focused on the development of performance metrics for the airport operational sustainability for GA Regional and Local airports. Table 15 presents the process of performance metrics development used in this research.

Table 15. Process for performance metrics development

Step	Description
Step 1. Develop Measurement Context	The performance measurement context are the performance goals of the three common themes and the associated subcategories.
Step 2. Define Relevant Assessment Criteria	The activity of this step is to develop criteria for determining if candidate metrics are relevant.
Step 3. Identify Current Metrics	The goal of this step is to determine which metrics are used in the five cases.
Step 4. Identify Candidate Metrics	Identify candidate performance metrics from the documents of five cases and from the sources listed in Appendix B.
Step 5. Map Candidate Metrics to Criteria	At this step, a matrix that lists some number of metrics for each assessment criterion is produced.
Step 6. Assess Candidate Metrics for Relevance	This activity extends the matrix to map each of the metrics to relevance assessment criteria.
Step 7. Rationalize the Performance Metrics Set	At this step, the metrics are examined to eliminate redundancies to ensure completeness and identify potential overlap.
Step 8. Formalize the Performance Metrics	Finally, the researcher formalizes a new set of performance metrics.

Note. The steps of performance metrics development are modified based on the process generated by Adams (1999).

Step 1 of the process was performed in the first part of the data analysis. By the end of Step 1, a performance measurement context for assessing candidate metrics was established, based on the new definition of airport operational sustainability and the performance goals of the three themes defined in the first part of the data analysis. The outcome of the second part of the data analysis is a set of performance metrics of airport operational sustainability for U.S. GA Regional and Local airports.

3.7 Validity and Reliability

Yin (2014) claimed that four logic tests are commonly used to justify the quality of case study research. These four tests are construct validity, internal validity, external validity, and reliability (Yin, 2014).

Construct validity identifies the "correct operational measures for the concepts being studied" (Yin, 2014, 35). In case study research, the researcher often fails to develop a set of adequate operational measures and deviates from the preconceived notions (Yin, 2014).

Yin (2014) defined that internal validity of a case study seeks to "establish a causal relationship, whereby certain conditions are believed to lead to other conditions, as distinguished from spurious relationships" (p. 36). Merriam (1995) argued that the internal validity decides whether the study answers the question expected to be answered, and whether the questions are answered with correct methods. Merriam (1995) mentioned the strategies for strengthening the internal validity, including triangulation, member checks, peer examination, statement of researcher's experiences, assumptions, biases, and engagement in the research situation.

External validity decides the extent to which the findings of a study can be generalized (Yin, 2014). Merriam (1995) argued that external validity or generalizability determines if the results of a study can be transferred to other situations. Merriam (1995) mentioned that many

qualitative researchers believe qualitative research has an inherent limitation on generalizability, because of differences between the limits in size of the sample and the entire population. The multiple-case study has been selected as the research method for the proposed study, since this method has an advantage of external validity. Yin (2014) noticed that the multiple-case study methods have more robust results by providing the researcher with an opportunity to analyze the units in the replication of cases.

Yin (2014) defined the reliability of case study research as the ability to "demonstrate that the operations of study can be repeated, with the same results" (p. 35). According to Yin (2014), strengthening reliability is to minimize the errors and isolated biases in a study. The strategy of the audit trail is suggested by both Merriam (1995) and Yin (2014) to enhance reliability. The prerequisite for performing an audit trail is based on an existing report that describes in detail the procedures for data collection and data analysis.

3.7.1 Strategies for Ensuring Validity and Reliability.

Creswell (2017) recommended that at least two justifying strategies should be used in any qualitative study. The strategies suggested in Merriam (1995) and Yin (2014) and associated brief explanations are shown in Table 16. To ensure the validity and reliability of proposed research, the researcher employs three strategies: triangulation, peer examination, and thick description.

To enhance the construct validity of a case study, the researcher limited the extent of the study to focus on understandings of airport operational sustainability among U.S. Regional and Local GA airports.

The internal validity can be was enhanced by using the strategy of triangulation. To use the strategy of triangulation, the researcher collects data from multiple sources to answer the

research questions. Also, the multiple-case study method has an advantage in validating studies (Johnston, Leach & Liu, 1999).

Table 16. Case study strategies for four criteria of quality

Criterion	Strategies	Explanation
Construct validity	Multiple sources of evidence	Convergent lines of inquiry
Internal validity	Triangulation	Use "multiple sources of data, or multiple methods to confirm the findings" (Merriam, 1995, p. 55).
	Member checks	Ask participants "if the interpretations of data are plausible (Merriam, 1995, p. 55).
	Peer examination	"Ask peers or colleagues to examine the data and to comment on the plausibility of the findings" (Merriam, 1995, p. 55).
	Statement of the researcher's experiences, assumptions, and biases	"Enable the reader to understand better how the data interpreted in the way in which they were" (Merriam, 1995, p. 55).
	Engagement in the research situation	"Collect data over a long enough period to ensure an in-depth understanding of the phenomenon." (Merriam, 1995, p. 55).
External validity	Thick description	Providing enough information about the case to help readers determine "how closely their situations match the research situation" (Merriam, 1995, p. 55).
	Multi-case designs	Use several cases that representing some variations
	Model comparisons	Describe how "typical the program, event, or sample" is compared with most others in the same class (Merriam, 1995, p. 55).
	Sampling within	Randomly sample each part of a phenomenon
Reliability	Triangulation	"Use of multiple methods of data collection" (Merriam, 1995, p. 55).
	Peer examination	"Ask peers or colleagues to examine the data and to comment on the plausibility of the findings" (Merriam, 1995, p. 55).
	Audit trail	Ask an auditor to verify the processes of data collections and data analysis

Note. The criteria, strategies, and Explanation are from Merriam (1995) and Yin (2014).

In terms of external validity, the strategy of thick descriptions was used by providing a sufficient description of the situation of cases. In addition, the results of multiple-case study research inherently can be applied to "a greater range of other similar situations" (Merriam, 1995, p.8).

The thick description must provide enough information for others to understand enough to determine whether their own case is similar to the studied cases. The information can help readers determine how closely their situations match the airport conditions in order to use the findings of this research. As there is no other criteria or general templates for thick descriptions, the researcher developed a set of topics that were used to create the five thick descriptions in this study. To develop the thick description of each airport, the researcher collected information of :

- Airport Profile and Role
- Airport Facilities and Operations
- Airport Sustainability Perspectives

According to Merriam (1995), a study with reliability means its findings will be found again. The strategy of peer examination was conducted to enhance the reliability of this study. The researcher discussed the research process and finding with two aviation graduate students, and asked them to independently perform a coding process based on the coding scheme developed. The researcher then compared the thematic areas of the two peer researchers with his own. Based on these three sets of thematic areas, the researcher sought convergence of common areas and resolution of perceived differences.

3.7.2 Researcher Bias

Since the data were collected via the Internet, the bias that could occur during interaction between the participants and the researcher was avoided. The potential biases of this study may

present in the data analysis process, coding, and development of emerging themes. The researcher has a bachelor's degree in Aviation Management from Louisiana Tech University and a master's degree in aerospace and aviation management from Purdue University. The researcher also has work experience as an assistant for the airport director of a small commercial airport. These experiences of the researcher may help readers to assess the researcher bias. The researcher mitigated his bias by asking two peer researchers to examine the data collected and the findings of this study. A question of "whether or not the results represent the understanding of the five airports on airport operational sustainability" was used to remind the researcher the purpose of the study in order to mitigate the researcher bias during analyzing the data.

3.8 Summary

This chapter presents the research methodology used in this study. The purpose of this study is to develop a definition of airport operational sustainability and associated performance metrics for U.S. Regional and Local GA airports based on the current understanding of airport operational sustainability and existing metrics.

In order to achieve this goal, the multiple-case exploratory study was selected. The primary data sources for this study were the five U.S. GA airports that have developed and published sustainability planning documents. Using these documents, the research explored the understanding of five airports on operational sustainability. The definitions, descriptions, categories, goals, and activities of airports operational sustainability that are present in the five cases were coded and analyzed, and then served as the criteria for defining a definition of airport operational sustainability and selected performance metrics.

In order to enhance the validity and reliability of the study, the strategies of triangulation, peer examination, and thick description were conducted.

CHAPTER 4. RESULTS

This chapter starts with the case summaries of the five airports in this study. Each summary includes a section of thick description of the case airport, a section of the airport understanding of operational Sustainability, and a section of the thematic areas of operational sustainability identified by the researcher in this study. Then, a cross-case summary was presented. In this cross-case summary, a definition of airport operational sustainability for U.S. GA Regional and Local airports was developed, based on exploration of the five case airports. The three common themes and their associated subcategories for airport operational sustainability were defined. Finally, a set of performance metrics of airport operational sustainability for U.S. GA Regional and Local airports were selected based on the performance goals of their themes and the subcategories. To mitigate the researcher bias and ensure the reliability of the study, the peer examinations are conducted during the research.

4.1 Five Case Summaries for the Five Airports

Each case summary consists of a thick description of the airport, airport understandings understanding of operational sustainability, and the thematic areas of operational sustainability for each airport that was identified by the researcher. Fremont County Airport and Rifle Garfield County Regional Airport reported that they each developed their airport sustainability plans using the Tool Kit provided by Colorado Airport Sustainability Program. Therefore, the understanding of airport operational sustainability is influenced by the perspectives of Colorado Airport Sustainability Program. Please see Section 2.4 Airport Sustainability Planning to find out more details about the Colorado Airport Sustainability Program.

The section of thick description provides information regarding the airports and helps others to understand enough to determine whether their own case is similar to the studied cases. The thick description in this study contains:

- Airport Profile and Role – The description of the airport's location, ownership, and the airport role in local, state, and national air transportation system.
- Airport Facilities and Operation – The description of the airport's major facilities for aviation activities, number and component of based aircraft, number of annual airport operation, and contributions to the economy.
- Airport Sustainability Perspectives – A summary of the airport's perspectives of airport sustainability.

The section of Airport Understanding of Operational Sustainability is a summary of the airport's definitions, descriptions, sustainable areas/categories, sustainable goals, activities, and performance metrics that related to airport operational sustainability/efficiency. This section is a summary of the answers for the five questions used to identify the relevant contents of the study. These questions are shown in Table 14 in Section 3.6 Data Analysis.

The last section of each case summary is the thematic Areas of Operational Sustainability for Each Airport. The thematic areas of operational sustainability are based on the researcher's coding of information collected during this study. The codes of this study are list in Appendix A. To improve reliability, the coding process was repeated by two aviation graduate students, and their results were compared, to develop a convergence. Please see Appendix C Thematic Areas Defined by the Three Researchers.

4.1.1 Coeur d'Alene Airport (COE)

4.1.1.1 Thick Description

Airport Profile and Role

Coeur d'Alene Airport (COE) is a general aviation airport owned by Kootenai County, Idaho. The airport is organized by the Board of County Commissioners (BOCC). COE is in Kootenai County in Idaho and provides the residents and businesses of Kootenai County and the surrounding region access to the National Airspace System (NAS). The airport considered itself as an economic driver for the community and a connectivity point to "medical transport, forest firefighting, business, recreation, flight charter, and flight training" (Coeur d'Alene, 2016b, p.4). COE is also a Part 139 Class IV airport. Per the FAA, Part 139 Class IV airport "serve only unscheduled operations of large [at least 31 seats] air carrier aircraft" (FAA, 2015b, p.4).

COE is one of the three airports having the designation of Regional Business Airport that is classified by the Idaho Transportation Department – Aeronautics. The airport supports regional economic activities by connecting state and national economies and serving all types of general aviation aircraft (Coeur d'Alene, 2016b). COE is considered a part of the FAA's National Plan of Integrated Airport Systems. Therefore, COE is qualified to receive federal funding assistance, such as the FAA's Airport Improvement Program (AIP) grant. The National Plan of Integrated Airport Systems (NPIAS) has classified COE as a "Regional" GA Airport that typically averages 90 based aircraft and three jets and "supports regional economies by connecting communities to statewide and interstate markets" (FAA, 2012, p12). COE, however, is more likely a "National", GA Airport which has "average 200 based aircraft"and 30 jets, and "supports the national and state system by providing communities with access to national and international markets in multiple states and throughout the United States" (FAA, 2012, p12).

Airport Facilities and Operations

Coeur d'Alene Airport has a 7,400-foot runway (RWY 06/24) with precision instrument approaches and a 5,400-foot runway (RWY 02/20). COE also owns a T-Hangar building and another large hangar facility. These two hangars are leased to one of two Fixed Base Operators (FBOs) at the airport. The services of "fueling, aircraft handling, and terminal facilities" are provided by private businesses (Coeur d'Alene, 2016b, p.4). COE provides the runways, taxiways, aircraft parking aprons for aircraft operations, land for building private storage hangars and commercial aviation development, and limited FAR Part 139 Aircraft Rescue and Firefighting (ARFF) services (Coeur d'Alene, 2016b).

Coeur d'Alene Airport does not have an air traffic control tower on site. COE had 252 based aircraft in 2014, including 220 single-engine aircraft, 16 multi-engine aircraft, eight jets, seven helicopters, and one ultra-light aircraft (GCR, 2014). The airport operations were 123,048 in 2014. The business jet operations transfer passenger and cargo from COE to "all 50 of the U.S. States as well as Canada, Mexico and Central America" (Coeur d'Alene, 2016b, p. 3). There are 87 private hangars at the airport which provide aircraft storage for the based aircraft. Coeur d'Alene Airport is a hub and the headquarters for Empire Airlines. Specialized aviation services, such as aircraft maintenance and manufacturing, helicopter, emergency transport, are presented at or near the airport. Based on the *Idaho Airport System Plan*, Coeur d'Alene Airport is generated more than $ 129 million per year for the local and regional economy and creates more 1,000 jobs directly and indirectly (Idaho, 2010). Coeur d'Alene Airport data are shown in Table 17.

Table 17. Coeur d'Alene Airport data

Item	Information
Airport Name	Coeur d'Alene Airport, Pappy Boyington Field
Airport Identifier	COE
Address	10375 Sensor Ave Hayden, ID 83835
Distance/Direction From Business Center	9 miles NW of Coeur d'Alene
Owner	Kootenai County
Governing Body	Kootenai County Board of Commissioners Airport Advisory Board
Size	1,100 acres
Elevation (MSL)	2,320 feet (MSL)
Number of Runways	2
Long Runway	RWY 06/24: 7,400' X 100'
Short Runway	RWY 02/20: 5,400'x75'
Air Traffic Control Tower	No
Airport Type	FAR Part 139 Class IV, Regional GA
Airport Role	Spokane Reliever, Business & Leisure GA, Resort
Economic Impact (Total)	a $129 Million per year, 1,000 jobs
Based Aircraft	252
Airport Operations	b 123,048 (in 2014)
Fixed Base Operators	2
Specialized Aviation Service Operators	7
Hangars	87 private hangars and T-Hangar buildings

Note. The airport data are from Coeur d'Alene (2016b). a The data of economic Impact of COE are from Idaho (2010). b The number of airport operations is from the *FAA Form 5010 Airport Master Record* (GCR, 2014)

Based on the report of the airport's Fiscal Year 2014 finances, the four parts of airport revenue were lease fee, fuel flowage fee, use fee, and miscellaneous income. COE identified its potential revenue opportunities as:

- "Car Rental Fees
- GA Landing Fees
- Ramp Fees for Day Use
- Fuel Flowage Fees
- Land Lease Fees
- T-Hangars
- Ski and Resort Destination Charters" (Coeur d'Alene, 2016b, p.7).

Airport Sustainability Perspectives

The Coeur d'Alene Airport stated that its purpose for developing its sustainability plan as "incorporating sustainable goals to run a more efficient and effective airport" (Coeur d'Alene, 2016a). The airport used the ACI-NA's definition of airport sustainability, because this definition includes operational efficiency. The airport believed the ACI-NA's definition reflects the values and goals of the airport and its stakeholders. COE developed its airport sustainability mission statement to incorporate the sustainability principles into its existing mission statement as:

> "The mission of the Coeur d'Alene Airport is to preserve and improve the Airport as an economically valuable, socially responsible, and environmentally sustainable facility from which to provide an efficient gateway to the region" (Coeur d'Alene, 2016a. p4).

COE identified its sustainable focus categories that represent its interests and focuses on sustainability. These categories help COE to narrow the focus of a sustainability plan to those elements that are important for both the airport and community. COE identified seven sustainable categories:

- “Planned Development
- Operations and Maintenance of Airport Facilities
- Energy
- Natural Resources
- Airport Finance
- Community Relations
- Adjacent Land Use Compatibility” (Coeur d’Alene, 2016a, pp.5-6).

COE set different goals to reflect the desired targets in each category. The airport listed metrics that measure success for each goal and states specific actions/initiatives to meet goals. These categories reflect the current highest priorities of COE and may be expanded based on the future condition of the airport.

4.1.1.2 Airport Understanding in Operational Sustainability

Among the seven sustainable categories of COE, the category of Operations and Maintenance of Airport Facilities most clearly reflects the airport’s understanding of operational sustainability. COE believed operation and maintenance of the airport facilities take up most of the staff time and financial resources. Therefore, there is an excellent opportunity for incorporating sustainability into airport management and structures through operations and maintenance activities. COE selected the category of Operations and Maintenance of Airport Facilities to discover the ways to “reduce time and money on maintenance over the long term

and reduce overall stress on staff due to reoccurring maintenance constraints" (Coeur d'Alene, 2016a, pp.4-5).

The Coeur d'Alene Airport set four different goals for the category of Operations and Maintenance of Airport Facilities. Each goal has various metrics that are used to track progress and measure success. Table 18 lists the sustainable goals and metrics selected for the category of Operations and Maintenance of Airport Facilities.

Table 18. Sustainable goals and metric in the category of operations and maintenance of airport facilities

Goal	Metric
Goal 1. "Continue to provide and maintain a safe and efficient Airport" (p.8).	• "Compliance with current the FAA recommendations (this may be primarily accomplished through engineering and planning for improvements) • Surveys completed by aircraft operators (every two years) • Pavement condition index (every three years)" (p.8).
Goal 2. "Use sustainability principles to maximize operational efficiency, reduce long-term maintenance costs and improve the environment" (p.9).	• "Maintenance portion of Airport expenses (field maintenance, equipment maintenance, grounds maintenance, non-eligible infrastructure improvements) • Number of airport projects that incorporate sustainability practices / number of airport projects" (p.9).
Goal 3. "Invest in developing the people working at the Airport" (p.9).	• "Number of training • Amount of funding allotted to professional development/training" (p.8).
Goal 4. "Promote employee well-being to improve productivity and efficiency" (p.9).	• "Employee performance reviews • Number of incentive/recognition programs" (p.8).

Note. The sustainability goals and metrics are from Coeur d'Alene (2016a)

COE described Goal 1 in two aspects. The airport committed to maintaining an efficient and safe operational environment for both users and tenants. Meanwhile, the airport undertaked to maintain airport infrastructure, facilities, equipment, and signage to meet the FAA standards. Under Goal 2, COE intended to reduce airport expenses that relate to the maintenance activities, and increase the proportion of airport projects that incorporate sustainability practices. Goal 3 and Goal 4 have only one direction of focus, respectively, as shown in the Table 18.

In addition to the category of Operations and Maintenance of Airport Facilities, the category of Planned Development is related to the airport operation. COE stated that the planning, design, and contracting processes of the airport are the potential areas to incorporate sustainable practices. Maintaining the airport facilities and infrastructure to be efficient and compatible for future growth help "ensure the viability of the airport into the future and contribute to all four aspects of sustainability," which also include the operational pillar (Coeur d'Alene, 2016a, p. 4). Therefore, the Sustainable goals in the Category of Planned Development may reflect COE's understanding of operational sustainability. Table 19 lists the sustainable goals and metrics selected for the category of Planned Development.

Table 19. Sustainable goals and metric in the category of planned development

Goal	Metric
Goal 1. "Develop and maintain facilities and infrastructure at the airport to support long-term, compatible, efficient, and flexible growth" (p. 8).	• "Pavement condition index (every three years) • Maintenance portion of Airport expenses (field maintenance, equipment maintenance, grounds maintenance, non-eligible infrastructure improvements)" (p. 8).
Goal 2. "Enhance sustainability practices for all airport activities (e.g. O&M, administration, procurement, design/construction/post-construction) as conducted by all involved in the operation of the Airport" (p. 8).	• "Number of airport projects that incorporate sustainability practices/number of airport projects" (p. 8).

Note. The sustainability goals and metrics are from Coeur d'Alene (2016a).

4.1.1.3 Thematic Areas of Operational Sustainability for Coeur d'Alene Airport

Safety. Safety is a thematic area for Coeur d'Alene Airport. The category of Operations and Maintenance of Airport Facilities included safety as a part of its one sustainable goal (Coeur d'Alene, 2016a). In the category of Planned development, safety is a factor for evaluating the performance of the airport. Safety is not only mentioned in the operation-related sustainable categories, but it also states in the other categories in diverse ways (Coeur d'Alene, 2016a).

Efficient facility and infrastructure in the long-term. Coeur d'Alene Airport considered operating and maintaining airport facilities and infrastructures an ongoing and long-term task. The goal is to ensure the airport facilities and infrastructures are efficient to use for current and future airport users. This goal requires the airport to continually operate and maintain airport facilities and infrastructure, and to keep them in excellent condition. Furthermore, COE has a goal to keep improving its facilities and infrastructure to be efficient and compatible in the long term (Coeur d'Alene, 2016a).

Cost and time reduction. In the categories of Operations and Maintenance of Airport Facilities, COE identified cost and time reduction as part of its sustainable goals. The airport planned to achieve this target via streamlining and reducing the maintenance burden and constraints for the employees. The airport considered sustainability measures, such as energy-saving strategies, potential ways to cut costs (Coeur d'Alene, 2016a).

Incorporation of sustainability practices in operation and maintenance. Coeur d'Alene Airport regarded operation and maintenance activities as great opportunities to incorporate sustainability practices into "both the management and structure of the airport" (Coeur d'Alene, 2016a, p. 5). Incorporation of sustainability practices into operation and maintenance are potential ways to reduce time and cost and to improve the operational efficiency of the airport (Coeur d'Alene, 2016a).

Employee well-being, productivity, and efficiency. Coeur d'Alene Airport appeared to believe that the airport employees' productivity and efficiency are highly related to the operational efficiency and safety of the airport. The airport planned to "develop reward, recognition, and promotion structures" to promote employees' satisfaction, and "develop and implement safety, sustainability, and educational training programs" to improve employees' capabilities (Coeur d'Alene, 2016a, p. 16).

4.1.2 Kent State University Airport (1G3)

4.1.2.1 Thick Description

Airport Profile and Role.

Kent State University Airport (1G3) is a public-use GA airport which is owned and operated by Kent State University. The airport is included in the FAA NPIAS program and identified as a "Local" GA airport. Therefore, the airport has the role to "supplement local communities by providing access primarily to intrastate and some interstate markets" (FAA, 2012, p.12). In the *Ohio Airports Focus Study*, GA airports in Ohio are categorized into four levels depending on the available facilities and services at the airports (Ohio Department of Transportation, 2014). Kent State University Airport is a Level 3 airport according to the study, which that mainly "serve piston-powered aircraft, meeting nearly all of their needs" (Kent, 2016a, p. 2-2). As a Level 3 airport, Kent State University airport is required to provide pavement maintenance automated weather reporting, and Precision Approach Path Indicators (PAPIs) in order to perform its role in the state aviation system. Kent State University Airport is the base of the Kent State Aeronautics Program. The flight training operations of the Kent State Aeronautics Program accounts for 88 percent of airport operations (Kent, 2016b).

Airport Facilities and Operations.

Kent State University Airport has approximately 290 acres airport property. Runway 1/19 is the only runway of the airport, and is 4,000 feet long and 60 feet wide. The airport has a one 6,200-square-foot joint hangar/terminal, one 24,300-square-foot community hangar, and a T-hangar with two storage garages. In addition, the airport has about 19,000 square yards of apron pavement of which 80 percent is available for aircraft storage. Another 20 percent of the apron is used for maintenance, fueling, and temporary parking (Kent, 2016).

Kent State University Airport does not have an air traffic control tower on site. There were 41 based aircraft in by August 2017 including 39 single-engine aircraft, and two multi-engine aircraft. There were 75,100 airport operation between August 2016 and August 2017. Kent State University Aeronautics Program estimates that the number of students that enroll in their flight training program will increase from 90 to 250 per semester in 10 years. Student flight operations is anticipated to grow to 108,860 in 2022 (Kent, 2016b). The revenue sources of the airport are fuel and oil sales, aircraft storage, pilot merchandise, commercial contracts, and aircraft rental (Kent, 2016). Kent State University Airport contributes $4.7 million to local and regional economy and 102 jobs to the communities it serves annually (Kent, 2016a). The Kent State University Airport data is shown in Table 20.

Table 20. Kent State University Airport data

Item	Information
Airport Name	Kent State University Airport
Airport Identifier	1G3
Address	4020 Kent Rd, Stow, Ohio 44224
Distance/Direction From Business Center	1.2 miles east of the city center of Stow 3.8 miles west of the city center of Kent 4.1 miles northeast of Cuyahoga Falls
Owner	Kent State University
Governing Body	Airport Manager and Staff
Size	290 acres
Elevation	1134 feet (MSL)
Runway	RWY 01/19: 4,000’X 60’
Air Traffic Control Tower	No
Airport Type	General Aviation, Local
Airport Role	General Aviation
Economic Impact (Total)	$4.7 Million per year, 102 jobs
Based Aircraft	41
Airport Operations	[a] 75,100 (in 2017)
Fixed Base Operators	None
Specialized Aviation Service Operators	None
Hangars	1 joint hangar/terminal, 1 community hangar, and 1 T-hangar

Note. The airport data are from Kent (2016a). [a] The number of airport operations is from the *FAA Form 5010 Airport Master Record* (GCR, 2017b).

Airport Sustainability Perspectives

Kent State University Airport adopted ACI-NA's definition and the EONS framework of airport sustainability. The airport committed to sustainability by incorporating sustainability into each step of its airport master plan. The airport conducted a sustainability baseline assessment and established goals for integrating sustainability into the airport's management and operations. The sustainability mission statement of Kent State University Airport was not found in the available documents.

Kent State University Airport included sustainability in its master plan and identifies six sustainability areas within the three pillars of the EONS framework:

- "Energy - Natural Resource Conservation
- Air Quality and Greenhouse Gases - Natural Resource Conservation
- Sustainable Materials Management - Natural Resource Conservation
- Land Use Compatibility - Social Responsibility
- Community Outreach - Social Responsibility
- Airport Business Model/Operations - Operational Efficiency" (Kent, 2016a, p. 4-29).

The pillar of Economic Viability was not mentioned by Kent State University Airport. Kent State University Airport identified seven development alternatives that integrated with sustainability practices and evaluated these alternatives by using the criteria that created based on the EONS frame.

4.1.2.2 Airport Understanding of Operational Sustainability

Kent State University Airport considered operational efficiency a key component of airport sustainability as the same importance as the other pillars. The airport expressed that the success of an airport is "highly dependent on its ability to efficiently operate while maintaining a

safe environment" (Kent, 2016a, p. 5-35) Therefore, Kent State University Airport not only used operational efficiency as a criterion for evaluating the airport development alternatives, but also included it as "a specific resource category in the sustainability effort" (Kent, 2016c, p. H-49). The factors within the evaluation criterion of operational efficiency are shown in Table 21.

Table 21. Factors within the evaluation criterion of operational efficiency

Factor	Description
Airport Design Standards	"Ability to meet FAA design standards and ensure a safe operating environment" (p. 5-36).
Constructability	"Timeframe, availability of technology, and available support/partners for implementation" (p. 5-36).
Ownership/Management	"Impact on operations of having the Airport sponsorship transferred or the facility operated by another entity; also considers the operational efficiency of any configuration changes" (p. 5-36).
Impact on Flight Training	"Operational impacts on Flight Training associated with the alternatives including its relocation to a non-Kent State-owned facility" (p. 5-36).

Note. The Factors and their descriptions are from Kent (2016a).

Kent State University Airport identified a subject area under operational efficiency, which was Airport Business Model/Operations. Within this sustainability area, the airport established one goal and five broad strategies that help airport meet the goal. Table 22 shows the goal, five broad strategies, and the metrics selected to measure the success of achieving the goals.

Table 22. Goal, broad strategies, and associated metrics within the airport business model/operations sustainability area

Goal	Broad Strategy	Metric
"The airport aims to become financially self-sufficient and economically stable while accommodating growth in Flight Training" (p. 4-36).	"Increase efficiency of the airport's management / operation" (p. 4-36).	• "Increase/decrease in annual dollars of expenses (%)" (p. 4-36).
	"Increase revenue at the Airport" (p. 4-36).	• "Increase/decrease in annual dollars of revenue (%) • Number of revenue sources (#)" (p. 4-36).
	"Increase the airport's market share of activity" (p. 4-37).	• "Market share of activity (Kent State aircraft operations divided by total GA operations at area airports including Kent State" (p. 4-37).
	"Market the airport to potential users and tenants" (p. 4-37).	• "Based aircraft unrelated to Flight Training (# of based aircraft)" (p. 4-37).
	"Market the airport and Kent State University to potential students" (p. 4-37).	• "Enrollment of Flight Technology Students (# of students)" (p. 4-37).

Note. The goal, broad strategies, and metrics are from Kent (2016a).

4.1.2.3 Thematic Areas of Operational Sustainability for Kent State University Airport

Safety. Kent State University Airport identified safety as a critical factor for the success of airport operation. The airport did not include safety into its sustainable subject areas. Safety, however, is a factor within the evaluation criteria of operational efficiency (Kent, 2016a).

Efficient management/operation. Kent State University Airport established five broad strategies for its sustainable subject area of Airport Business Model/ Operations to achieve the goal of financially self-sufficient and economically stable airport (Kent, 2016a). Among the five strategies, one was to "increase the efficiency of the airport's management/operation" (Kent, 2016a). The performance of the airport in this strategy is measured by using the metrics of

increase or decrease in airport expenses. The airport identified four factors within the evaluation criteria of operational efficiency to examine its sustainable alternatives, which allows the airport to include multiple factors that enhance the efficiency of operation into decision-making (Kent, 2016a). Please see Table 21 to find the factors within the evaluation criterion of operational efficiency.

Marketing airport. Kent State University Airport selected marketing airport as a strategy to enhance the airport's business operation. This strategy includes two part of actions: 1. Marketing the airport to the potential users that increases the number of based aircraft and an increase in market share; 2. Marketing the airport and the university to potential students that increase the number of flight training students (Kent, 2016a).

Strengthening revenue streams. Kent State University Airport had a goal to increase airport revenues. This goal is planned to be achieved by establishing new sources of revenue, which is related to strengthen revenue streams (Kent, 2016a).

4.1.3 Fremont County Airport (1V6)

4.1.3.1 Thick Description

Airport Profile and Role.

Fremont County Airport (1V6) is a "Local" general aviation airport that is located in Canon City, Colorado. The airport is owned by Fremont County, Colorado and serves Canon City and the surrounding areas (Fremont, 2016). Fremont County Airport was identified in NPIAS as a "Local" GA airport (FAA, 2018). Therefore, the airport has the role to "supplement local communities by providing access primarily to intrastate and some interstate markets" (FAA, 2012, p.12). The airport defines its airport mission as to "provide safe, efficient

aeronautical services and facilities for commercial, corporate, private and military aviation" (Fremont, 2019).

Airport Facilities and Operations.

Fremont County Airport has 620 total acres of airport property. There are two runways at the airport: Runway 11/29 which is 5,399 feet long and 75 feet wide; and Runway 17/35 which is 1.800 feet long and 35 feet wide (Fremont, 2019). Fremont County Airport does not have an air traffic control tower on site. Fremont County Airport had 88 based aircraft in 2017 including 67 single-engine aircraft, 9 multi-engine aircraft, one jet, one helicopter, eight gliders, and two ultra-light aircraft. There were 16,643 airport operations in 2017 (GCR, 2017a). The airport has one fixed-based operator at the airport (Fremont, 2019).

Fremont County Airport had a significant impact on the local economy (CODT, 2013a). The impact has three components: On-airport activities including the administration, operation and maintenance of the airport and the activities of airport tenants that "provide aviation services or support the airport's customers" (p. 2); airport capital improvement; and impact from air visitors (CDOT, 2013a). Around 2,000 visitors enter Colorado through Fremont County Airport (CDOT, 2013a). Based on a study of Colorado, Fremont County airport contributes $6.8 million in economic output and 65 jobs (CDOT, 2013a). The revenue sources of Fremont County Airport are not found. Fremont County Airport data are shown in Table 23.

Table 23. Fremont County Airport data

Item	Information
Airport Name	Fremont County Airport
Airport Identifier	1V6
Address	60298 Highway 50 Penrose, CO 81240
Distance/Direction From Business Center	6 miles East of Canon City
Owner	Fremont County
Governing Body	Airport Advisory Board
Size	620 acres
Elevation	5,439 feet (MSL)
Number of Runways	2
Long Runway	RWY 11/29: 5,399'X 75'
Short Runway	RWY 17/35: 1,800'X 35'
Air Traffic Control Tower	No
Airport Type	General Aviation, Local
Airport Role	General Aviation
Economic Impact (Total)	[a] $6.8 Million per year, 65 jobs
Based Aircraft	88
Airport Operations	[b] 16,643 (in 2017)
Fixed Base Operators	1
Specialized Aviation Service Operators	None
Hangars	A corporate, heated hangar

Note. The airport data are from Fremont (2019). [a] The data of economic Impact of 1V6 are from CDOT (2013a). [b] The number of airport operations is from the *FAA Form 5010 Airport Master Record* (GCR, 2017a)..

Airport Sustainability Perspectives

Fremont County Airport voluntarily participated in the Colorado Airport Sustainability Program and used the CDOT General Aviation Airport Sustainability Tool Kit to prepare its airport sustainability plan. In this sustainability plan, Fremont County Airport referred the ACI-NA's definition and EONS framework for its airport sustainability. The Airport considered sustainability as an "approach to efficiently and responsibly operating the core business" and can help the airport to identify opportunities for innovation (Fremont, 2016, p. 3).

Fremont County Airport appeared to believe that their traditional business decision-making often emphasized the importance of budgetary or financial considerations, but neglect other elements that do not have a pure dollar value. Applying a sustainability framework in the decision-making process allowed the airport management teams to weight the traditionally non-core business issues alongside conventional business issues. Therefore, the airport used this sustainability plan as a management tool to "integrate sustainability concepts into the airport planning, management, operations, and development" and as a roadmap for implementing sustainability initiatives (Fremont, 2016, p.4). By including sustainability concepts, the airport created its sustainability mission statement:

> "Fremont County Airport aims to demonstrate financial responsibility without sacrificing the utmost level of safety that has always been at the core of all airport operations, and to continue to promote environmental stewardship and economic development that is beneficial to the airport and the communities that it serves" (Fremont, 2016, p.4).

The CDOT created 15 sustainable focus categories within the four pillars of the EONS sustainability framework are identified in the CDOT Tool Kit, as shown in Table 24 (CDOT, 2016).

Table 24. Sustainability focus categories in CDOT tool kit

EONS Pillars	Sustainability Focus Categories
Economic Vitality	• Revenue Generation • Expense Generation • Economic Development
Operational Efficiency	• Operations and Maintenance • Asset Management • Business Operations
Natural Resources	• Energy • Water • Waste • Climate and Air Quality
Social Responsibility	• Community • Airport User • Employees • Noise

Note. The sustainability focus categories are from Fremont (2016).

Fremont County Airport created its sustainability plan based on EONS framework, the resources available, and areas that are most important to the airport. Fremont County Airport selected eight categories from the 15 sustainable focus categories. These focus categories reflect the interests of sustainability for Fremont County Airport:

- Economic Vitality – Revenue Generation, Expense Generation, Economic Development
- Operational Efficiency – Operations and Maintenance, Asset Management, Business Operations
- Natural Resources – Water
- Social Responsibility – Community.

4.1.3.2 Airport Understanding in Operational Sustainability

Within operational efficiency, the Fremont County Airport identified three sustainability focus categories, Operations and Maintenance, Asset Management, and Business Operations. The descriptions of these focus categories represented the airport's understanding of operational sustainability.

Fremont County Airport identified Operations and Maintenance as one of the sustainability focus categories within the Operational Efficiency pillar. Operation and maintenance are the principal duties of operating an airport. By incorporating sustainability practices into airport operations and maintenance activities, the operational efficiency of the airport may be improved. Fremont County Airport stated that "goals tied to operations and maintenance involve improving the overall functionality of the airport and emphasize improving aircraft operations, streamlining maintenance activities, and ensuring continued safety and service performance" (Fremont, 2016, p. 8).

Asset Management is another sustainability focus category within Operational Efficiency pillar. To efficiently manage the airport's facilities and employees, Fremont County Airport committed to achieving "sustainable construction and investment in land, capital, and human resources" of the airport (Fremont, 2016, p. 8).

Fremont County Airport addressed sustainable business operations to enhance the economic position and competitive advantages. The airport identified a series of actions that serve to enhance the business operations of the airport, including "actions to establish business partnerships, secure long-term operating arrangements, improve the attractiveness of the airport for business," and strengthen revenue streams of the airport (Fremont, 2016, p. 8). Incorporating sustainability principles within the business operations was recognized by the airport as a chance to integrate sustainability into decision-making.

Fremont County Airport identified many measurable targets within its focus categories. These sustainability goals were selected based on the aspirations and needs of the airport. The goals identified are tied to either a specific focus category or to multiple focus categories in its plan. For each goal identified, Fremont County Airport assigned a metric to measure the performance on each target. Table 25 lists the sustainability goals and metrics used to measure the performance on each goal.

Table 25. Sustainability goals and metric for the focus categories within operational efficiency

Focus Category	Goal	Metric
Operations and Maintenance	GOAL 1: "Improve and streamline existing operations and practices at the airport to stretch resources, improve flexibility, and improve accountability (p.15).	Revenue increase in dollars
	GOAL 2: "Increase the average operating and economic life of airport assets" (p.15).	Increase in years of life
Asset Management	GOAL1: "Increase the average operating and economic life of airport assets" (p.15).	Increase in years of life
Business Operations	GOAL 1: "Increase aeronautical revenue" (p.16).	Revenue increase in dollars

Note. The sustainability goals and metrics are from Fremont (2016).

4.1.3.3 Thematic Areas of Operational Sustainability for Fremont County Airport

Safety. In the airport sustainability plan, Fremont County Airport stated that the inclusion of operational efficiency in airport sustainability "emphasizes the importance of safety and efficiency" (Fremont, 2016, p. 3). The airport counted safety as the "core of all airport operations" in its sustainability mission statement (Fremont, 2016, p. 4). The airport included providing continued safe performance as a target in the focus category of Operations and Maintenance.

Cost and time reduction. Fremont County Airport identified the reduction of operational costs as a benefit of incorporation of sustainability. The airport considered cost reductions as a target for both the focus categories (Operations and Maintenance and Asset Management) in Operational Efficiency. The airport established a joint sustainable goal to "increase the average operating and economic life of airport assets" (Fremont, 2016, p.15). In the descriptions of the category of Operations and Maintenance, the streamlining of maintenance activities is expected to result in a reduction of operational cost, maintenance time and burden for airport staff. These reductions in cost support the goal for improving the efficiency of the operations and maintenance.

Incorporation of sustainability practices. Fremont County Airport regarded operation and maintenance activities as opportunities to "incorporate sustainable practices into regular airport activities with a direct and measurable positive impact" (Fremont, 2016, p. 8). The specific goals and actions were not mentioned by the airport.

Increasing efficiency of operating airport assets. Fremont County Airport considered airport facilities and employees as part of its assets. The airport stated that the focus of the sustainable focus category of Asset Management is to "efficiently managing the airport's facilities and employees" (Fremont, 2016, p. 8). Within the category of Asset Management, the airport set a goal to "increase the average operating and economic life of airport assets" (Fremont, 2016, p.15). This goal was planned to be achieved via developing a maintenance management plan.

Strengthening revenue streams and establishing business partnerships. In the airport sustainability plan, Fremont County Airport identified its current interest within the Business operations focus category is to increase airport revenue. The airport identified actions that

increase airport revenue including changing airport rental rates for airport facilities, establishing partnerships with local agencies, installing self-service fuel facility, and getting input from airport tenants. These actions involve strengthening revenue streams and establishing business partnerships.

4.1.4 Rifle Garfield County Regional Airport (RIL)

4.1.4.1 Thick Description

Airport Profile and Role.

Rifle Garfield County Regional Airport (RIL) is a "Regional" general aviation airport tis located in the City of Rifle, Colorado. The airport is owned by Garfield County and operated by an appointed airport director and staff members (Rifle, 2015). The airport's location is within the Rocky Mountain Range and is a short drive to nearby ski area.

Rifle Garfield County Airport was identified by in NPIAS as a "Regional" GA airport, and has a role to "support regional economies by connecting communities to statewide and interstate markets." (FAA, 2012, p.12). RIL was the third busiest general aviation airport in Colorado in 2016. RIL is an alternative to many higher mountain airports that frequently suffer from weather delays. After nearly $47 million investments in improving the airport's infrastructures (i.e., the runway, taxiway, and apron system), RIL has become "a premier, business jet capable General Aviation (GA) airport in the state of Colorado and the Federal Aviation Administration's (FAA) Northwest Mountain Region" (Rifle, 2015, p.1-1).

Airport Facilities and Operations.

Rifle Garfield County Airport has 517 total acres of airport property. The airport has one runway. Runway 08/26 is 7,000 feet long and 100 feet wide (Rifle, 2015). Rifle Garfield County Airport does not have an air traffic control tower on site. RIL had 69 based aircraft in 2015

including 45 single-engine aircraft, six multi-engine aircraft, nine turboprop engine aircraft, seven jets, and two gliders (GCR, 2015). There were 14,382 airport operations in 2015 (GCR, 2015). Rifle Garfield County Airport has one full-service fixed based operator at the airport, two T-hangars, seven privately owned box hangars, and four FBO hangars.

Rifle Garfield County Airport has three primary revenue sources: aviation-related revenue, non-aeronautical revenues, and non-operating revenues. Aviation-related revenue sources include "hangar land leases, aviation fuel flowage and storage fees, fuel tax reimbursements, tiedown fees, landing fees, and miscellaneous permits fees" (Rifle, 2015, p. 8-2). The non-aeronautical revenue is from the "solar farm, rental cars, water utility reimbursements, sponsorship/economic development, and other miscellaneous fees" (Rifle, 2015, p. 8-2). The non-operating revenue is the interest on income and grant receipts.

According to the CDOT study on airport economic impact, Rifle Garfield County Airport generated approximately $56.9 million per year for the local and regional economy and creates 456 jobs directly and indirectly. These economic contributions consist of "on- and off-airport employment that supports the administration, operation, and maintenance of the airport; activities associated with tenants or businesses at each airport; on-airport investment in improvements; and off-airport spending by visitors" (Rifle, 2016, p. 25) Rifle Garfield County Airport data are shown in Table 26.

Table 26. Rifle Garfield County Airport data.

Item	Information
Airport Name	Rifle Garfield County Airport
Airport Identifier	RIL
Address	0375 County Road 352, Bldg 2060 Rifle, Colorado 81650
Distance/Direction From Business Center	27 miles from Glenwood Springs, 46 miles to Eagle, 61 miles to Aspen, 65 miles to Grand Junction, and 88 miles to Vail
Owner	Garfield County
Governing Body	Airport Director and Staffs
Size	517 acres
Elevation	5,537 feet (MSL)
Runway	RWY 08/26: 7,000'X 100'
Air Traffic Control Tower	No
Airport Type	General Aviation, Regional
Airport Role	General Aviation
Economic Impact (Total)	[a] $56.9 Million per year, 456 jobs
Based Aircraft	69
Airport Operations	[b] 14,382 (in 2015)
Fixed Base Operators	1
Specialized Aviation Service Operators	None
Hangars	2 T-hangars, 7 privately owned box hangars, and 4 FBO hangars

Note. The airport data are from Rifle (2015). [a] The economic Impact of RIL are from CDOT (2013a). [b] The number of airport operations is from the *FAA Form 5010 Airport Master Record* (GCR, 2015).

Airport Sustainability Perspectives

Rifle Garfield County Airport voluntarily participated in the Colorado Airport Sustainability Program. The airport sustainability plan of RIL was created by using the CDOT General Aviation Airport Sustainability Tool Kit. RIL depicted sustainability in the same way as the Fremont County Airport did in its sustainability plan. RIL referred to ACI-NA's definition and the EONS framework for airport sustainability in its sustainability mission statement as:

> "Sustainability is to maintain and enhance the long-term viability of the Rifle Garfield County Airport in a way that properly balances economic, social, and environmental pressures while still meeting the operational needs of the airport" (Rifle, 2016, p.4)

Rifle Garfield County Airport selected 11 out of the 15 sustainable focus categories that were identified in the CDOT Tool Kit:

- Economic Vitality – Revenue Generation, Expense Generation, Economic Development
- Operational Efficiency – Operations and Maintenance, Asset Management, Business Operations
- Natural Resources – Energy, Climate and Air Quality
- Social Responsibility – Airport User, Community, Noise

Please see Table 24 for a list of all 15 sustainability focus categories.

4.1.4.2 Airport Understanding of Operational Sustainability

Rifle Garfield County Airport identified three sustainability focus categories (Operations and Maintenance, Asset Management, and Business Operations) within the Operational Efficiency pillar of EONS framework. The descriptions of these focuses categories are as same as the descriptions represented in the Fremont County Airport's sustainability plan. Although the

two airports have the same sustainability focus categories, each set different goals within each category. These sustainability goals reflect their unique interests of sustainability. The RIL's sustainable goals and associated metrics are shown in Table 27. Goal 2 of the Operations and Maintenance focus category is to increase airport safety. RIL does not provide specific metrics for measuring the success of this goal (Rifle, 2016). For Goal 1 and Goal 3, the airport does not list the metrics should be used.

Table 27. Sustainability goals and metric for the focus categories within operational efficiency

Focus Category	Goal	Metric
Operations and Maintenance	GOAL 1: "Ensure that new construction at the airport supports long-term, efficient, flexible growth" (p.15).	Not mentioned
	GOAL 2: "Increase airport safety" (p.15).	[a] "Number of …" (p.11).
Asset Management	GOAL 3: "Ensure that new construction at the airport supports long-term, efficient, flexible growth" (p.15).	Not mentioned
Business Operations	GOAL 4: "Increase aeronautical revenue." (p.15).	Revenue change in dollar
	GOAL 5: "Increase airport safety." (p.16).	[a] "Number of …" (p.11).
	GOAL 6: "Increase revenue from aviation fuel sales." (p.16).	"Gallons" (p.11).

Note. The sustainability goals and metrics are from Rifle (2016). [a] No further information is listed on this metric.

4.1.4.3 Thematic Areas of Operational Sustainability for Rifle Garfield County Airport

Safety. Rifle Garfield County Airport regarded safety as a core of its airport operations (Rifle, 2016). The airport established increasing airport safety as a goal in the focus category of both Operation and Maintenance and Business Operations. The activity selected by the airport to reach this goal is to "regularly inspect and maintain facilities, infrastructure, and equipment" (Rifle, 2016, p. 16).

Cost reduction. Rifle Garfield County Airport identified that a benefit of incorporating sustainability is the reduction of operational cost; however, the airport did not establish any specific goal or associated activities for reducing cost (Rifle, 2016).

Incorporation of sustainability practices. Rifle Garfield County Airport identified that operation and maintenance activities are significant opportunities for the incorpertating sustainability practices into airport activities (Rifle, 2016).

Sustainable facilities and infrastructures. Rifle Garfield County Airport selected the focus category of Asset Management to represent its interest and needs within operational efficiency. The airport focuses on integrating sustainability practices into airport new construction projects that "supports long-term, efficient, flexible growth" (Rifle, 2016, p. 15).

Strengthening revenue streams. In the airport sustainability plan, Rifle Garfield County Airport identified its current interest within this category is to increase airport revenue. Rifle Garfield County Airport planned to reach this goal by increasing fuel sales revenues.

4.1.5 Vero Beach Regional Airport (VRB)

4.1.5.1 Thick Description

Airport Profile and Role.

Vero Beach Regional Airport (VRB) is a general aviation airport in the City of Vero Beach, Florida. The airport is owned by the City of Vero Beach and operated by an appointed airport director and staff members (Vero, 2016). Vero Beach Regional Airport was identified by in NPIAS as a "Regional" GA airport that has the role to "support regional economies by connecting communities to statewide and interstate markets." (FAA, 2012, p.12). The airport is a Class I Air Carrier Airport under Federal Aviation Regulations Part 139 serves "all types of scheduled operations of air carrier aircraft designed for at least 31 passenger seats (large air carrier aircraft) and any other type of air carrier operations" (FAA, 2017, para. 7).

Airport Facilities and Operations.

Vero Beach Regional Airport has 1,707 total acres of airport property. The airport has three runways: Runway 04/22 which is 4,974 feet long and 100 feet wide, Runway 12L/ 30R which is 3,504 feet long and 75 feet wide, and Runway 12R/ 30L which is 7,314 feet long and 106 feet wide. Vero Beach Regional Airport has an air traffic control tower that is operated from 7:00 AM until 9:00 PM local time. There were 190 based aircraft in 2017 at the airport including 146 single-engine aircraft, 37 multi-engine aircraft, Six jets, and one helicopter (GCR, 2017c). There were 207,583 airport operations in 2017. There were 122 scheduled air carrier operations (GCR, 2017c). The majority of operations at the airport are general aviation operations including private, flight training, charter, and corporate aircraft operations. Vero Beach Regional Airport has several fixed based operators at the airport including four full-service FBOs (Vero, 2015). The scheduled air carrier the Elite Airways. Vero Beach Regional Airport has five executive box hangars, six medium box hangars, 28 small T-hangars, and eight medium T-hangars. These

hangars are available for leasing. In addition to aviation services, Vero Beach Regional Airport promotes commercial and industrial development by offering land and facilities to non-aviation businesses. Vero Beach Regional Airport data are shown in Table 28.

Table 28. Vero Beach Regional Airport data

Item	Information
Airport Name	Vero Beach Regional Airport
Airport Identifier	VRB
Address	3400 Cherokee Drive Vero Beach, FL 32960
Distance/Direction From Business Center	2 miles NW of Vero Beach
Owner	City of Vero Beach
Governing Body	Airport Commission Airport Director and staffs
Size	1,707 acres
Elevation (MSL)	2,320 feet (MSL)
Number of Runways	3
Long Runway	RWY 06/24: 7,400’ X 100’
Short Runway	RWY 02/20: 5,400’x75’
Air Traffic Control Tower	Yes
Airport Type	FAR Part 139 Class IV, Regional GA
Airport Role	General Aviation and Part 139
Economic Impact (Total)	[a] $129 Million per year, 1,000 jobs
Based Aircraft	252
Airport Operations	[b] 123,048 (in 2014)
Fixed Base Operators	6
Hangars	5 executive box hangars, 6 medium box hangars, 28 small T-hangars, and 8 medium T-hangars

Note. The airport data are from Rifle (2015). [a] The data of economic Impact of VRB are from FDOT (2014). [b] The number of airport operations is from the *FAA Form 5010 Airport Master Record* (GCR, 2017c).

Vero Beach Regional Airport generated approximately $ 469 million annually for the local and regional economy (Florida Department of Transportation, 2014). These economic contributions consist of direct contributions that come from "tenants/businesses located at the airport and construction projects that are undertaken by the airport or by on-site businesses," and indirect contributions associated with spending from air visitors (FDOT, 2014, p. 2).

Airport Sustainability Perspectives

Vero Beach Regional Airport's vision statement defined the meaning of a self-sustaining airport for VRB: "a vibrant, forward-looking regional airport serving the aviation industry and the public; an airport contributes to our local economy while honoring our historic and natural heritage" (Vero, 2016, p. 2). A self-sustaining airport requires the airport to effectively manage the airport's resources: financial, energy, environmental, and community and integrate resources into the airport development (Vero, 2016).

Vero Beach Regional Airport updated its airport master plan and integrated sustainability into its airport planning through a grant from the FAA Sustainable Master Plan Pilot Project. The sustainability mission statement of Vero Beach Regional Airport was not found. VRB adopted the three core principles of the FAA program: "(1) protecting the environment, (2) maintaining high and stable levels of economic growth, and (3) supporting social progress that recognizes all stakeholders' needs—into airport planning" (Vero, 2016, p. 1). These three core principles correspond to the three pillars of the Triple Bottom Line: social, environmental, and financial. The airport defined four key planning priorities, eight focused goals, and fourteen focused actions to support the airport's self-sustaining ability through the collaboration with the airport stakeholders. The four key planning priorities and eight focused goals expressed the critical aspects for VRB to be a self-sustaining airport. These focused actions help the airport to

accomplish its goals. All focused actions identified are tied to multiple focused goals. The priorities and goals are shown in Table 29.

Table 29. The planning priorities and focused goals of VRB

Planning Priority	Focused Goal	Involvement
Overall Master Plan	• "Maintain an up-to-date Airport Layout Plan in compliance with FAA and Florida Department of Transportation (FDOT) regulations • Maintain safe aircraft operations, giving consideration to uncertain federal funding" (p. 7).	• "Planning within the regulatory framework • Safety • Fiscal responsibility" (p. 2).
Financial Responsibility	• "Develop strategies to strengthen existing Airport businesses and attract new businesses to the Airport • Offer competitive Airport rates and charges to local businesses (aeronautical and non-aeronautical) • Evaluate utility development and other infrastructure needs to support existing tenants and candidate parcels identified for development" (p. 7).	• "Local economic driver • Tenant businesses • Sustainable economic base" (p. 2).
Community	• "Instill a sense of community pride in VRB • Be an attractive destination airport" (p. 7).	• "Community planning integration • Community partnerships" (p. 2).
Energy and Environment	• Consider means to reduce energy use in a cost-effective manner" (p. 7).	• "Energy management • Natural resources management" (p. 2).

Note. The planning priorities, focused goals, and the involvements are from Vero (2016).

4.1.5.2 Airport Understanding of Operational Sustainability

Vero Beach Regional Airport did not provide any definition and description of airport operational efficiency or sustainability, and did not identify any activities related to airport operations. The airport, however, stated its role is to "provide safe and efficient facilities to meet the region's aviation needs" (Vero, 2016, p. 1). There were some statements related to

operational efficiency. For example, VRB had a focused action of "Market Vero Beach Regional Airport" (Vero, 2016, p. 14). Kent State Airport had a similar broad strategy to "Market the airport to potential users and tenants" (Kent, 2016, p. 4-37).Vero Beach Regional Airport did not identify any metrics in its sustainability documents.

4.1.5.3 Thematic Areas of Operational Sustainability for Vero Beach Regional Airport

Safety. Vero Beach Regional Airport mentioned that providing a safe environment to aviation users is a part of its airport role. The airport established a focused goal to "maintain safe aircraft operations" (Vero, 2016, p. 8). The sustainable focused actions of "Update and Improve Airport Guiding Documents" and "Enhance Wildlife Management" are identified by the airport to contribute to the achievement of the focus goals. The focused action of "Update and Improve Airport Guiding Documents" involves tracking of airfield incidents and accidents. The focused action of "Enhance Wildlife Management" involves mitigating the safety hazard (Vero, 2016).

Marketing the airport. In the sustainable airport master plan, Vero Beach Regional Airport identified a focused action that involves marketing the airport which is "Market Vero Beach Regional Airport" (Vero, 2016, p. 14). This focused action intends to promote VRB's new businesses to existing tenants to enhance the economic self-sufficiency of the airport. Although Vero Beach Regional Airport did not relate marketing airport to airport operational sustainability, Kent State University Airport had a similar strategy and a similar goal within operational efficiency (Kent, 2016).

Strengthening revenue streams. Vero Beach Regional Airport had three focused actions that contribute to strengthening revenue streams to the airport. These three focused actions are "Restore Scheduled Commercial Air Service" (p. 9), "Develop the Airport Commercial Village" (p. 11), and "Promote the Airport as a Business-Friendly Place" (Vero, 2016, p. 15). Per the

airport, the focused action of “Restore Scheduled Commercial Air Service” contributes to the “financial self-sufficiency” of the airport and supports both the local and regional economies (Vero, 2016, p. 14). VRB identified the focused action of “Develop the Airport Commercial Village” as a way to increase the non-aeronautical revenues of the airport.

Increasing attractiveness for business. Vero Beach Regional Airport created the focused action of Promote the Airport as a “Business-Friendly Place” that supports the “pursuit of attracting new businesses to the Airport and retaining existing businesses” (Vero, 2016, p. 15). Again, VRB did not relate these actions to its airport operational sustainability, yet these actions contribute to enhancing the economic position and competitive advantages of the airport which is the sustainable goal of business operations found in the plans of both Fremont County Airport and Rifle Garfield County Regional Airport (Fremont, 2016 & Rifle, 2016).

4.2 Cross-Case Summary

Through an analysis of the five case-studies, a cross-case summary was developed. This summary resulted in the three common themes and their subcategories, a definition of airport operational sustainability for U.S. GA Regional and Local airports, and a set of performance metrics selected in the sustainability documents from the five cases.

The three common themes and their subcategories were defined through combining and harmonizing the thematic areas of five airport cases. The definition of airport operational sustainability was defined based on the three common themes and their performance goals. The performance metrics were selected based on the measurement context which are the performance goals of the three common themes and the associated subcategories.

4.2.1 Theme One – Operations and Maintenance

Operations and maintenance of the airport facilities occupy most of the airports' staff time and financial resources. There is a great opportunity for including sustainability into airport management and structures through operations and maintenance activities. According to CODT, "Sustainable operation and maintenance of airport facilities and infrastructure support long-term growth and resiliency" (CDOT, 2016, p. 14). The sustainable performance goal of operation and maintenance is to efficiently and sustainably operate and maintain facilities and infrastructure. This goal requires airports to improve the efficiency of the airport facilities and infrastructures, reduce operation cost and time, and ensure a continued safe operating environment for airport users. Therefore, the subcategories within this theme are safety, efficient facility and infrastructure, cost and time reduction, and incorporation of sustainability practices. Figure 3 shows the affinity diagrams used to develop the theme of operations and maintenance.

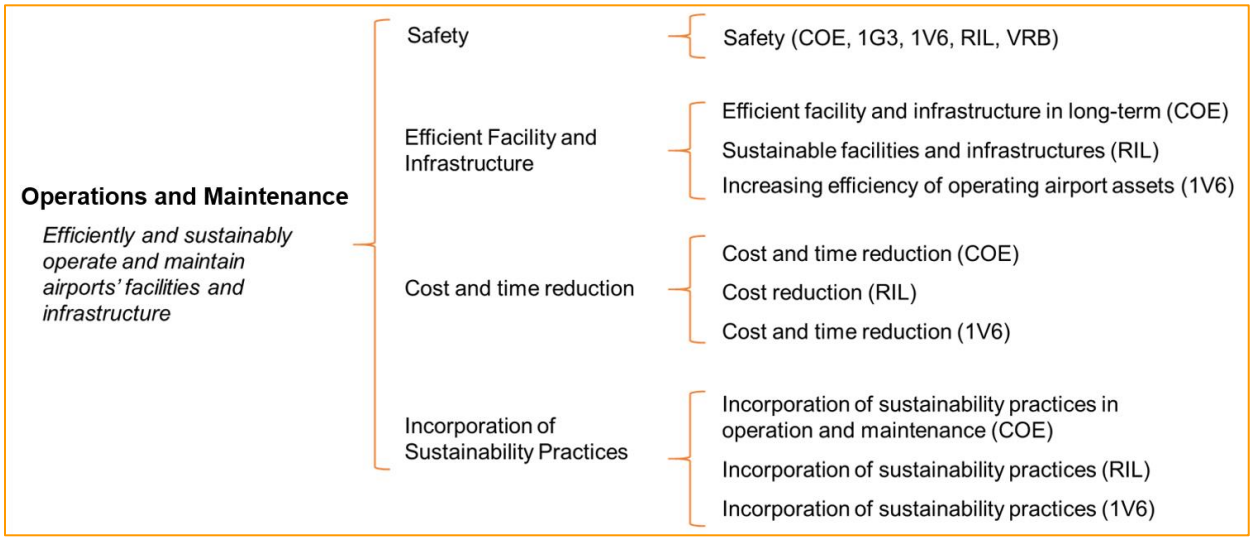

Figure 3. Affinity diagrams used for developing the theme of operations and maintenance

Safety. Safety is a core factor in airport operations. Besides Fremont County Airport and Kent State University Airport, the other three airports selected in this study established sustainable goals to ensure continued safety environment at their airports. Fremont County Airport has stated that operational efficiency "emphasizes the importance of safety and efficiency" (Fremont, 2016, p. 3). Although Kent State University Airport did not have a sustainability goal that tied to operation and maintenance, the airport identified safety as a critical factor for the success of airport operation (Kent, 2016).

Efficient facility and infrastructure. Coeur d'Alene Airport considered efficient facility and infrastructure as a sustainable goal. The goal is to maintain and improve the airport facilities and infrastructure to be efficient for airport users and to support long-term airport growth (Coeur d'Alene, 2016a). For Fremont County Airport and Rifle Garfield Regional Airport, an efficient facility and infrastructure is the responsibility of airport asset management. Vero Beach Regional Airport regarded providing efficient facilities is one part of its airport role (Vero, 2016).

Cost and time reduction. Coeur d'Alene Airport, Fremont County Airport, and Rifle Garfield County Airport each noted that a sustainable airport should reduce the cost and time spent on operations and maintenance. The ways listed by these airports that contribute to the cost and time reduction included increasing the economic life of airport assets, streamline the operation and maintenance activities (Fremont, 2016), and reducing maintenance burden and constraints (Coeur d'Alene, 2016a &Fremont, 2016). Coeur d'Alene Airport planned specific sustainability measures, such as energy-saving strategies a potential way to reduce costs (Coeur d'Alene, 2016a). Kent State University Airport had a goal to increase the efficiency of operation/ management at the airport. This goal was measured by the increase or decrease in airport expenses.

Incorporation of sustainability practices. Fremont County Airport and Rifle Garfield County Airport identified that operations and maintenance activities are significant opportunities for the incorporating sustainability practices into airport activities (Fremont, 2016 & Rifle, 2016). The two airports did not mention specific goals and actions. Coeur d'Alene Airport regards incorporating sustainability practices into operations and maintenance as potential ways to reduce time and cost and to improve the operational efficiency of the airport.

4.2.2 Theme Two – Asset Management

Asset management is a common theme that resulted form based on the understanding of selected airports in this study. Airport assets include airport physical properties, such as land, facilities, and infrastructure, and human resources, such as management and operation teams. The Colorado Department of Transportation states that "sustainable construction and investment in land, capital, and human resources can contribute to a thriving airport and community" (CDOT, 2016, p. 14). The sustainable performance goal of asset management is to efficiently and sustainably develop and promote assets and employees. To achieve excellent performance on sustainable asset management, airport operators are required to efficiently manage the airport properties and employees (Fremont, 2016 & Rifle, 2016). Within the theme of asset management, two subcategories are selected to improve the efficiency and sustainability of facility and infrastructure, and to promote the efficiency, capability, and well-being of employees. The affinity diagrams used for developing the theme of asset management is shown as Figure 4.

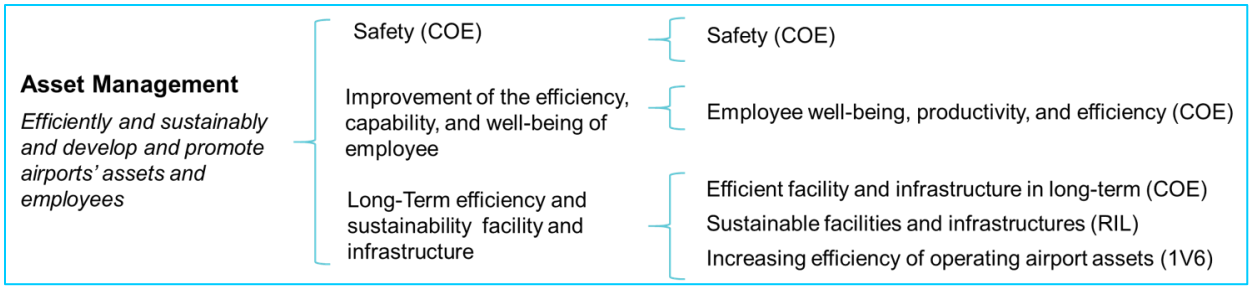

Figure 4. Affinity diagrams used for developing the theme of asset management

Safety. Coeur d'Alene Airport includes safety as a topic of the training programs for the airport employees (Coeur d'Alene, 2016a). Safety is a core value of airport operations and should be included in the long-term planning process of airport facility and infrastructure. To represent this idea, safety is considered as a subcategory of the theme of asset management.

Long-term efficiency and sustainability of facility and infrastructure. Fremont County Airport and Rifle Garfield County Airport focused on "sustainable construction and investment in land, capital, and human resources" (Fremont, 2016, p. 8 & Rifle, 2016, p. 8). Fremont County Airport intends to improve the "average operating and economic life of the airport assets" (Fremont, 2016, p.15). This goal was planned to be achieved by developing a maintenance management plan. Rifle Garfield County Airport aimed to integrate sustainability practices into airport new construction projects that "supports long-term, efficient, flexible growth" (Rifle, 2016, p. 15). Coeur d'Alene Airport committed to keeping its facilities and infrastructures that to be efficient and compatible in a long-term. The achievement of this target involves the incorporation of sustainability practices into the plan, design, and contracting processes of airport projects (Coeur d'Alene, 2016a).

Improvement of the efficiency, capability, and well-being of employee. Fremont County Airport and Rifle Garfield County Airport consider airport employees is part of its asset. The tasks of asset management include efficiently manage the airport's employees. Coeur

d'Alene Airport believed that promoting the productivity and efficiency of airport employees would improve the operational efficiency and safety of the airport. An effective reward, recognition, and promotion structure would promote employees' satisfaction (Coeur d'Alene, 2016a). The implementation of safety, sustainability, and educational training programs would improve employees' capability, efficiency, and productivity (Coeur d'Alene, 2016a).

4.2.3 Theme Three – Business Operations

Business operations is the last common theme within airport operational sustainability in this study. The Colorado Department of Transportation addressed the benefit of "incorporating sustainability principles" into the business operations of airports as maximizing efficiency and allowing "for multiple elements to be factored into decision-making" (CDOT, 2016, p. 14). The sustainable performance goal of business operations is to efficiently and sustainably enhance the economic position and competitive advantages of the airport. Several strategies that were identified by the selected airports in this study can contribute to this goal, including marketing airport, enhancing and establishing business partnerships, increasing attractiveness for business, and strengthening revenue streams. These strategies are also the subcategories within the theme of business operations. Figure 5 shows the affinity diagrams used to develop the theme of business operations.

Safety. Rifle Garfield County Airport was the only airport within the five cases that tied safety to the business operations of the airport. Under its focus category of Business Operations, the airport established a goal to increase the safety at the airport and planned to achieve the goal by regularly inspecting and maintaining the facilities, infrastructure, and equipment.

Figure 5. Affinity diagrams used for developing the theme of business operations

Marketing the airport. The strategy of marketing the airport was used by Kent State University Airport and Vero Beach Regional Airport. The purpose of marketing airport was to increase the financial self-sufficiency and economic stability of the airports (Kent, 2016 & Vero, 2016). Vero Beach Regional Airport planned to market its airport to existing and potential tenants of the airport. The marketing targets for Kent State University Airport were the potential users of the airport and the potential students to the Kent State University aeronautical program.

Establishing business partnerships. Fremont County Airport had a sustainable initiative to establish partnerships with the local agencies, such as "chamber of commerce, economic development, local officials" (Fremont, 2016, p. 13). Fremont County Airport considered the initiative as a way to increase airport revenue and improve the economic position of the airport.

Efficient management/operation. Kent State University Airport established a broad strategy to increase "the efficiency of the Airport's management/operation" as a way to achieve its sustainability goal of being a financially efficient and economically stable airport (Kent, 2016a, p. 4-36). The performance of the airport in this strategy is measured using the increase or decrease in airport expenses.

Increasing attractiveness for business. Vero Beach Regional Airport is the only airport that used the strategy of increasing attractiveness for business. The airport selected a focused action to attract new businesses to the airport and to retain existing businesses by promoting the airport as a "business-friendly place" (Vero, 2016, p. 15). The airport did not relate the strategy to the business operations of the airport, but this strategy was listed as an action that serves to enhance business operations by Fremont County Airport and Rifle Garfield County Airport. Vero Beach Regional Airport believed this action would increase the airport revenue and support "the airport's ability to remain self-sustaining" (Vero, 2016, p. 11).

Strengthening revenue streams. Vero Beach Regional Airport had three focused actions to increase aeronautical and non-aeronautical revenues (Vero, 2016). Kent State University Airport had a sustainable goal to increase airport revenues by establishing new sources of revenue (Kent, 2016a). Rifle Garfield County Airport identified that its interest within business operations is to increase airport revenue. Fremont County Airport planned to increase airport revenue via a series of activities (Fremont, 2016). Rifle Garfield County Airport identified one current interest within business operations as increasing the airport revenue (Rifle, 2016).

Table 30 shows the three themes, their associated subcategories, and the airport contributed to the development of the themes. The five case airports of this study are represented by their airport identify codes. After each subcategory, the airports that contributed to the development of this subcategory are marked.

Table 30. Airports contributed the development of themes and their subcategories

Theme	Subcategory	COE	1G3	1V6	RIL	VRB
Operation and Maintenance	Safety	✓	✓	✓	✓	✓
	Cost and Time Reduction	✓	✓	✓	✓	
	Efficient Facility and Infrastructure	✓		✓	✓	
	Incorporation of Sustainability Practices	✓		✓	✓	
Asset Management	Safety	✓				
	Improvement of the Efficiency, Capability, and Well-Being of Employee	✓		✓	✓	
	Long-term Efficiency and Sustainability Facility and Infrastructure	✓		✓	✓	
Business Operations	Safety				✓	
	Marketing airport		✓			✓
	Establishing business partnerships			✓		
	Efficient Management and Operation	✓	✓			
	Increasing Attractiveness for Business					✓
	Strengthening Revenue Streams enhancement		✓	✓	✓	✓

4.2.4 Definition of Airport Operational Sustainability

The purpose of this study was to develop a definition of airport operational sustainability and associated performance metrics for U.S. Regional and Local GA airports based on the current understanding of airport operational sustainability and existing metrics. The new definition of airport operational sustainability for U.S. General Aviation Regional and Local airports presented this section answered Research Question 1: What are the current understandings of airport operational sustainability among U.S. GA Regional and Local airports; and what would be a synthesized definition of airport operational sustainability for U.S. GA Regional and Local airports?

Three themes and associated subcategories were developed based on the exploration and analysis of the five airports' understanding of airport operational sustainability. A definition of airport operational sustainability for U.S. General Aviation Regional and Local airports is

proposed based on the three themes, their sustainable performance goals, and the five case airports' understandings airport operational sustainability. The definition is:

> *Within the context of EONS, airport operational sustainability is the ability to efficiently and sustainably*
>
> - *operate and maintain facilities and infrastructure,*
> - *develop and promote assets and employees, and*
> - *enhance the economic position and competitive advantages*
>
> *to support the airport's long-term growth and resiliency while maintaining a safe environment for airport users and nearby communities.*

Airport operational sustainability is defined as an ability because Vero Beach Regional Airport defines sustainability as the ability of self-sustaining (Vero, 2016). The word "efficiently" presents the requirement of efficient use of airport assets for airport operations which is mentioned by all the selected airports in this study. The word of "sustainably" expresses the idea of incorporating sustainability practices into airport operations. These words are applied to the following three statements. The statement of "operate and maintain facilities and infrastructure" represents the sustainable performance goal of the theme of operation and maintenance. The statement of "develop assets and promote employees" is the task and the performance goal for the theme of asset management. The statement of "enhance the economic position and competitive advantages" is the performance goal of the theme of business operations. The phrase "support airport's long-term growth and resiliency" is from the CDOT description for the sustainable category of Operation and Maintenance (CDOT, 2016, p. 14). The source of this idea is stated in all five airports' in sustainability documents. The efforts on three themes defined in this study contribute to serving this goal. The phrase of "maintaining a safe

environment for airport users and nearby communities" is used because safety is a core value of airport operations and is mentioned in by all five airports. In the themes of operation and maintenance, safety is a subcategory. In the theme of asset management, safety is a target for promoting airport employees' productivity and efficiency.

Johnson and Gu (2017) defined airport operational sustainability by combining and harmonizing the different viewpoints of airports, aviation organizations, and researchers as "the ability to operate an airport in the most effective and efficient manner to safely move people and cargo while providing improved levels of service and function without increasing the impacts on the environment or compromising the needs and values of the local community" (p. 6). This definition is different from the definition developed in this study. The researcher provides a detailed comparison of these two definitions in Chapter 5.

To improve reliability, the researcher presented and discussed the research process and findings with two aviation graduate students. The coding process was repeated by these two peer researchers, and their results were compared to develop a convergence. The codes and themes that identified by two peer researchers and the researcher represent were very close. The only difference was that one of the peer researchers identified "Long-Term Improvement" as one thematic area in all five cases. The other researchers incorporated "Long-Term Improvement" within the other thematic areas defined for the five cases. Through discussion, all three researchers agreed to include "Long-Term Improvement" as a part of general goal of airport operational sustainability. Please see Appendix C, Thematic Areas Defined by the Three Researchers.

4.2.5 Performance Metrics for Airport Operational Sustainability

A set of performance metrics for airport operational sustainability is developed based on the metrics used by the five airports in this study. This outcome answered Research Question 2: What are performance metrics for airport operational sustainability among U.S. GA Regional and Local airports?

The performance goals of the three themes and the associated subcategories defined in this study established the measurement context for selecting the relevant metrics. Based on this measurement context and the metrics development process shown in Table 15, the researcher developed a set of performance metrics for airport operational sustainability as shown in Table 31. All metrics in this table were from the five case airports in this study.

The metrics were selected for each subcategory were from metrics for the corresponding sustainable subject areas, categories, goals, and actions presented by the five selected airports. For example, Coeur d'Alene Airport has a goal to “enhance sustainability practices for all airport activities as conducted by all involved in the operation of the Airport” (Coeur d’Alene, 2016, p. 8). The goal contributes to the development of the subcategory of incorporation of sustainability practices within the theme of operation and maintenance. Therefore, the metrics used by the Coeur d'Alene Airport to measure the success of this specific goal were selected for the subcategory of incorporation of sustainability practices. Safety as a subcategory was included all three themes.

Table 31. Performance metrics for airport operational sustainability

Theme	Subcategory	Metric
Operation and maintenance	Safety	• [a] "Number of..." (Rifle, 2016, p.11). • "Compliance with current FAA recommendations" (Coeur d'Alene, 2016, p. 14)
	Efficient facility and infrastructure	• Change in annual revenue in percentage /dollars • "Maintenance portion of Airport expenses (field maintenance, equipment maintenance, grounds maintenance, non-eligible infrastructure improvements) • Surveys completed by aircraft operators • Pavement condition index" (Coeur d'Alene, 2016, p. 14).
	Cost and time reduction	• Change in annual expenses in percentage /dollars • "Maintenance portion of Airport expenses" (Coeur d'Alene, 2016, p. 14)
	Incorporation of sustainability practices	• "Number of airport projects that incorporate sustainability practices/number of airport projects" (Coeur d'Alene, 2016, p. 14) • "Maintenance portion of Airport expenses" (Coeur d'Alene, 2016, p. 14)
Asset management	Safety	• "Number of..." (Rifle, 2016, p.11). • "Compliance with current FAA recommendations" (Coeur d'Alene, 2016, p. 14)
	Long-term efficiency and sustainability of facility and infrastructure	• Years of "economic life of airport assets" (Fremont, 2016, p.11) • Change in annual expenses in percentage /dollars
Asset management	Improvement of the efficiency, capability, and well-being of employee	• "Number of training • Amount of funding allotted to professional development/ training • Employee performance reviews • Number of incentive/recognition programs" (Coeur d'Alene, 2016, p. 14)

Table 31 continued

Business operations	Safety	• "Number of..." (Rifle, 2016, p.11) • "Compliance with current FAA recommendations" (Coeur d'Alene, 2016, p. 14)
	Marketing airport	• "Market share of activity (aircraft operations at the airport divided by total GA operations at area airports" (Kent, 2016p. 4-37). • ″Number of based aircraft" (Kent, p. 4-37)
	Establishing business partnerships	• Change in annual revenue in percentage /dollars
	Efficient management and operation	• Change in annual expenses in percentage /dollars
	Increasing attractiveness for business	• Change in annual revenue in percentage /dollars
	Strengthening revenue streams	• "Number of revenue sources (%)" (Kent, 2016, p. 4-36). • Change in annual revenue in percentage /dollars

Note. The metrics are from Kent (2016), Fremont (2016), Coeur d'Alene (2016a), and Rifle (2016). [a] No further information is listed on this metric.

The metrics associated with the subcategories of safety within the two themes are the same. Several metrics used by the selected airports have a similar meaning of "change in annual revenues/expenses in percentage/dollars". Based on these metrics, two metrics for change in annual revenue in percentage/dollars and change in annual expenses in percentage/dollars were created. The metrics selected from the sustainability documents of the five airports are not sufficient. For example, the metrics of "Number of..." is from the Rifle Garfield County Airport's airport sustainability plan (Rifle, 2016, p.11). The airport did not provide any further information on this metric. In the Chapter 5 Discussion, this set of performance metrics is expanded.

4.3 Summary

This chapter presents two outcomes of this study. Research Question 1: What are the current understandings of airport operational sustainability among U.S. GA Regional and Local airports and; what would be a standard definition of airport operational sustainability for U.S. GA Regional and Local airports? To answer the Research Question 1, a definition of airport operational sustainability for U.S. GA Regional and Local airport is proposed. To develop this definition, the researcher first explored the five selected airports' understandings of airport operational sustainability and identified the thematic areas of operational sustainability for each airport via coding and analyzing the data. These thematic areas were combined and harmonized into three common themes and associated subcategories. Finally, a new definition of airport operational sustainability for U.S. GA Regional and Local airport were defined based on the three themes and their performance goals, and the associated subcategories defined in this study.

Research Question 2: What are performance metrics for airport operational sustainability among U.S. GA Regional and Local airports? To answer Research Question 2, a set of performance metrics of airport operational sustainability for U.S. GA Regional and Local airports was developed. The three themes, their performance goals, and the associated subcategories developed in this study established the measurement context for selecting the performance metrics. Based on this measurement context, the performance metrics were chosen from the airport sustainability planning documents of the five airports.

In addition to the outcomes of this study, a thick description of each case was presented in each case summary. The thick description included three sections: airport profile and role, airport facilities and operations, and airport sustainability perspectives. To improve reliability, peer examinations was conducted.

CHAPTER 5. DISCUSSION

This chapter examines the results of this study that answered the two research questions. The new definition of airport operational sustainability for U.S. GA Regional and Local airports is compared with the definition developed in a previous study. The performance metrics selected from the sustainability documents of the five airports are expanded by adding more metrics.

5.1 Comparison between the Two Definition of Airport Operational Sustainability

A definition of airport operational sustainability is proposed in this study based on the understanding of the five GA Regional and Local airports as:

> *Within the context of EONS, the airport operational sustainability is the ability to efficiently and sustainably operate and maintain facilities and infrastructure, develop and promote assets and employees, and enhance the economic position and competitive advantages in order to support airports' long-term growth and resiliency while maintaining a safe environment for airport users and nearby communities.*

The statements, "operate and maintain facilities and infrastructure, develop and promote assets and employees, and enhance the economic position and competitive advantages," respectively represent the performance goals of the three themes defined in this study, which are operations and maintenance, asset management, and business operations.

Through combining and harmonizing the different viewpoints of eight large commercial airports, aviation organizations, and researchers, Johnson and Gu (2017) defined airport operational sustainability as:

> "The ability to operate an airport in the most effective and efficient manner to safely move people and cargo while providing improved levels of service and function without increasing the impacts on the environment or compromising the needs and values of the local community" (p. 6).

These two definitions are different from each other in three ways. First, the objectives of the two studies are different. The new definition of airport operational sustainability in this study was developed based on the understandings of GA Regional and Local airports. The definition of airport operational sustainability created in Johnson and Gu (2017) represented the viewpoints of large commercial airports.

Second, the methodologies of the two studies are different. Johnson and Gu (2017) explored the viewpoints of eight large commercial airport on operational sustainability and harmonized the viewpoints to create a definition of airport operational sustainability. This research was an exploratory multiple-case study. The new definition was developed based on the findings of qualitative analysis and coding process.

Finally, the contents of the two definitions are different. The definition in Johnson and Gu (2017) has a broad goal for airport operational sustainability, which is "to operate an airport in the most effective and efficient manner" (p.6). The definition in this study divides the goals into three statements, which are "to efficiently and sustainably operate and maintain facilities and infrastructure, develop and promote assets and employees, and enhance the economic position and competitive advantages." This new definition presentd more details of the goals of airport operational sustainability which would be helpful for airport operators to evaluate their sustainability performance and to establish the goals for the airport operations.

On the other hand, the two definitions have similar components. Both definitions emphasize the importance of safety. The new definition states that airport operational sustainability includes ability of "maintaining a safe environment." The definition in Johnson and Gu (2017) highlighted the ability to "safely move people and cargo" (p.6). In the new definition, "long-term growth and resiliency" of airports is a general goal of airport operational sustainability. In the definition in Johnson and Gu (2017), the statement of "improved levels of service and function" reflects the meaning of continuing improvement, which is similar to long-term growth.

5.2 Other Findings about Airport Operational Sustainability

Same subcategory in the different themes. Safety in the new definition is a general goal for airport operational sustainability and is identified as a subcategory within all three themes. This situation reflects that the efforts from different themes can contribute to the same sustainable goal. An example of this awareness is that Rifle Garfield County Airport sets a sustainable goal to "ensure that new construction at the airport supports long-term, efficient, flexible growth" both for its operations and maintenance, and its asset management (p. 15).

Different subcategories in the same theme. Each theme of the airport operational sustainability has several subcategories. These subcategories are identified based on the understanding of the five selected airports. Within a theme, the different subcategories represent the diverse interests and needs of airports regarding operational sustainability. While developing airport sustainability plans, airports may select single or multiple subcategories with problems or recognized as targeted areas. However, as measuring the performance of airport operational sustainability, all subcategories should be assessed via comprehensive measurement.

Interaction among the three themes. Each theme may facilitate the airport's performance in the other two themes. For instance, Coeur d'Alene Airport believes identified a strategy of developing and implementing training programs for employees to improve the employees' productivity and capability, and to reduce the operational costs and time at the airport. This strategy is related to the theme of asset management. As the productivity and capability of airport employees improved, the better performance of employees would have positive impacts on operation and maintenance and business operations.

Another example is that Rifle Garfield County Airport sets the same sustainability goal of ensuring the new construction supports long-term, efficient, flexible growth for two sustainable categories: Operations and Maintenance, and Asset Management. The airport plans to "promote efficiency and professional business jet ambiance" by implementing new construction (Rifle, 2016, p. 11). This task required joint efforts from the operation and maintenance and asset management.

Impacts on the other aspects of airport sustainability. The improvement of airport operational sustainability may have positive impacts on the other pillars of airport sustainability. The improvement on the efficiency of operation and maintenance can reduce operational cost and maintenance time and increase the lifecycle of airports' facilities and infrastructure. This improvement would contribute to the economic viability and to the natural resource conservation of the airport. The promotion of employee capability and well-being is also in the effort on airport social responsibility. The performance goal of the theme of business operation is to enhance the economic position and competitive advantages of the airport. Achieving this goal can improve the economic viability of the airport and may contribute to the local and regional economy.

On the other hand, the improvement of airport operational sustainability may have negative impacts on the other pillars of airport sustainability. For example, the use of ground vehicles could improve the efficiency of airport operation, meanwhile the use of ground vehicles has effects on the environment. The promotion of employee capability can increase the working efficiency of airport employees, but the development of training programs may increase the burden on the airport budget. Therefore, the airport management team should consider the potential benefits and loss for the other aspects of airport sustainability, while establishing and evaluating the activities that are related to airport operational sustainability.

Furthermore, the airport management team may consider the benefits for the surrounding communities during the decision-making process because airports have the responsibility to benefit the local communities as the properties of local governments. Vero Beach Airport provided an example of how to contribute to the benefit of the local community in airport planning. Vero Beach Airport planned to improve the Aviation Boulevard which is the primary access to the airport for the community. Vero Beach Airport identified the benefits from this action including increasing community exposure to the airport businesses and reinforcing "the use of Aviation Boulevard as a natural alternative to congested downtown routes, thereby improving the community level of service throughout the roadway network" (Vero, 2016, p. 12). The airport may be not directly benefited from this action, but the action contributes to developing the city and promoting the well-being of the city's residents.

5.3 Expanded Performance Metrics for Airport Operation Sustainability

A set of performance metrics for airport operational sustainability was developed based on the metrics used by the five airports in this study in Chapter 4. Please see Table 31 in Chapter 4. Results. This set of performance metrics, however, is not sufficient to use. For example, Rifle

Garfield County Airport selects “Number of...” as the metric for measuring the performance of safety (Rifle, 2016, p.11). The airport did not state any specific event that should be taken count of (Rifle, 2016). To improve the applicability and flexibility, this metrics set is expanded. The process of performance metrics development shown in Table 15 is conducted. Besides the five airports selected in this study, the sources of sustainability metrics that used in this study are listed in Table 32.

Table 32. Sources of metrics used in the study.

Organization	Programs
Airports Council International	Guide to Airport Performance Measures
Airport Cooperative Research Program	Report 19A: Resource Guide to Airport Performance Indicators
Dallas-Fort Worth International Airport	Airport Sustainability Management Plan
Global Reporting Initiative	GRI Standard with Airport Operators Sector Supplement
Institute for Sustainable Infrastructure	Envision™ Sustainability Rating System
Virginia Department of Aviation	Virginia Airports Sustainability Management Plan

Although the metrics used in this study are from six sources listed in Table 31 and the five case airports, there were many sources of sustainability performance metrics reviewed in this study to establish a pool of candidate metrics. These sources are listed in Appendix B.

Since there numerous metrics are available, materiality was used for choosing metrics in addition to the measurement context. Materiality requires metrics selected in this study to reflect: 1. Significant operational impacts on airports; 2. Substantiality influence on assessment and decisions of stakeholders (GRI, 2014).

In addition, the metrics that are only applicable to commercial airports are disregarded from this selection process. For example, the metric of average departure delay per flight in minutes is not considered in this study. Based on different needs, metrics may be manipulated to meet the requirements for GA airports. For instance, ACI defines a metric, "Number of public injuries per thousand passengers" to measure safety (ACI, 2012, p. 19). Generally, a GA airport does not have a large number of passengers, so the metric is changed to Number of public injuries per thousand/hundred aircraft operations. The number of aircraft operations at GA airports have a vast range. Therefore, airports may choose either thousand or hundred of aircraft operations based on the number of operations that for that particular airport has.

Since all three themes defined in this study have an individual subcategory of safety, there are redundancies and overlaps of the metrics for measuring safety. Therefore, the researcher combined the three subcategories of safety into a single category that is independent from the three themes. The expanded set of performance metrics for airport operational sustainability for U.S. GA Regional and Local airport is shown in Appendix D.

5.4 Summary

The study sought to answer two questions regarding airport operational sustainability for GA Regional and Local airports. To answer THE first research question about the understanding of GA airport on airport operational sustainability, a new definition of airport operational sustainability was proposed. Compared to the definition of airport operational sustainability proposed in Johnson and Gu (2017), the new definition represents the understandings of GA airport and provide more details on the sustainable performance goals regarding airport operations.

By exploring the understandings of five GA airports on airport operational sustainability, the researcher found that the airports may have diverse subject areas within one theme. These subject areas reflected the airports' different interests and needs of operations. On the other hand, the improvement on one subject area, such as safety, may require joint efforts on different themes. Another finding of this study shows was that efforts to improve airport operational sustainability may either benefit or harm the other aspects of airport sustainability. Therefore, the airport may consider the potential benefits and loses to economic, environmental and social pillars during the decision-making process regarding operational sustainability.

To answer the second research question about the performance metrics for airport operational sustainability, a set of performance metrics was developed. However, this set of metrics was not adequate to use. The researcher expanded this metrics set by adding metrics selected from six additional sources of sustainability performance metrics. The expanded metrics set provided more flexibility to airport operators for selecting appropriate metrics.

CHAPTER 6. CONCLUSION

This chapter is divided into three sections: summary of the study, significance, and contribution of research, and recommendations for future research. The summary of the study concludes overall study and presents the final findings. The significance and contribution of research focus on how this research might contribute to the understanding of airport operational sustainability. The recommendations for future research discuss the potential research can be conducted based on the findings of this study.

6.1 Summary of the Study

The two research questions of this research are RQ1: What are the current understandings of airport operational sustainability among U.S. Regional and Local GA airports and what would be a standard definition of airport operational sustainability for U.S. GA Regional and Local airports? and; RQ 2: What are the performance metrics for airport operational sustainability among U.S. Regional and Local GA airports? An exploratory multiple-case study of five GA Regional and Local airports is conducted answer the two questions.

The sustainability documents of these five airports were collected. The understandings of the five airports on airport operational sustainability were explored by coding and analyzing the sustainable categories, goals, actions, and metrics regarding airport operation, and the definitions and descriptions of airport operational sustainability. The researcher combined and harmonized the findings of each single case into one framework and proposed a new definition of airport operational sustainability for U.S GA Regional and Local airport as:

Within the context of EONS, airport operational sustainability is the ability to efficiently and sustainably operate and maintain facilities and infrastructure, develop and promote assets and employees, and enhance the economic position and competitive advantages in order to support the airport's long-term growth and resiliency while maintaining a safe environment for airport users and nearby communities.

This outcome answered the Research Question 1. Three themes and the subcategories for the airport operational sustainability are identified:

- Operation & Maintenance
    - Safety
    - Efficient facility and infrastructure
    - Cost and time reduction
    - Incorporation of sustainability practices
- Asset Management
    - Safety
    - Long-term efficiency and sustainability of facility and infrastructure
    - Improvement of the efficiency, capability, and well-Being of employees
- Business Operations
    - Safety
    - Marketing airport
    - Establishing business partnerships
    - Efficient Management and Operation
    - Increasing Attractiveness for Business
    - Strengthening Revenue Streams enhancement

Based on the new definition, the themes and their performance goals, and subcategories, a set of performance metrics of airport operational sustainability for U.S. GA Regional and Local airports is developed. This performance metrics set answers the Research Question 2. Please see Appendix D to find the whole set of metrics. To ensure the external validity, a thick description is provided for each case of this study. The researcher asked two peer researchers to examine the findings and to repeat the coding process in order to improve the reliability of the research.

6.2 Significance and Contribution of Research

Fundamentally, the contribution and significance of the research is the development of a definition and a set of performance metrics for airport operational sustainability for U.S. GA Regional and Local airports.

While much research exists in the economic and environmental sustainability of airports, few studies focus on operational sustainability (Adler et al., 2013; Gu & Johnson 2018; Johnson & Gu, 2017 & Upham & Mills, 2005). To the knowledge of the researcher, there is not an agreed upon and explicit definition of airport operational sustainability used by airports, aviation organizations, and aviation policy-makers, or an agreed upon a way to assess it. The FAA and SAGA recommend that airports conduct a sustainability baseline assessment before establishing their sustainability focus areas and goals. This new definition will enable GA airports to better understand airport operational sustainability as a part of their planning. In addition to GA Regional and Local airports, the new definition may be useful in expanding the sustainability perspectives for airports in other categories.

Converting sustainability concepts into quantitative decision-making and into sustainability measurement tools for airport operation is a challenge (Gu & Johnson, 2018). This challenge is especially difficult for GA airports because GA airports “lack the expertise and

resources, both financial and labor, to develop and implement sustainability programs" (Martin-Nagle & Klauber, 2015, p. 7). The performance metrics can be used by airport operators to understand and assess operational sustainability, and to improve airport operational sustainability.

This research may be used to inform future research on the effectiveness and impacts of airport sustainability efforts.

6.3 Recommendations for Future Research

This study focused on exploring the understanding of airport operational sustainability for U. S. GA Regional and Local airports. Besides these two types of airports, there are many other categories of airports. The approach used in this study can be applied to define airport operational sustainability and to develop performance metrics for other categories of airports within and outside the United States. Furthermore, the definition proposed in this study can be compared with the definitions of airport operational sustainability for the other airport categories to enhance a deeper understanding of airport operational sustainability.

A set of performance metrics for airport operational sustainability for U.S. GA Regional and Local airport was developed in this research. The applicability of this set of metrics should be examined by the industry. Therefore, the researcher in future may reach out to airport managers of U.S. GA Regional and Local airports to evaluate the applicability of the metrics. The set of metrics will be improved based on the feedback. Also, the metrics for measuring airport operational sustainability of GA airports may be compared with the metrics for measuring airport operational sustainability of commercial airports to investigate the similarities and differences.

Airports that commit to enhancing sustainability progress should track and measure the performance made toward achieving their goals. However, it is a challenge to convert sustainability concepts into quantitative measuring tools (Gu & Johnson, 2018). A quantitative assessment method as a decision-making tool would help airports to evaluate the continued performance of airport operational sustainability, to identify the gaps, to set sustainability goals, and to select the best practices for improving airport operational sustainability. Research looking into this aspect may have broad impacts.

APPENDIX A. CODES

#	Code	Airport	Page
1	Cost effectiveness	Coeur d'Alene (2016)	1
2	Safe facility	Coeur d'Alene (2016)	3
3	Efficient facility	Coeur d'Alene (2016)	3
4	Efficient Facilities and infrastructure in the long term	Coeur d'Alene (2016)	4
5	Continued maintenance and operation of the facilities	Coeur d'Alene (2016)	4
6	Updating/enhancing conditions of airport	Coeur d'Alene (2016)	4
7	Great opportunity for incorporation of sustainability	Coeur d'Alene (2016)	5
8	Reduce time and money	Coeur d'Alene (2016)	5
9	Reduce overall stress on staff	Coeur d'Alene (2016)	5
10	Support long-term growth	Coeur d'Alene (2016)	8
11	Meet user needs and safety regulations	Coeur d'Alene (2016)	8
12	Safe and efficient Airport	Coeur d'Alene (2016)	8
13	Keep facilities, infrastructure, equipment, and signage in good condition	Coeur d'Alene (2016)	8
14	Maximize operational efficiency	Coeur d'Alene (2016)	9
15	Reduce maintenance costs	Coeur d'Alene (2016)	9
16	Improve the environment	Coeur d'Alene (2016)	9
17	Incorporate sustainability practices	Coeur d'Alene (2016)	9
18	Invest in employees	Coeur d'Alene (2016)	9
19	Ensure staff have the training and resources	Coeur d'Alene (2016)	9
20	Continue to safe operation	Coeur d'Alene (2016)	9
21	Promote employee well-being to improve productivity and efficiency	Coeur d'Alene (2016)	9
22	Appreciation of high-quality work	Coeur d'Alene (2016)	9
23	Encourage continual improvement.	Coeur d'Alene (2016)	9
24	Develop and sustain public relations	Coeur d'Alene (2016)	11
25	Building strong relationships with local stakeholders	Coeur d'Alene (2016)	11
26	Cost-savings.	Coeur d'Alene (2016)	16
27	Streamline and reduce maintenance burden	Coeur d'Alene (2016)	16
28	Use sustainability principles to maximize operational efficiency	Coeur d'Alene (2016)	17
29	Employee satisfaction	Coeur d'Alene (2016)	17
30	Employee professional development	Coeur d'Alene (2016)	17
31	Reduce operational costs	Rifle (2016)	2
32	cost-saving	Rifle (2016)	7
33	Continued operation and maintenance	Rifle (2016)	8
34	Keep the airport running	Rifle (2016)	8

35	Improve the operational efficiency of airport assets	Rifle (2016)	8
36	Incorporate sustainable practices	Rifle (2016)	8
37	Improving the overall functionality of the airport	Rifle (2016)	8
38	Improving aircraft operations	Rifle (2016)	8
39	Streamlining maintenance activities	Rifle (2016)	8
40	Ensuring continued safety and service performance	Rifle (2016)	8
41	Sustainable construction and investment in land, capital, and human resources	Rifle (2016)	8
42	thriving airport and community	Rifle (2016)	8
43	Efficiently managing the airport's asset	Rifle (2016)	8
44	Asset Management	Rifle (2016)	8
45	Operations and Maintenance	Rifle (2016)	8
46	Business Operations	Rifle (2016)	8
47	Enhance the airport's economic position and competitive advantages	Rifle (2016)	8
48	Establish business partnerships	Rifle (2016)	8
49	Long-term operating arrangements	Rifle (2016)	8
50	Improve the attractiveness of the airport for business	Rifle (2016)	8
51	Maximizes airport efficiency	Rifle (2016)	8
52	Incorporate multiple elements of sustainability into decision-making	Rifle (2016)	8
53	Employees are critical to the successful operation and growth of airports	Rifle (2016)	8
54	Supports long-term, efficient, flexible growth	Rifle (2016)	11
55	Increase aeronautical revenue	Rifle (2016)	11
56	Improve airport safety	Rifle (2016)	11
57	Market airport	Rifle (2016)	11
58	Increase revenue	Rifle (2016)	11
59	Reduce operational costs	Fremont (2016)	2
60	Cost-saving	Fremont (2016)	7
61	Continued operation and maintenance	Fremont (2016)	8
62	Keep the airport running	Fremont (2016)	8
63	Operational efficiency of airport assets	Fremont (2016)	8
64	Incorporate sustainable practices	Fremont (2016)	8
65	Improving the overall functionality of the airport	Fremont (2016)	8
66	Improving aircraft operations	Fremont (2016)	8
67	streamlining maintenance activities	Fremont (2016)	8
68	Ensuring continued safety and service performance	Fremont (2016)	8
69	Sustainable construction and investment in land, capital, and human resources	Fremont (2016)	8
70	Thriving airport and community	Fremont (2016)	8
71	Efficiently managing the airport's assets	Fremont (2016)	8

72	Asset Management	Fremont (2016)	8
73	Operations and Maintenance	Fremont (2016)	8
74	Business Operations	Fremont (2016)	8
75	Enhance the airport's economic position and competitive advantages	Fremont (2016)	8
76	Establish business partnerships	Fremont (2016)	8
77	Long-term operating arrangements	Fremont (2016)	8
78	Improve the airport attractiveness for business	Fremont (2016)	8
79	Strengthen the airport's revenue streams	Fremont (2016)	8
80	Maximizes airport efficiency	Fremont (2016)	8
81	Incorporate multiple elements of sustainability into decision-making	Fremont (2016)	8
82	Employees are critical to the successful operation and growth of airports	Fremont (2016)	8
83	Improve and streamline existing operations	Fremont (2016)	11
84	Increase aeronautical revenue	Fremont (2016)	11
85	Increase the average operating and economic life of airport assets	Fremont (2016)	11
86	Partner with local agencies	Fremont (2016)	16
87	Emphasizes the importance of improving safety	Kent (2016b)	7
88	Constructability - timeframe, availability of technology, support/partners	Kent (2016b)	7
89	Impact on flight training	Kent (2016b)	7
90	Ownership - sponsorship transferred to another entity	Kent (2016b)	7
91	Management - operational efficiency of any configuration changes	Kent (2016b)	7
92	Reducing operation/management issues	Kent (2016b)	8
93	Optimize operational and maintenance practices	Kent (2016b)	8
94	Increase efficiency of the Airport's management / operation	Kent (2016)	4_36
95	Increase revenue	Kent (2016)	4_37
96	Financially self-sufficient and economically stable	Kent (2016)	4_37
97	Accommodating growth in flight training	Kent (2016)	4_37
98	Market the airport to potential users and tenants	Kent (2016)	4_37
99	Market the airport and Kent State University to potential students	Kent (2016)	4_37
100	Develop/implement key management documents	Kent (2016)	5_30
101	Increase revenue	Kent (2016)	5_30
102	Explore/institute a different management structure	Kent (2016)	5_30
103	Reduce expenses	Kent (2016)	5_30
104	Operate efficiently	Kent (2016)	5_35
105	Maintaining a safe environment	Kent (2016)	5_35
106	Provide safe and efficient facilities	Vero (2016)	2

107	Future capacity and operational needs	Vero (2016)	4
108	Maintain safe aircraft operations	Vero (2016)	8
109	Strengthen airport businesses	Vero (2016)	8
110	Attract new businesses	Vero (2016)	8
111	Increase the airport revenues	Vero (2016)	11
112	Enhanced birport businesses	Vero (2016)	12
113	Market airport	Vero (2016)	14
114	Retaining existing businesses	Vero (2016)	15
115	Promote the airport	Vero (2016)	15
116	Long-term growth	Vero (2016)	19
117	Wildlife management - Safety focused	Vero (2016)	20

APPENDIX B. SOURCE OF PERFORMANCE METRICS

Organization	Programs
Airports Council International	Guide to Airport Performance Measures
Chicago Department of Aviation	Sustainable Airport Manual
Columbus Regional Airport Authority	Capital Program Sustainable Design Guidance Manual
Global Reporting Initiative	GRI Standards with Airport Operators Sector Supplement
Los Angeles World Airports	Sustainable Airport Planning, Design, and Construction Guidelines
Massachusetts Port Authority	Sustainable Design Standards and Guidelines
Association for the Advancement of Sustainability in Higher Education	Sustainability Tracking and Rating System (STARS)
Institute for Sustainable Infrastructure	Envision™ Sustainability Rating System
Sustainable Sites Initiative	Sustainable Sites Initiative: Guidelines and Performance Benchmarks
US Environmental Protection Agency	ENERGY STAR
US Green Buildings Council	Leadership in Energy and Environmental Design (LEED) Rating Systems
Airports Council International	Guide to Airport Performance Measures
Airport Cooperative Research Program	Report 19A: Resource Guide to Airport Performance Indicators
Dallas-Fort Worth International Airport	Airport Sustainability Management Plan
Global Reporting Initiative	GRI Standard with Airport Operators Sector Supplement
Institute for Sustainable Infrastructure	Envision™ Sustainability Rating System
Virginia Department of Aviation	Virginia Airports Sustainability Management Plan

APPENDIX C. THEMATIC AREAS DEFINED BY THE THREE RESEARCHERS

Case	Thematic Area		
	Author	Peer Researcher One	Peer Researcher Two
Coeur d'Alene Airport	• Safety • Efficient facility and infrastructure in long-term • Cost and time reduction • Incorporation of sustainability practices in operation and maintenance • Employee well-being, productivity, and efficiency	• Safety • Efficient facility and infrastructure • Cost reduction • Sustainable operation and maintenance • Employee well-being • Long-Term improvement	• Safety • Long-Term efficiency of facility and infrastructure • Cost reduction • Incorporation of sustainability practices • Employee well-being, productivity, and efficiency
Kent State University Airport	• Safety • Efficient management/operation • Marketing airport • Strengthening revenue streams	• Safety • Efficient operation • Marketing airport • Increase revenue • Long-Term improvement	• Safety • Efficient operation • Marketing airport • Enhancing economic performance
Fremont County Airport	• Safety • Cost and time reduction • Incorporation of sustainability practices • Increasing efficiency of operating airport assets • Strengthening revenue streams and establishing business partnerships	• Safety • Cost reduction • Efficient operation • Establishing business partnerships • Sustainable facilities and infrastructures • Strengthening revenue streams • Long-Term improvement	• Safety • Cost and time reduction • Establishing business partnerships • Increasing efficiency of operation • Sustainable airport assets • Enhancing economic performance

Rifle Garfield County Regional Airport	• Safety • Cost reduction • Incorporation of sustainability practices • Sustainable facilities and infrastructures • Strengthening revenue streams	• Safety • Cost reduction • Sustainable facilities and infrastructures • Strengthening revenue streams • Long-Term improvement	• Safety • Cost reduction • Sustainable and efficient operation • Sustainable facilities and infrastructures • Enhancing economic performance
Vero Beach Regional Airport	• Safety • Marketing airport • Strengthening revenue streams • Increasing attractiveness for business	• Safety • Marketing airport • Strengthening revenue streams • Increasing attractiveness for business • Long-Term improvement	• Safety • Marketing airport • Enhance economic performance • Increasing attractiveness for business

APPENDIX D. PERFORMANCE METRICS FOR AIRPORT OPERATIONAL SUSTAINABILITY

Table D-1. Performance metrics for the theme of operation and maintenance

Theme	Subcategory	Metric
Operation & maintenance	Efficient facility and infrastructure	• Total aircraft operations per employee per year (ACI, 2012). • Operating costs per aircraft operations. (ACI, 2012). • Operating costs per workload units (WU) (ACI, 2016). • Maintenance portion of airport expenses • Operating time of airport facility and infrastructure per aircraft operations. (COE, 2016a). • Surveys completed by aircraft operators (COE, 2016a).
	Cost and time reduction	• Operating costs per thousand /hundred hours worked (ACI, 2012). • Maintenance portion of Airport expenses (COE, 2016a).
	Incorporation of sustainability practices	• "Number of airport projects that incorporate sustainability practices/number of airport projects" (COE, 2016, p. 14) • "Presence of sustainability tracking system" (DFW, 2014, p. 73)

Note. The metrics are from ACI (2012), COE (2016a), and DFW (2014).

Table D-2. Performance metrics for the theme of Asset Management

Theme	Subcategory	Metric
Asset Management	Long-term efficiency and sustainability of facility and infrastructure	• Average age of airport assets (Fremont, 2016) • Years of use beyond standard life for assets (DFW, 2014) • "Number of airport projects that incorporate sustainability practices/number of airport projects" (COE, 2016a, p. 14 & ISI, 2012) • Presence of a long-term operation and maintenance plan" (DFW, 2014, p. 73) • The incorporation of sustainable actions or goals in the airport planning (DOVA, 2016c) • "percentage of products purchased with sustainability attributes (based on dollar value)" (DFW, 2014, p. 49) • Change in annual expenses in percentage /dollars.
	Improvement of the efficiency, capability, and well-Being of employee	• Number of educational training programs for employees (COE, 2016a). • Amount of funding allotted to professional development/ training (ACI, 2012). • Employee performance reviews (COE, 2016a) • "Number of incentive/recognition programs" (COE, 2016a, p. 14) • "Annual employee turnover (The number of employee departures divided by the average number of employees over the course of the year) (Hazel, 2011, p. 143) • "The average level of employee satisfaction based on survey information" (Hazel, 2011, p. 146)

Note. The metrics are from ACI (2012), COE (2016a), DFW (2014), DOVA (2016b), Fremont (2016), Hazel (2011), and ISI (2012).

Table D-3. Performance metrics for the theme of Business operations

Theme	Subcategory	Metric
Business operations	Marketing airport	• "Market share of activity (aircraft operations at the airport divided by total GA operations at area airports" (Kent, 2016p. 4-37). • "Number of based aircraft" (Kent, p. 4-37) • Change in aeronautical revenues collected per aircraft operations (ACI, 2012) • Change in non-aeronautical revenues in percentage /dollars (ACI, 2012)
	Establishing business partnerships	• Change in annual revenue in percentage /dollars • Change in non-aeronautical revenues in percentage/dollars • Number of new Bossiness partnerships
	Efficient management and operation	• Change in annual expenses in percentage /dollars • Foster collaboration and teamwork (ISI, 2012) • Commitment to the principles of sustainability and sustainable performance improvement (ISI, 2012)
	Increasing attractiveness for business	• Change in annual revenue in percentage /dollars • Change in non-aeronautical revenues in percentage/dollars • Change in the number of tenants • Number of new Bossiness
	Strengthening revenue streams	• "Number of revenue sources (%)" (Kent, 2016, p. 4-36). • Change in annual revenue in percentage /dollars • Change in non-aeronautical revenues in percentage/dollars

Note. The metrics are from ACI (2012), ISI (2012), and Kent (2016).

Table D-3. Performance metrics for safety

Combined Category	Metrics
Safety	• Number of aircraft accidents per thousand /hundred aircraft operations (ACI, 2012). • Number of aircraft incidents per thousand /hundred aircraft operations (ACI, 2012). • Number of wildlife strikes per thousand /hundred aircraft operations (GRI, 2014). • Number of public injuries per thousand /hundred aircraft operations (ACI, 2012). • "Occupational injuries per thousand worked (ACI, 2012, p. 16). • "Compliance with current FAA recommendations" (COE, 2016a, p. 14). • Number of safety training programs for employees (COE, 2016a).

Note. The metrics are from ACI (2012), COE (2016a), and GRI (2014). The category of safety is the combination of three subcategories of safety of the three themes defined in this study.

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