



# **2023 Texas Statewide AERR Airport Emissions Inventory and 2011 through 2050 Trend Inventories**

## **FINAL REPORT**

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**Abstract**                    This final report provides details about the development of 2023 statewide airport Emission Inventories (EI) required for submittal to the Environmental Protection Agency (EPA) per 2023 Air Emissions Reporting Requirements (AERR). Tasks involved the development of a comprehensive, statewide, non-road mobile 2023 analysis year aircraft, Ground Support Equipment (GSE), and Auxiliary Power Unit (APU) source category EI required to be submitted to the EPA per the AERR and support revisions to various State Implementation Plans. In addition to the 2023 AERR EI, statewide controlled and uncontrolled trend EIs were also developed by projecting baseline

emissions for all aircraft, GSE, and APU source categories to calendar years 2011 through 2050. TTI developed annual (tons per year) and average summer weekday (tons per day) controlled and uncontrolled EI estimates of Criteria air pollutants (CAP), CAP precursors, and Hazardous Air Pollutants.

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## LIST OF ACRONYMS AND ABBREVIATIONS

<b>Acronym</b>	<b>Definition</b>
AEDT	Aviation Environmental Design Tool
AEO	Annual Energy Outlook
AERR	Air Emissions Reporting Requirements
AMR	FAA's Airport Master Record Dataset
AirNav	A privately owned website that publishes aeronautical and airport information
APU	Auxiliary Power Unit
ASPM	Aviation System Performance Metrics
ASQ/ANSI	American Society for Quality, American National Standard Institute
BTS	Bureau of Transportation Statistics
CAA	Clean Air Act
CAP	Criteria air pollutants
CERS	Consolidated Emissions Reporting Schema
CH <sub>4</sub>	Methane
CNG	Compressed Natural Gas
CO	Carbon monoxide
CO <sub>2</sub>	Carbon dioxide
CSA	Commercial Service Airports
DAL	Dallas Love Field International Airport
DFWIA	Dallas/Fort Worth International Airport
EDMS	Emissions and Dispersion Modeling System
EI	Emission Inventories
EIA	Energy Information Administration's
EIS	Emissions Inventory System
EPA	Environmental Protection Agency
ERG	Eastern Research Group
FAA	Federal Aviation Administration
GSE	Ground Support Equipment
H <sub>2</sub> O	Water
HAP	Hazardous Air Pollutants
HC	Hydrocarbons
LPG	Liquefied Petroleum Gas
LTO	Landing/Takeoff Cycles
MSA	Metropolitan Statistical Area
NAAQS	National Ambient Air Quality Standards
NCTCOG	North Central Texas Council of Governments
NEI	National Emissions Inventory

<b>Acronym</b>	<b>Definition</b>
NEPA	National Environmental Policy Act
NH <sub>3</sub>	Ammonia
NO <sub>x</sub>	Nitrogen oxides
NPIAS	National Plan of Integrated Airport Systems
OPSNET	FAA Air Traffic Operations and Delays Data
Pb	Lead and lead compounds
PM <sub>10</sub> Primary	Primary (filterable + condensable) particulate matter with an aerodynamic diameter equal to or less than 10 microns
PM <sub>2.5</sub> Primary	Primary (filterable + condensable) particulate matter with an aerodynamic diameter equal to or less than 2.5 microns
QA/QC	Quality Assurance and Quality Control
QAPP	Quality Assurance Project Plan
SCC	Source Classification Code
SIP	State Implementation Plans
SO <sub>2</sub>	Sulfur dioxide
SO <sub>x</sub>	Sulfur oxides
TAF	Terminal Area Forecast
TASP	Texas Airport System Plan
TCEQ	Texas Commission on Environmental Quality
TexAER	Texas Air Emissions Repository
TMFSC	Traffic Flow Management System Counts
TOGs	Total Organic Gases
TTI	Texas A&M Transportation Institute
TxDOT	Texas Department of Transportation
U.S.	United States
UHC	Unburned Hydrocarbons
VALE	Voluntary Airport Low Emission
VOC	Volatile organic compounds
XML	Extensible Markup Language

## EXECUTIVE SUMMARY

The Texas Commission on Environmental Quality (TCEQ) is required to submit periodic emission inventories (EIs) for all 254 Texas counties under the Air Emissions Reporting Requirements (AERR) to support the Environmental Protection Agency's (EPA) comprehensive three-year cycle National Emissions Inventory (NEI). Deliverables for this project include the development of the calendar year 2023 aircraft, auxiliary power unit (APU), and ground support equipment (GSE) non-road mobile source EI data required to be submitted to the EPA per the AERR. In addition to the 2023 AERR EI (AERR23), statewide controlled and uncontrolled trend EIs were developed by projecting baseline emissions for all aircraft, APU, and GSE source categories to calendar years 2011 through 2050. The pollutants, reporting categories, spatial scope, and temporal scope are as follows:

- **Pollutants:** Criteria air pollutants (CAP), CAP precursors, hazardous air pollutants (HAPs), and other species of total organic gases (TOGs) reported by the emission modeling software.
- **Reporting Categories:** The emissions sources for this EI include nine aircraft and aircraft-related sources—six for the aviation and aircraft combination types, one for the APU, and two for the GSE (accounting for different fuel types). The sources are represented by EPA's source classification codes (SCC).
- **Spatial scope:** The emissions are computed separately for each facility and aggregated based on the reporting requirements. According to the EPA's AERR guidance, emissions for aircraft are only computed for landing/takeoff cycles (LTO) and capped by a mixing height<sup>1</sup> of 3,000 feet (ft) in altitude above field elevation. An LTO cycle includes taxi-out, climb, landing, and taxi-in.
- **Temporal scope:** The temporal levels of coverage of the EIs are average summer weekday<sup>2</sup> (in units of tons per day) and annual calendar year (in units of tons per year). To develop the required analysis year EIs, the Texas A&M Transportation Institute (TTI) developed 2023 emissions (baseline) using the Federal Aviation Administration's (FAA) latest version of the Aviation Environmental Design Tool

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<sup>1</sup> The height of the atmosphere where relatively vigorous mixing of pollutants and other gases takes place. Directly above the mixing height, the atmosphere is fairly stable and there is limited upward dispersion of polluted air. The mixing height varies both diurnally and seasonally.

<sup>2</sup> Since most of the airports do not report operations on a daily basis, the average summer weekday is estimated by dividing annual emissions by 365.

(AEDT)<sup>3</sup> and projected the emissions to historical and future years by applying the appropriate projection factors.

Based on the activity information, airports were grouped such that priority could be given to the airports with the majority of activity. The airports were divided into the following categories based on the Texas Airport System Plan (TASP) and other attributes from FAA's Airport Master Record (AMR) datasets.

- Commercial Service Airports
- Reliever Airports
- Other TASP Facilities
- Military Airports
- Medical Facility Heliports
- Farm or Ranch Facilities
- Other Public and Private Facilities

The 2023 aircraft activities were first estimated by using the methods developed in TTI's previous study titled "Improving Aircraft Emissions Inventory Development. TCEQ Grant Number 582-21-10369,"[1] and then revised based on the review by airports. The data collected and used in TCEQ's previous airport EI studies [2, 3], such as taxi times and control measures, were updated with more recently obtained activity data when available during the completion of this project. Controlled emissions were obtained by considering two control measures: gate electrification and GSE electrification. Only the facilities where control measure information was available are included. The only difference between the uncontrolled and controlled inventories occurs for the GSE and APU categories.

All facilities were modeled individually by using AEDT. The resulting emissions developed for this study were compared with the aircraft EI reported in the AERR 2020 (AERR20) and the AERR 2017 (AERR17) for reasonableness when applicable. The total percent difference in LTOs between the studies is within two percent. Table 1 and Table 2 show the statewide controlled annual and average summer weekday criteria emissions, respectively.

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<sup>3</sup> AEDT 3F was released on December 13, 2023, and was the latest version of AEDT at the time of this study was conducted.

**Table 1. Statewide Controlled 2023 Annual Emissions by Criteria Pollutant (Tons/Year).**

SCC Description	VOC	NO <sub>x</sub>	CO	PM <sub>10</sub> or PM <sub>2.5</sub>	SO <sub>2</sub>	Pb
Commercial Aviation	1047.25	9337.56	7485.90	119.97	879.35	0.01
Air Taxi: Piston	0.40	0.02	39.32	0.00	0.03	0.02
Air Taxi: Turbine	224.47	1904.71	1047.01	28.44	158.30	-
General Aviation: Piston	502.63	47.60	32367.59	21.52	33.29	19.17
General Aviation: Turbine	1846.24	1165.69	4536.38	35.07	186.34	-
Military	1921.21	1580.51	8995.05	32.13	221.70	0.04
APU	19.54	226.40	395.29	30.36	35.03	-
GSE: Gasoline-fueled	100.73	72.72	3749.22	4.22	0.46	-
GSE: Diesel-fueled	3.54	43.70	14.45	2.36	0.26	-
<b>Total</b>	<b>5666.02</b>	<b>14378.91</b>	<b>58630.21</b>	<b>274.07</b>	<b>1514.76</b>	<b>19.23</b>

VOC = volatile organic compounds; NO<sub>x</sub> = oxides of nitrogen; CO = carbon monoxide; PM<sub>10</sub> = particulate matter of less than 10 microns in diameter; PM<sub>2.5</sub> = particulate matter of less than 2.5 microns in diameter; SO<sub>2</sub> = sulfur dioxide; Pb = Lead.

**Table 2. Statewide Controlled 2023 Summer Weekday Emissions by Criteria Pollutant (Tons/Day).**

SCC Description	VOC	NO <sub>x</sub>	CO	PM <sub>10</sub> or PM <sub>2.5</sub>	SO <sub>2</sub>	Pb
Commercial Aviation	2.86919	25.58237	20.50931	0.32868	2.40918	0.00002
Air Taxi: Piston	0.00110	0.00007	0.10773	0.00001	0.00009	0.00005
Air Taxi: Turbine	0.61498	5.21839	2.86853	0.07791	0.43369	-
General Aviation: Piston	1.37706	0.13041	88.67834	0.05897	0.09121	0.05251
General Aviation: Turbine	5.05820	3.19366	12.42843	0.09608	0.51053	-
Military	5.26358	4.33015	24.64396	0.08801	0.60739	0.00010
APU	0.05354	0.62027	1.08299	0.08317	0.09597	-
GSE: Gasoline-fueled	0.27597	0.19923	10.27184	0.01157	0.00126	-
GSE: Diesel-fueled	0.00971	0.11973	0.03958	0.00646	0.00071	-
<b>Total</b>	<b>15.52334</b>	<b>39.39426</b>	<b>160.63071</b>	<b>0.75087</b>	<b>4.15003</b>	<b>0.05269</b>

# 1 INTRODUCTION

The TCEQ works with local planning districts, the Texas Department of Transportation (TxDOT), and TTI to develop EIs of air pollutants for meeting various regulatory requirements. Per the EPA's AERR, TCEQ is required to prepare and submit a comprehensive statewide periodic EI to support the EPA's NEI every three years. The three-year cycle inventory year for this work was 2023 and is due to the EPA by January 15, 2025.

This report provides details about the development of 2023 statewide airport EIs required for submittal to the EPA per AERR. It covers the tasks involved in the development of a comprehensive, statewide, non-road mobile 2023 analysis year aircraft, GSE, and APU source category EI that is required to be submitted to the EPA per the AERR, and supports revisions to various State Implementation Plans (SIP). In addition to the 2023 AERR EI (AERR23), statewide controlled and uncontrolled trend EIs were also required within the project's scope. These were developed by projecting baseline (i.e., year 2023) emissions for all aircraft, GSE, and APU source categories to calendar years 2011 through 2050. TTI developed annual (tons per year) and average summer weekday (tons per day) controlled and uncontrolled EI estimates of CAPs, CAP precursors, and HAPs.

## 1.1 OBJECTIVE

The purpose of this document is to describe the methodology and data used in the development of aircraft, GSE, and APU source category EIs for all Texas counties with at least one landing facility. The EI development methods described in this document were based on the EPA guidance for estimating non-road mobile airport source emissions. The EIs were developed for each of the analysis years from 2011 through 2050. An annual and average summer weekday controlled and uncontrolled EI is developed for each of these analysis years.

The following are the primary deliverables submitted for the AERR23.

- Statewide AERR23 controlled and uncontrolled EIs for all airport facility sources, including aircraft, APU, and GSE, in a plain text file format. (in **5.4-Deliverable A**)
- Statewide AERR23 controlled and uncontrolled EIs for all airport sources including aircraft, APU, and GSE developed in the Consolidated Emissions Reporting Schema (CERS) Extensible Markup Language (XML) format for loading

into the Texas Air Emissions Repository (TexAER) as non-road sources. (in **5.4-Deliverable B**)

- Statewide AERR23 controlled EI for all airport sources, including aircraft, APUs, and GSE developed in the CERS XML format for loading into the EPA Emissions Inventory System (EIS) as point sources. (in **5.4-Deliverable C**)

The following are the primary deliverables submitted for 2011 through 2050 trend EIs.

- Statewide 2011 through 2050 controlled and uncontrolled annual and ozone season daily EIs for all airport facility sources, including aircraft, APU, and GSE in a plain text file format. (in **5.4-Deliverable A**)
- Statewide 2011 through 2050 controlled and uncontrolled EIs for all airport sources, including aircraft, APUs, and GSE developed in the CERS XML format for loading into TexAER as non-road sources. (in **5.4-Deliverable B**)

## 1.2 EMISSIONS INVENTORY SCOPE

The scope of the EIs to be developed in terms of the emissions sources, their applicable SCC, pollutants, geographic coverage, temporal details, control programs, and the basic emissions estimation methodology is described below.

The AERR23 and 2011 through 2050 trend EIs for airport sources include controlled and uncontrolled emissions estimates for CAPs, CAP precursors, HAPs, and other species of TOGs. Table 3 provides a list of CAPs and CAP precursors. Note that ammonia is not reported in AERR23 as the airport emissions modeling software used (FAA's AEDT) does not provide emissions estimates for ammonia.

**Table 3. Criteria Air Pollutants.**

Pollutant	Description
VOC	Volatile organic compounds
NO <sub>x</sub>	Nitrogen oxides
CO	Carbon monoxide
PM <sub>10</sub> Primary	Primary (filterable + condensable) particulate matter with an aerodynamic diameter equal to or less than 10 microns
PM <sub>2.5</sub> Primary	Primary (filterable + condensable) particulate matter with an aerodynamic diameter equal to or less than 2.5 microns
Pb	Lead and lead compounds
NH <sub>3</sub>	Ammonia
SO <sub>2</sub>	Sulfur dioxide

HAP emissions and other species of TOGs were estimated by applying speciation profiles (or HAP fractions) to the TOG emission estimates obtained from AEDT. The speciation profiles are obtained from the AEDT database. List of Appendices

The appendix for this report includes the following:

Appendix	Title	Description
A	TOG speciated pollutants	This appendix contains an Excel Spreadsheet that lists the HAPs and other TOG-speciated gases included in AERR23 and their mass fraction. This appendix is only available electronically.
B	Airport Contacts	This appendix contains an Excel Spreadsheet that lists the contact information collected. This appendix is only available electronically.
C	2023 LTOs	This appendix contains an Excel Spreadsheet that lists the LTOs from Texas Airports in 2023. This appendix is only available electronically.
D	Fleet Mix	This appendix contains a series Excel Spreadsheet containing the airport LTO and fleet mix from 2011 to 2050. Each analysis year is in its own Excel Spreadsheet. This appendix is only available electronically.
E	Projected LTOs and Fleet Mixes from 2011 to 2050	This appendix contains an Excel Spreadsheet that lists the LTOs from Texas Airports from 2011 through 2050. This appendix is only available electronically.
F	ASIF and AEDT Results	This appendix contains 6 files: 3 XML and 3 CSV for each of commercial reliever TASP, noncommercial reliever TASP, and unsimulated airport. This appendix is only available electronically.
G	Uncontrolled Annual and Daily County-Level Emissions for Texas	This appendix contains 2 CSV file representing the annual and daily uncontrolled emissions inventory for 2011 through 2050 by county. This appendix is only available electronically.
H	Controlled Annual and Daily County-Level Emissions for Texas	This appendix contains 2 CSV file representing the annual and daily controlled emissions inventory for 2011 through 2050 by county. This appendix is only available electronically.
I	Uncontrolled and Controlled Emission Raw Data	This appendix contains the raw uncontrolled and controlled emissions data. This appendix is only available electronically.

Appendix A lists the HAPs and other TOG-speciated gases included in AERR23 and their mass fraction.

This study used EPA’s guidance to choose different airport-related sources for which emission estimates are reported separately. The emissions sources for this EI include nine aircraft and aircraft-related sources—six for the aviation and aircraft combination types, one for the APU, and two for the GSE (accounting for different fuel types). AEDT did not provide emissions for compressed natural gas (CNG) and Liquefied petroleum gas (LPG); thus, these SCCs were not reported. The sources are represented by EPA’s SCC listed in Table 4. Emissions for all nine SCCs are reported under the point data category for EPA’s AERR submission. Pollutants emitted by one source might not be by others, depending on the fuel used by different sources.

**Table 4. Airport Emissions Sources by SCC per EPA.**

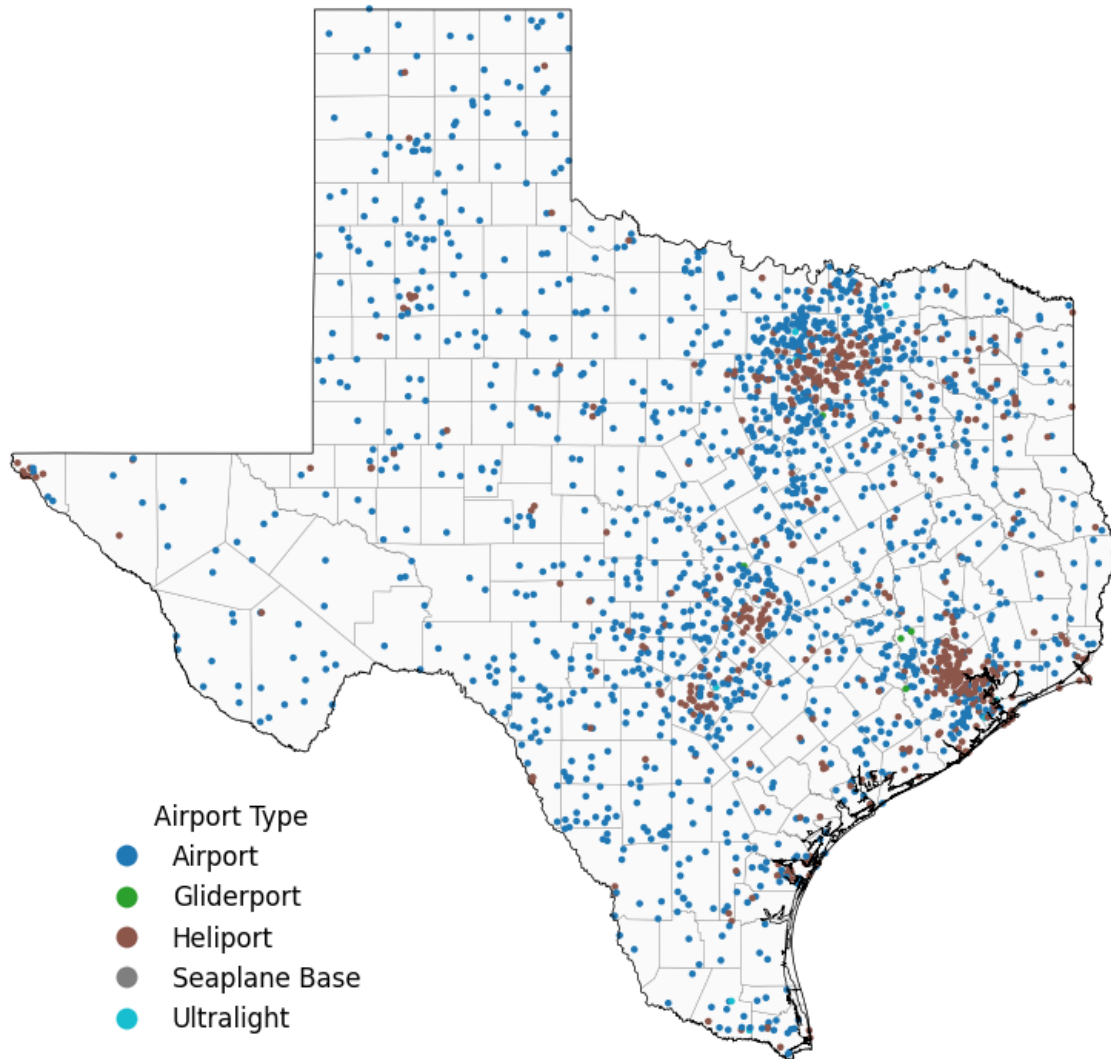
SCC	SCC Description
2275020000	Commercial Aviation
2275060011	Air taxis: Piston Driven
2275060012	Air taxis: Turbine Driven
2275050011	General Aviation: Piston Driven
2275050012	General Aviation: Turbine Driven
2275001000	Military
2275070000	APUs
2268008005	GSE: Compressed natural gas (CNG)-fueled*
2270008005	GSE: Diesel-fueled
2265008005	GSE: Gasoline-fueled
2267008005	GSE: Liquefied petroleum gas (LPG)-fueled**

\*AEDT does not provide emissions for GSE: CNG-fueled and GSE: LPG-fueled SCC.

The emissions are computed separately for each facility and reported at the individual facility level for the EPA’s EIS XML reporting. The emissions are aggregated to the county level for TexAER reporting. Figure 1 shows the map of all Texas airport facilities. The geographical scope encompasses all 254 Texas counties and all landing facilities within those counties. The landing facilities considered in AERR23 cover 250 Texas counties.

The temporal levels of coverage of the EIs are average daily (in units of tons per day) and annual calendar year (in units of tons per year). The average summer weekday is an average Monday through Friday for the June through August period.

According to the EPA's AERR guidance, aircraft source emissions are computed for LTOs and capped by a mixing height of 3,000 feet in altitude above field elevation. An LTO cycle includes taxi-out, climb, landing, and taxi-in.



**Figure 1. Texas Counties Airport Map.**

## 1.3 ORGANIZATION

This report is organized as follows:

- **Section 2** provides the background on the relevant regulations that warranted these EIs, major aircraft emission processes for EIs, control strategies, and prior studies on aircraft emissions development.
- **Section 3** provides an overview of the methodology for developing the EIs.
- **Section 4** delineates the various datasets used in AERR23 and provides details on the finalized data used.
- **Section 5** details the emission modeling procedure. It provides an overview of AEDT and expounds on the AEDT model parameters used for different facility groups.
- **Section 6** provides information on the development and preparation of reporting files per appropriate guidance and following the requests of the TCEQ project manager.
  - 2011 through 2050 electronic activity data reporting files for all source categories per guidance provided by EPA.
  - Statewide AERR23 for all airport sources in the CERS XML format suitable for loading into TCEQ's TexAER as non-road sources and EPA's EIS as point sources.
  - Statewide trend EIs in the CERS XML format are suitable for loading into TexAER as non-road sources.
- **Section 7** provides information on the quality assurance and quality control (QA/QC) procedures and project management processes employed to develop airport EIs.

## 2 BACKGROUND

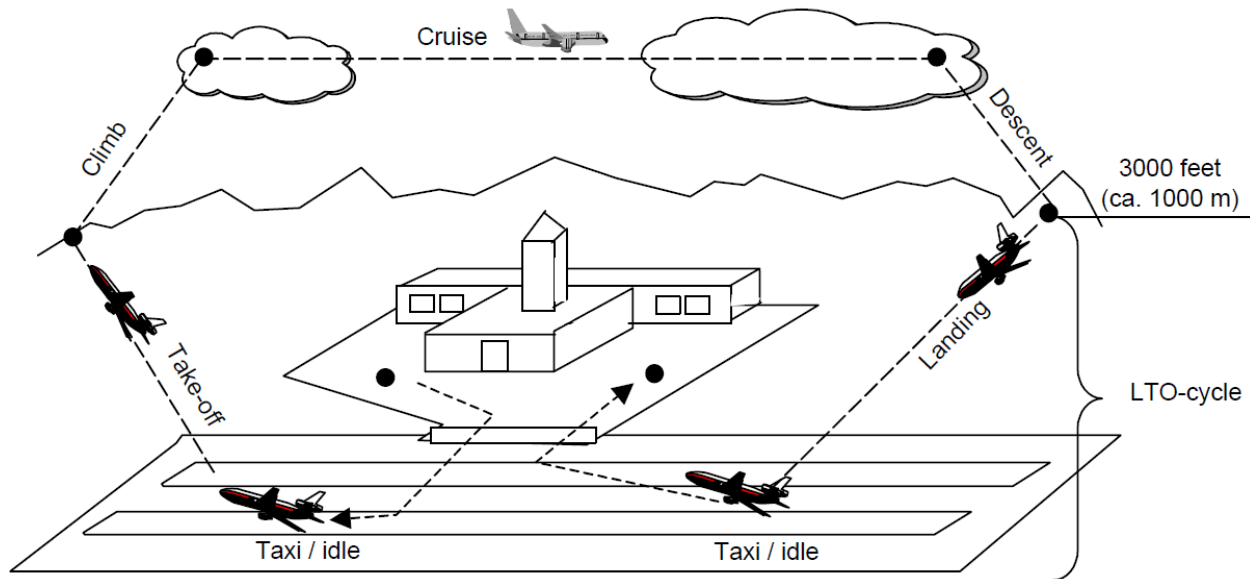
This section provides background on the pertinent regulations warranting aircraft and airport equipment EI development, an overview of airport emissions, and a synthesis of the literature on previous airport EIs developed for Texas.

### 2.1 REGULATIONS

There are several regulations governing aircraft emissions at the federal and state levels. Under the Clean Air Act (CAA), the EPA sets the national ambient air quality standards (NAAQS) for six CAPs: NO<sub>2</sub>, SO<sub>2</sub>, PM, CO, O<sub>3</sub>, and Pb [4]. The FAA enforces EPA's aircraft engine emissions standards through its certification regulations. In addition to these regulatory standards at the federal level, several permitting programs are administered by state agencies. The National Environmental Policy Act (NEPA) [5] applies to airport construction projects to ensure that the projected project emissions in the nonattainment areas conform to the respective SIPs. TCEQ is required under the CAA to determine how best to meet the CAA goals through developing SIPs to achieve the NAAQS. The process of determining compliance with the SIPs requires accurate quantification of the emissions from existing airport operations and other related emission sources, including the use of APUs and GSE. Aircraft Emissions

The majority of airport emissions can be attributed to aircraft operations (shown in Figure 2) that can be broadly classified into two categories based on the altitude at which they occur [6].

- LTO: this corresponds to all operations below an altitude of 3,000 feet (about 915 meters) above field elevation. These operations correspond to taxi-in, taxi-out, takeoff, and landing.
- Cruise: this corresponds to operations that occur above an altitude of 3,000 feet (about 915 meters) above field elevation and include a climb to cruise altitude, cruise, and descent from the cruise.



**Figure 2. Aircraft Operations.**

Per the EPA's AERR guidance, this study only computed the emissions from LTOs—capped by a mixing height of 3,000 feet.

Key pollutants released by aircraft are  $\text{CO}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{NO}_x$ ,  $\text{SO}_x$ ,  $\text{CO}$ ,  $\text{PM}$ , partially combusted or unburned hydrocarbons (HC), and other trace compounds. Except for  $\text{CO}$  and HCs, most aircraft emissions (approximately 70-90 percent) are released during aircraft operations that occur at 3,000 feet or higher altitudes. The remaining airport emissions are released during ground-level operations and operations that occur below 3,000 feet. Most  $\text{CO}$  and HC emissions (approximately 70 percent) are released during ground-level operations when engines operate at their lowest combustion efficiency. The remaining emissions of these pollutants occur during operations above 3,000 feet [7]. The different aircraft pollutant emissions and their sources are described in Table 5. The total emissions depend on three main factors, namely 1) fuel composition, especially the presence of sulfur and complex compounds that reduce the combustion efficiency, 2) aircraft operations related to the amount of time, efficiency, and fuel spent during different operations, and 3) aircraft construction material and technological sophistication.

**Table 5. Aircraft and Related Emissions**

Pollutant	Description	Emission Source
CO <sub>2</sub>	Carbon dioxide is the product of the complete combustion of hydrocarbon fuels like gasoline, jet fuel, and diesel. Carbon in the fuel combines with oxygen in the air to produce CO <sub>2</sub> .	Aircraft, APUs, GSEs, vehicles, stationary power plants, construction equipment
H <sub>2</sub> O	Water vapor is the other product of complete combustion as hydrogen in the fuel combines with oxygen in the air to produce H <sub>2</sub> O. This is the source of water in condensation trails (contrails).	Aircraft, APUs, GSE, vehicles, stationary power plants, construction equipment
NO <sub>x</sub>	Nitrogen oxides are produced when air passes through high temperature/high-pressure combustion, and nitrogen and oxygen present in the air combine to form NO <sub>x</sub> . NO <sub>x</sub> contributes to ozone and secondary particulate matter formation.	Aircraft, APUs, GSE, vehicles, stationary power plants, construction equipment
HC	Hydrocarbons are emitted due to incomplete fuel combustion. They are often referred to as unburned hydrocarbons (UHC) or volatile organic compounds (VOCs). Some of the compounds in the HC emissions are toxic and hazardous air pollutants (HAPs). HC contributes to ozone formation.	Aircraft, APUs, GSE, vehicles, stationary power plants, construction equipment
CH <sub>4</sub>	Methane is the most basic hydrocarbon. Commercial aircraft are net consumers of methane while cruising and are not listed in the emissions source column. The net impact of methane from airport sources is highly dependent on local circumstances.	APUs, GSE, vehicles, stationary power plants, construction equipment
CO	Carbon monoxide is formed due to the incomplete combustion of the carbon in the fuel. CO contributes to ozone formation.	Aircraft, GSE, vehicles, construction equipment
SO <sub>x</sub>	Sulfur oxides are produced when small quantities of sulfur, present in essentially all petroleum fuels, combine with oxygen from the air during combustion. SO <sub>x</sub> contributes to secondary particulate matter formation.	Aircraft, APUs, GSE, construction equipment
PM	Particulate matter is small particles of soot (a.k.a. black carbon) formed due to incomplete combustion.	Aircraft, APUs, GSE, vehicles, stationary power plants, construction equipment

Adapted from *Aviation Emissions, Impacts, and Mitigation: A Primer* [8]

## 2.2 CONTROL STRATEGIES

To reduce emissions from aircraft operations and GSE, several emissions control measures have been implemented. These measures include using hybrid, electric,

compressed natural gas, and alternative fuel vehicles. The FAA and EPA initiated the Voluntary Airport Low Emission (VALE) program which encourages airports to use low-emission vehicles, develop infrastructure for alternative fuels, supply gate electricity and air for parked aircraft, and other emission reduction options [9]. In addition to emissions from aircraft operations, emission reductions associated with these emission control measures can also be quantified. Information about the VALE program [10] implemented at various airports was also acquired to account for control strategies in the EIs developed for this project.

The use of gate electrification reduces the time APUs are operating during an LTO cycle by a percentage identified by the airport personnel. APU emission estimates for aircraft operations can be acquired directly from the AEDT model. The uncontrolled APU emission estimates from the AEDT were reduced by the APU percentage usage reduction reported by the airports to reflect the use of electricity and preconditioned air.

## 2.3 PRIOR STUDIES

The following sections provide details for previous airport EI studies conducted for Texas and the Dallas/Fort Worth (DFW) metropolitan area. Five studies were reviewed for this project.

- Eastern Research Group (ERG) 2011 Statewide Airport Emissions Inventory Report
- North Central Texas Council of Governments (NCTCOG) Study, 2011
- ERG Study, 2017; EPA 2017 NEI
- TTI Study, 2021; EPA 2020 NEI
- TTI Study to Improve the Estimation of Airport-level Aircraft Activity

The five studies are described below.

### 2.3.1 ERG 2011 Statewide Airport Emissions Inventory Report

The ERG prepared the 2011 EIs for CAPs and HAPs for Texas airports [11] in 2012, excluding the NCTCOG's (DFW Metropolitan Planning Organization) Metropolitan Statistical Area (MSA) counties<sup>4</sup>, to support the SIP and other airport-related inquiries.

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<sup>4</sup> Collin, Dallas, Denton, Ellis, Henderson, Hood, Hunt, Johnson, Kaufman, Parker, Rockwall, and Tarrant counties

ERG acquired the Texas airport activity data from several sources. These sources included US Department of Transportation data (i.e., the T-100 dataset from the Bureau of Transportation Statistics [BTS], the FAA's Terminal Area Forecast [TAF] dataset, and the FAA's AMR), direct contacts with medium and large airports, and by internet searches of airport websites. Out of the total of 35 airports selected for direct contact, which accounted for 32 percent of activity in Texas according to the 2008 Texas airports inventory (excluding airports from the Dallas/Fort Worth area), the response rate consisted of 40 percent of airports reporting 2011 operations data, 26 percent reporting taxi time estimates, and 11 percent reporting control strategies information. For an additional 9 percent of the airports, ERG acquired data by conducting internet searches. Depending on the level of detail available, ERG used two emissions estimation methods. For activity data that included aircraft-specific data (i.e., only commercial aircraft and air taxi aircraft), ERG used the FAA's Emissions and Dispersion Modeling System (EDMS) to estimate emissions. Where aircraft-specific detail was not available, ERG applied a more general approach by aviation type (i.e., air taxis, general aviation, and military).

### **2.3.2 NCTCOG Study, 2011**

NCTCOG in 2011 [12] developed an EI and activity data for airports in the DFW twelve county MSA, which covers Collin, Dallas, Denton, Ellis, Henderson, Hood, Hunt, Johnson, Kaufman, Parker, Rockwall, and Tarrant Counties. The inventory consisted of CAPs, CAP precursors, and HAPs and was used for SIP development.

The data collection process consisted of gathering data from BTS and FAA data sets as described in sections 3.2 and 3.3 and through an online data request application to gather specific inputs and activity data required for emissions modeling. Out of the total of 344 facilities identified providing aviation-related services such as airports, heliports, or glideports, data was obtained for 62 facilities. Among the 62 facilities, Dallas Love Field International Airport (DAL) and Dallas/Fort Worth International Airport (DFW) were identified as major commercial facilities with significant activities. Additionally, 28 facilities were identified as significant airports due to annual operations of more than 18,000 LTOs or being included in the National Plan of Integrated Airport Systems (NPIAS). The remaining 32 airports were grouped as "other" and had less than 18,000 annual operations reported. The resulting activity data was used to model the EIs using the FAA's EDMS.

Activity data were available for medium and large airports and were directly used to estimate emissions. Data gaps for smaller airports, air taxis, general aviation, and military

aircraft were addressed following the EPA's NEI guidance. In addition to activity data, information obtained from emission control strategies was utilized to evaluate these strategies' impact on the EIs.

### **2.3.3 ERG Study, 2017**

Similar to the study conducted in 2011, ERG prepared activity and EIs for aircraft operations to meet EPA's AERR for 2017 [13, 14]. ERG followed the same protocols for activity characterization and emissions estimation as done for the 2011 study. ERG used the FAA's AEDT model for this analysis, replacing the FAA's earlier EDMS for modeling airport emissions. ERG increased the number of airports from which they acquired information through direct contact compared to the previous study. Of the 2,016 airports in Texas, ERG contacted a total of 213 airports and obtained information on the LTO data, taxi times, emission control strategies, and seasonality of activities to help with summertime emissions estimation. Response rates consisted of 23 airports providing operation data, 15 reporting taxi time data, and 9 providing control strategy and seasonality information. The resulting 2017 activity and emissions data were projected using the FAA's TAF datasets.

### **2.3.4 TTI Airport EI Study 2021**

TTI prepared activity and EIs for aircraft operations to meet EPA's AERR for 2020 [13, 14] for Texas landing facilities. TTI followed similar protocols for activity characterization and emissions estimation as done for previous AERRs. TTI used data collected in the study [3] and data sets from FAA, TxDOT, and previous AERRs to develop the AEDT inputs such as aircraft activity and taxi times. The resulting 2017 activity and emissions data were projected using data from the FAA and EIA.

### **2.3.5 TTI Aircraft Activity Study 2022**

Recognizing the challenges in preparing aircraft activity data, TTI has enhanced the methodology used to estimate airport-level LTO cycles and the associated fleet mix. This improved methodology primarily utilizes publicly available data sources.

The methodology comprises two parts:

- A four-level hierarchical approach to estimate LTOs at landing facilities.
- An estimation of the distribution of airframe and engine types for the estimated LTOs.

The aircraft activity estimates derived from this improved methodology were compared with those from AERR20. The total LTOs estimated by the improved method were about 10% higher than those in AERR20, although the LTO estimates for commercial airports were nearly identical in both studies. The improved method estimated the LTO market share by air carriers to be about half of the AERR20 estimate, while the market shares for other user classes were higher than those in AERR20. Additionally, the market share of LTOs by jet-engine aircraft estimated by the improved method was about 10% lower, whereas the market share of LTOs by piston-engine aircraft was about 10% higher. These differences are mainly due to the difference in the methodology and data sets used between the two studies.

### 3 METHODOLOGY

The EI estimation in AERR23 consisted of grouping the facilities into different categories based on the hub sizes and the types of operations. Next, the modeling resolution for different facility groups was selected based on the facility group's data availability and their contribution to the EIs with respect to the emissions from other facility groups. After distributing the facilities into facility groups and determining the modeling resolution, the FAA's latest AEDT tool (version 3F) was used to obtain emission quantities and emission rates. These quantities and rates were then post-processed to develop the EIs.

The following sections describe the facility group categorization, emission modeling, and post-processing.

#### 3.1 FACILITY GROUPS CATEGORIZATION

Airports have different hub sizes (small, medium, and large) that vary by operation. From a modeling and data collection perspective, it was necessary to group these airports to prioritize the airports with the majority of the activity. The FAA's AMR<sup>5</sup> [15] was used to develop facility groups for the 2023 baseline scenario. Information, such as airport size, type, usage, contacts, operations, etc., for 1,956 operational facilities were acquired. These facilities cover 250 counties in Texas. Table 6 provides a breakdown of the airports by facility type and public or private use extracted from the AMR data.

**Table 6. The Number of Airport Facilities in Texas by Facility Type and Use.**

Facility Type	Public-Use	Private-Use
Airport	382	993
Heliport	6	559
Glider port	0	5
Seaplane Base	1	2
Ultralight	0	8
<b>Total</b>	<b>389</b>	<b>1,567</b>

In contrast, 2,032 operational facilities were acquired in the airport EI of AERR 2020. The difference is mainly because of the net number of facilities closed after 2020.

<sup>5</sup> Accessed on February 6<sup>th</sup>, 2024

The airports and heliports in the state that perform an essential role in Texas's economic and social development are identified in the TxDOT's TASP. Two hundred eighty-five airports and three heliports meet the TxDOT requirements of the TASP [16]. All commercial and reliever airports are included in TASP but are considered separately in AERR23 due to their substantial influence on the EIs. Using this information and other attributes from the AMR, the Texas facility list was divided into the following categories.

- Commercial Service Airports
- Reliever Airports
- Other TASP Facilities
- Military Airports
- Medical Facility Heliports
- Farm or Ranch Facilities
- Other Public and Private Facilities

For this study, commercial service airport and reliever airport categories received TTI's greatest focus for data collection and modeling since these have the most emission-generating activity.

The following subsections describe each of these airport categories and detail how they are selected.

### **3.1.1 Commercial Service Airports**

The TASP report provided a list of commercial service airports. These facilities offer scheduled service by major airlines (American, Delta, Continental, Southwest, etc.), national airlines (US Air, etc.), and regional airlines (American Eagle, SkyWest, etc.). A total of 26 Texas facilities fall under this category. These airports support scheduled passenger service by large and medium transport aircraft, defined as those facilities that enplane at least 2,500 - 10,000 passengers annually [16]. All the Commercial Service airports provide access to business jets and commercial jet transport aircraft. TxDOT commercial service airports (in Texas) are listed in Table 7.

**Table 7. Texas Commercial Service Airports.**

<b>Airport ID</b>	<b>Airport Name</b>	<b>Associated City</b>	<b>Associated County</b>
ABI	Abilene Rgnl	Abilene	Taylor
ACT	Waco Rgnl	Waco	McLennan
AMA	Rick Husband Amarillo Intl	Amarillo	Potter
AUS	Austin-Bergstrom Intl	Austin	Travis
BPT	Jack Brooks Rgnl	Beaumont/Port Arthur	Jefferson
BRO	Brownsville/South Padre Island Intl	Brownsville	Cameron
CLL	Easterwood Fld	College Station	Brazos
CRP	Corpus Christi Intl	Corpus Christi	Nueces
DAL	Dallas Love Fld	Dallas	Dallas
DFW	Dallas-Fort Worth Intl	Dallas-Fort Worth	Tarrant
DRT	Del Rio Intl	Del Rio	Val Verde
ELP	El Paso Intl	El Paso	El Paso
GGG	East Texas Rgnl	Longview	Gregg
HOU	William P Hobby	Houston	Harris
HRL	Valley Intl	Harlingen	Cameron
IAH	George Bush Intcntl/Houston	Houston	Harris
ILE	Skylark Fld	Killeen	Bell
LBB	Lubbock Preston Smith Intl	Lubbock	Lubbock
LRD	Laredo Intl	Laredo	Webb
MAF	Midland Intl Air and Space Port	Midland	Midland
MFE	Mc Allen Miller Intl	Mc Allen	Hidalgo
SAT	San Antonio Intl	San Antonio	Bexar
SJT	San Angelo Rgnl/Mathis Fld	San Angelo	Tom Green
SPS	Sheppard Afb/Wichita Falls Muni	Wichita Falls	Wichita
TYR	Tyler Pounds Rgnl	Tyler	Smith
VCT	Victoria Rgnl	Victoria	Victoria

Source: Texas Department of Transportation, Aviation Division, 2010.

### 3.1.2 Reliever Airports

Reliever airports are located within a major metropolitan area and provide alternative airport facilities for general aviation users to relieve congestion at the larger commercial service airports. These were also identified based on the TASP report. There are 25 existing reliever airports in the TASP, as shown in Table 8.

**Table 8. Texas Reliever Airports.**

Airport ID	Airport Name	Associated City	Associated County
ADS	Addison	Dallas	Dallas
AFW	Fort Worth Alliance	Fort Worth	Tarrant
AXH	Houston-Southwest	Houston	Fort Bend
CXO	Conroe-North Houston Rgnl	Houston	Montgomery
DTO	Denton Enterprise	Denton	Denton
DWH	David Wayne Hooks Meml	Houston	Harris
EFD	Ellington	Houston	Harris
FTW	Fort Worth Meacham Intl	Fort Worth	Tarrant
FWS	Fort Worth Spinks	Fort Worth	Tarrant
GKY	Arlington Muni	Arlington	Tarrant
GLS	Scholes Intl At Galveston	Galveston	Galveston
GPM	Grand Prairie Muni	Grand Prairie	Tarrant
GTU	Georgetown Muni	Georgetown	Williamson
HQZ	Mesquite Metro	Mesquite	Dallas
HYI	San Marcos Rgnl	Austin	Caldwell
IWS	West Houston	Houston	Harris
LBX	Texas Gulf Coast Rgnl	Angleton/Lake Jackson	Brazoria
LNC	Lancaster Rgnl	Lancaster	Dallas
LVJ	Pearland Rgnl	Houston	Brazoria
RBD	Dallas Exec	Dallas	Dallas
SGR	Sugar Land Rgnl	Houston	Fort Bend
SKF	Kelly Fld	San Antonio	Bexar
SSF	Stinson Muni	San Antonio	Bexar
T41	La Porte Muni	La Porte	Harris
TKI	McKinney Ntl	Dallas	Collin

Source: Texas Department of Transportation, Aviation Division, 2010

### 3.1.3 Other TASP Facilities

Other TASP facilities (listed as a category in the TASP) include general aviation, business/corporate, community service, basic service, and general aviation heliports. General aviation airports (i.e., airports consisting of all aircraft operations that are not scheduled commercial service or reliever or military) represent most of the facilities included in the “Other” TASP facilities category. This category includes 230 operational airports, which include the following airport types [16].

- **General aviation airports** consist of all aircraft operations that are not scheduled for commercial service or military. The airports that serve this segment of aviation represent many of the facilities included in the TASP.
- **Business/corporate airports** provide access to turboprop and turbojet business aircraft and are located where there is sufficient population or economic activity to support a moderate to a high level of business jet activity and/or to provide capacity in metropolitan areas.
- **Community service airports** provide primary business access to smaller communities throughout the state, add capacity in many metropolitan areas, and provide access to agricultural and mineral production areas.
- **Basic service airports** are located within the service area of commercial service, reliever, business/corporate, or community service airports or may be located in remote areas of the state. These airports typically have very low usage and provide additional convenience for clear weather flying and training operations.
- **General aviation heliports** accommodate helicopters used by individuals, corporations, and helicopter taxi and medical services. Scheduled passenger service may be available if ample demand exists.

### 3.1.4 Military Airports

The military airports include a total of 20 operational<sup>6</sup> facilities that are owned by a branch of the United States military as identified in the AMR. Seventeen of these are listed as private-use airports, and three are listed as private-use heliports.

### 3.1.5 Medical Facility Heliports

Medical facilities were identified from the AMR. A total of 195 facilities were tagged as medical use in the database. All are classified as heliports.

### 3.1.6 Farm or Ranch Facilities

Farm or ranch facilities were identified from the AMR based on facility names (i.e., facility names that contained the word "farm" or "ranch"). A total of 407 facilities were placed in

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<sup>6</sup> Kelly Field airport in San Antonio and Wichita Falls Municipal in Wichita Falls are owned by the military, but fall under reliever and commercial categories respectively, they are not counted in the military category.

this group. Of these, 464 were classified as airports, 20 were as heliports, and two as ultralight facilities.

### 3.1.7 Other Public and Private Facilities

These are catch-all airports that were not included in any of the previous classifications. A total of 1,045 facilities are included in this category. Table 9 provides a breakdown of facilities under this group by facility type and public or private use.

**Table 9. The Number of Other Public and Private Facilities by Type and Use.**

Facility Type	Public-Use	Private-Use
Airport	93	601
Heliport	3	340
Glider port	0	5
Seaplane Base	1	2
Ultralight	0	8
<b>Total</b>	<b>97</b>	<b>956</b>

## 3.2 ACTIVITY DATA

The 2023 aircraft operations, associated projection factors, fleet mix, taxi times, and other critical data elements were estimated or collected for emissions modeling. Detailed activity data was available for commercial and reliever airports. Limited activity data was available for other facility groups; appropriate data reconciliation methods were used to obtain activity data for the facilities within these facility groups.

The following are the various aircraft and airport-equipment activity components that were required for modeling 2023 emissions and projecting the emissions for past and future years. The data chapter provides details on the finalized activity data.

### 3.2.1 Aircraft Activity- LTO

LTO refers to the number of aircraft that land and take off at any airport. LTOs are typically equal to the number of total aircraft operations (the sum of all arrivals and departures, as reported by the airports) divided by 2. Most aircraft go through a similar sequence during a complete operating cycle. Helicopters may combine specific modes such as takeoff and climb-out. The aircraft engines operate at a standard power setting for a given aircraft category during each mode of operation.

### 3.2.2 Projection Factors

Projection factors are used to obtain estimates of aircraft activity for historical and future years. This study collected or/and estimated the aircraft activity and other operation data for 2023. The data was used to develop the 2023 baseline EI. The projection factors were then used to backcast and forecast the 2023 aircraft activity and emissions to other years. The projection factors applied to the AERR23 were mainly based on the operation forecasts in the latest TAF dataset as operation forecasts used by the facilities in their airport master plan are expected to be consistent with the forecasts in the TAF [17].

### 3.2.3 Fleet-Mix Assignments

For a single LTO cycle, aircraft emissions vary considerably depending on the category of aircraft and the resulting typical flight profile. Aircraft activity for each facility is a critical modeling element needed for this study. The AEDT model treats each aircraft as a combination of a specific aircraft type (or airframe) and engine combination. There may be several different engine types available for use for each aircraft type, and emission factors may vary from engine to engine. This study utilized methods developed in the previous study [1] and various data sets from the FAA to assign AEDT equipment (i.e., the combination of AEDT airframe and engine) to the LTOs at each facility.

### 3.2.4 Taxi-In and Taxi-Out Times

Taxi/idle time, whether from the runway to the gate (taxi/idle-in) or from the gate to the runway (taxi/idle-out), depends on the size and layout of the airport, the amount of traffic, or congestion on the ground, and airport-specific operational procedures. Taxi/idle time can vary significantly for each airport throughout the day, as aircraft activity changes, and seasonally, as general travel activity increases and decreases. Airport-specific taxi times can be used to estimate emissions for all modeled airports, where available. The taxi times used for the AERR23 were developed based on those used for development of the previous airport EI in AERR 2020 with updates from the latest FAA data and feedback from facilities.

### 3.2.5 GSE Inventory

The GSE source category comprises vehicles or engines needed to support the aircraft while at the terminal or initiating takeoff. Before aircraft departure, GSEs are present to load baggage, food, and fuel. When an aircraft departs from a gate, a tug may be used

to push or tow the aircraft away from the gate and to the taxiway. Aircraft require a mix of GSE that includes the following:

- External air conditioners
- Compressors to help with engine starts
- Aircraft tractors or tugs
- Baggage tractors
- Belt loaders
- Cabin service trucks
- Catering trucks
- Lavatory trucks
- Water supply trucks
- External generators
- Hydrant fueling trucks

Most of the above-mentioned GSEs are used to support the operations of commercial flight operations. Therefore, in the airport EI in AERR 2020, the GSE emissions were only calculated from commercial and reliever airports. To be consistent with the previous practice, the current AERR 2023 also only included GSE emissions for commercial and reliever airports.

### **3.2.6 APUs**

When large aircraft are on the ground with their engines shut down, they need power and preconditioned air to maintain their operability. If a ground-based power and air source are unavailable, an APU, which is part of the aircraft, is operated. These units are essentially small jet engines, which generate electricity and compressed air. They burn jet fuel and generate exhaust emissions like larger engines. In use, APUs essentially run at full throttle. Some large airports may have converted their APU source of energy to electricity.

Similarly, in the airport EI in AERR 2020, the APU emissions were only calculated from commercial and reliever airports. To be consistent with the previous practice, the current AERR 2023 also only included APU emissions for commercial and reliever airports.

### 3.3 OUTREACH TO TEXAS COMMERCIAL AND RELIEVER AIRPORTS

Ensuring data assurance and quality is a crucial step in the development of the AERR23. To verify that the input data for the AEDT aligns with airport activity, the study team developed a set of Tableau dashboards. These dashboards facilitate data sharing with the airport's administration by centralizing the database and minimizing the effort required for data assessment. The dashboards provide summaries of LTOs (landing and take-off operations), LTO data, LTO projections, fractions of electrified GSE and gate operations, and taxi-in and taxi-out data for users to download and review.

The dashboards are available at <http://u.tamu.edu/Airport-LTO>. As shown in Figure 3, the first page (Home Page) provides a brief description of the study, contact information, a document guide, and navigation buttons for each page.

**Data Review for Texas Aircraft Emission Inventory**

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY | Texas A&M Transportation Institute

**1. Background**  
Welcome to the Aircraft Activity Dashboard.

Our platform is designed to facilitate collaboration among Texas landing facilities, Texas Commission on Environmental Quality (TCEQ), and Texas A&M Transportation Institute (TTI) to develop aircraft emission inventory (EI) for the United States Environmental Protection Agency (EPA) under the 2023 federal Air Emissions Reporting Requirements (AERR) and trend EIs for Texas counties from 2011 to 2050.

Please refer to the **DOCUMENT GUIDE** or reach out to our contacts for more information about our work.

**2. Our objective:**  
Invite you to **review and provide feedback** on our estimates of aircraft activity and emission control measures so that the aircraft emissions at your landing facility could be accurately represented in the 2023 AERR.

**3. For questions or comments, please reach out to:**  
- Tao Li (t-li@tti.tamu.edu)  
- Rodolfo Souza (r-souza@tti.tamu.edu)  
- Madhusudhan Venugopal (m-venugopal@tti.tamu.edu)  
- Palak Paul (palak.paul@tceq.texas.gov)  
- Cody McInn (cody.mcinn@tceq.texas.gov)

**4. Dashboards:**

**4.1 Summary LTO:**  
Top 20 aircraft landing and takeoff operations (LTOs) in each airport for 2023.

**4.2 Data LTO:**  
Download the detailed estimate of LTOs by aircraft airframe and engine (defined in AEDT) and user class for 2023.

**4.3 Data LTO Projection:**  
Download our projections of aircraft LTOs for your landing facility from 2011 to 2050.

**4.4 Data Emission Control:**  
Download the Emission Control Measures (gate and GSE electrification) from 2011 to 2050.

**4.5 Data Taxi Time:**  
Download average "Taxi-in and Taxi-out times" in 2023.

Please select your airport and navigate through different dashboards to review and provide feedback on specific data sets.

If you agree with our estimates, **NO ACTION** is required. Otherwise, please send us your feedback and/or spreadsheets reviewed by **May 31, 2024**. Thank you!

**1. Select Airport**  
Facility ID and Name  
DFW - DALLAS-FORT WORTH INTL

**2. Navigate to Dashboards**

4.1 Summary LTO | 4.2 Data LTO | 4.3 Data LTO Projection | 4.4 Data Emission Control | 4.5 Data Taxi Time

**Figure 3. Home page of the dashboards.**

The study team called all the commercial and reliever airports to inform them about the current study and get the email addresses and responsible names. The contact information collected is available in Appendix B.

On May 1, 2024, the study team sent data review invitations to commercial and reliever airports, followed by a reminder on May 20, 2024. By the end of the review period, feedback was received from the following airports:

- Dallas-Fort Worth International Airport (DFW): The airport administration met with the TTI study team to discuss the data review. They recommended comparing FAA TAF trends with the data provided by DFW and using the higher of the two trends. DFW also supplied detailed information about 2023 flight operation records.
- McKinney National Airport (TKI): The airport administration reviewed the data and suggested revisions to average taxi times and the percentage of GSE electrification. They also informed the TTI study team about plans to install in-pavement electrical plug-in stations for an all-electric Ground Power Unit (GPU) fleet in the future. However, this future GPU fleet is not considered as part of the development of the AERR23 as no specific start date was provided.
- David Wayne Hooks Memorial Airport (DWH): The airport administration reported no discrepancies and confirmed their understanding of most data elements.
- San Antonio International Airport (SAT): The airport approved the operational data but noted a discrepancy between TTI's estimate (5,930) and their database (4,808) for A320 operations. They also provided updates on the gate and GSE electrification.
- Perot Field/Fort Worth Alliance Airport (AFW): The airport contacted the study team to verify the legitimacy of the review request. No further feedback was provided.
- Houston Airport System: The study team's email was forwarded to the Houston Resiliency and Sustainability team, but no further feedback was received.
- Dallas Love Field Airport (DAL): The administration reported difficulties accessing the dashboards. The study team provided the data in an alternative format, confirmed by the airport, but no further feedback was received.

### 3.4 EMISSION MODELING AND POST-PROCESSING

The emissions were estimated using AEDT. TTI modeled 2023 emissions and used projection factors to backcast and forecast the aircraft activity and emissions to other years in the trend analysis.

AEDT does not generate the lead emissions produced by the operations of piston-engine aircraft. Following the practice used in developing the airport EI for AERR20, TTI applied the emission factors for aviation gasoline [18] to estimate lead emissions of piston-engine aircraft used for air taxis and general aviation activity. The following equation is used to estimate lead emissions based on the fuel consumption for each LTO cycle for piston-engine aircraft:

$$E_{pb} = \frac{FC}{D_{Avgas}} \times LC \times Rt = \frac{FC}{2707.946} \times 2.12 \times 0.95 = FC \times 0.000743737$$

Where,

$E_{pb}$  = Lead estimate (tons of lead)

$FC$  = Aviation gas fuel consumption (tons). (AEDT reports fuel consumption in tons.)

$LC$  = Lead content of aviation gas (2.12 grams lead/gallon of fuel)

$Rt$  = Lead retention rate 95 percent

$D_{Avgas}$  = Aviation gas density (2707.946 gram/ gallon at 15°C) [19]

The emissions results were required to be reported by SCC, as listed in Table 4. To aggregate the emissions by aircraft to emissions by SCC, TTI used the TAF, traffic flow management system counts (TFMSC) dataset, and AEDT airframe table to determine the engine types and user class for an aircraft [20]. After adding the respective SCC labels to the aircraft, TTI aggregated the emissions by SCC within each facility.

In addition to adding the SCC labels, TTI used speciation tables from the AEDT database (identical to those provided by EPA) to differentiate the organic gases into various species. List of Appendices

The appendix for this report includes the following:

Appendix	Title	Description
A	TOG speciated pollutants	This appendix contains an Excel Spreadsheet that lists the HAPs and other TOG-speciated gases included in

		AERR23 and their mass fraction. This appendix is only available electronically.
B	Airport Contacts	This appendix contains an Excel Spreadsheet that lists the contact information collected. This appendix is only available electronically.
C	2023 LTOs	This appendix contains an Excel Spreadsheet that lists the LTOs from Texas Airports in 2023. This appendix is only available electronically.
D	Fleet Mix	This appendix contains a series Excel Spreadsheet containing the airport LTO and fleet mix from 2011 to 2050. Each analysis year is in its own Excel Spreadsheet. This appendix is only available electronically.
E	Projected LTOs and Fleet Mixes from 2011 to 2050	This appendix contains an Excel Spreadsheet that lists the LTOs from Texas Airports from 2011 through 2050. This appendix is only available electronically.
F	ASIF and AEDT Results	This appendix contains 6 files: 3 XML and 3 CSV for each of commercial reliever TASP, noncommercial reliever TASP, and unsimulated airport. This appendix is only available electronically.
G	Uncontrolled Annual and Daily County-Level Emissions for Texas	This appendix contains 2 CSV file representing the annual and daily uncontrolled emissions inventory for 2011 through 2050 by county. This appendix is only available electronically.
H	Controlled Annual and Daily County-Level Emissions for Texas	This appendix contains 2 CSV file representing the annual and daily controlled emissions inventory for 2011 through 2050 by county. This appendix is only available electronically.
I	Uncontrolled and Controlled Emission Raw Data	This appendix contains the raw uncontrolled and controlled emissions data. This appendix is only available electronically.

Appendix A provides the TOG speciation profiles used in the AERR23. Note that some pollutants might be present for one category but can be absent for others. This is because these different categories use different fuel types.

Moreover, this study corrected the county assigned for certain airports where the AMR had errors in county assignment. Table 10 shows the facilities with the assigned county from the AMR and the corrected county. The correction is based on a spatial join between the airport coordinates in the AMR and the TxDOT county shapefile [21, 22].

**Table 10. Facility County Correction**

Facility ID	Facility Name	Facility Type	County (AMR)	County (Corrected)
06TS	M SANSOM RANCH	AIRPORT	CASTRO	Concho
08TS	FLYING G RANCH	AIRPORT	ANDERSON	Hill
15TA	J R RANCH	AIRPORT	BURNET	Edwards
16TA	SEVEN SPRINGS	AIRPORT	PECOS	Reeves
19TX	TEXAS CHILDREN HOSPITAL NORTH CAMPUS	HELIPORT	TRAVIS	Williamson
1F7	AIRPARK EAST	AIRPORT	ROCKWALL	Kaufman
1TA1	AREA 142	AIRPORT	ANDERSON	Shackelford
1TE2	BLACK FOREST	HELIPORT	ANDERSON	Montgomery
1XS8	PINON RANCH	AIRPORT	KINNEY	Edwards
22TA	PHARMNALL	AIRPORT	HALL	Hill
22XS	LONGHORN AUX LANDING STRIP	AIRPORT	BELL	Coryell
23XS	SHORTHORN AUX LANDING STRIP	AIRPORT	BELL	Coryell
2TA0	SHALE VALLEY RANCH	AIRPORT	ANDERSON	Burnet
2TE8	STAND FAST	AIRPORT	ANDERSON	Terrell
2TS6	AE139	HELIPORT	ANDERSON	Lamar
4TE1	POLYANNA RANCH	AIRPORT	ANDERSON	Navarro
4TE6	FRANCIS RANCH	AIRPORT	ANDERSON	Bosque
4XA6	MEDICAL CENTER OF SOUTHEAST TEXAS	HELIPORT	ANDERSON	Jefferson
68XA	UTLEY	AIRPORT	ANDERSON	Bastrop
6TA1	SKY RANCH	HELIPORT	HENDERSO N	Van Zandt
6TA3	CULP	AIRPORT	KAUFMAN	Dallas
6TA6	B & S WAREHOUSE	HELIPORT	HOUSTON	Harris
6TA9	ANDERSON RANCH	AIRPORT	ANDERSON	La Salle
72XS	WHITAKER'S LANDING	AIRPORT	LAMAR	Red River
7TX6	KEMAH WATERFRONT	HELIPORT	HARRIS	Galveston

Facility ID	Facility Name	Facility Type	County (AMR)	County (Corrected)
<b>88TS</b>	FORT WOLTERS HELICOPTERS	HELIPORT	PALO PINTO	Parker
<b>9XS7</b>	REEDER	AIRPORT	RAINS	Hunt
<b>TE37</b>	CANYON RANCH	AIRPORT	SUTTON	Edwards
<b>TE70</b>	BFS	AIRPORT	HALE	Floyd
<b>TE72</b>	TAYLOR FLD	AIRPORT	ANDERSON	Cass
<b>TE88</b>	BB AIRPARK	AIRPORT	HOUSTON	Brazoria
<b>TE92</b>	HARDEMAN RANCH	HELIPORT	TARRANT	Denton
<b>TS53</b>	TECMA	HELIPORT	ANDERSON	El Paso
<b>TX45</b>	HAWKEYE HUNTING CLUB	AIRPORT	SHELBY	McLennan
<b>TX59</b>	EDS ADMINISTRATION NR 2	HELIPORT	COLLIN	Hunt
<b>XA40</b>	RICHARDSON RGNL - BUSH HWY	HELIPORT	DALLAS	Collin
<b>XA80</b>	MARTIN ENERGY SVCS HARBOR ISLAND	HELIPORT	SAN PATRICIO	Nueces
<b>XS12</b>	LIBERTY HILL AIR RANCH	AIRPORT	BURNET	Williamson
<b>XS69</b>	HACKBERRY RANCH	AIRPORT	EDWARDS	Real

## 4 AEDT INPUT DATA

Compiled activity data, control strategy information, and airport facility data developed during the previous aircraft, APU, and GSE activity data collection project was used to develop the required modeling input files for use with AEDT and to further process and analyze the output file data as needed [3]. The following section lists the data sources used.

The subsequent sections describe the finalized activity data and control strategies used.

### 4.1 DATA SOURCES

This section describes the various activity data sources. The primary data sources include the BTS, FAA, TxDOT, and Texas facilities. The BTS and FAA provided various activity data, including data on operations, fleet mix, and taxi times. TxDOT resources provided a list of airports that play a significant role in Texas's economic and social development. Several Texas facilities provided their operation data, control measures, and taxi times either on their website or through TTI's data review dashboards.

#### 4.1.1 FAA

The FAA was established by the Federal Aviation Act of 1958 (72 Stat. 731). The agency became a component of the Department of Transportation in 1967 pursuant to the Department of Transportation Act (49 U.S.C. 106). It regulates civil aviation and U.S. commercial space transportation, maintains and operates air traffic control and navigation systems for civil and military aircraft, and develops and administers programs relating to aviation safety and the National Airspace System. It also hosts airport operations and performance data, including historical traffic counts, traffic forecasts of aviation activity, and delay statistics.

The following subsections list the FAA datasets used.

##### *4.1.1.1 Airport Master Record Dataset*

The FAA collects, maintains, and disseminates accurate, complete, and timely airport data for the safe and efficient running of the air transportation system. FAA AMR provides airport-specific data, contact information, and operation counts for public and private-use airports [15]. Airport location, contact information, and other operational information were used from this dataset.

#### 4.1.1.2 TAF Dataset

The TAF dataset includes forecasts for active airports in the NPIAS and contains historical and forecast data for enplanements, airport operations, Terminal Radar Approach Control operations, and based aircraft. TAF data covers 264 FAA-towered airports, 256 Federal contract tower airports, 30 terminal radar approach control facilities, and 2,790 non-FAA airports [23]. TTI extracted, summarized, and analyzed the TAF data for the years 1990 through 2045.

#### 4.1.1.3 Traffic Flow Management System Counts (TMFSC)

The TMFSC provides information on traffic counts by the airport, grouped by aircraft type or by the hour of the day. The TMFSC is valuable from the seasonality and fleet mix standpoint. This data is available for each month of the year by arrival and departure. An initial assessment showed that operations data for major commercial airports such as DFWIA, IAH, DAL, and others closely matched what was published in the TMFSC. In TMFSC, data are arranged by the following:

- flight type (domestic, foreign, US to foreign, foreign to the US)
- source-provided user class (commercial, air taxi, freight, general aviation, military, other)
- value-added equipment type (piston, turbine, jet, helicopter, other)
- value-added equipment weight class (heavy, 757, large jets, medium, small, other)
- business jets
- regional jets

#### 4.1.1.4 Operations Network (OPSNET)

The OPSNET dataset contains the FAA air traffic operations and delays data reported daily. The extracted data provides departure and arrival operations sorted by TMFSC user class [24].

#### 4.1.1.5 Aviation System Performance Metrics (ASPM)

The ASPM provides data on airport weather, runway configuration, and airport arrival and departure rates. This combination of flight and airport information provides a complete picture of air traffic activity for these airports and air carriers. The data also contains actual and unimpeded taxi times by the airport [25].

#### *4.1.1.6 General Aviation and Part 135 Activity Survey*

The General Aviation and Part 135 Activity Survey provides the FAA with information on GA and on-demand Part 135<sup>7</sup> aircraft activity. The survey enables the FAA to monitor the GA fleet so that it can anticipate and meet the demand for National Airspace System (NAS) facilities and services, assess the impact of regulatory changes on the fleet, and implement measures to ensure the safe operation of all aircraft in the NAS.

#### *4.1.1.7 Aircraft Registry*

The FAA's Aircraft Registry collects the information necessary to establish and maintain the record for all United States civil aircraft. Specifically, the registry data contains airframe and engine information of registered aircraft. Each aircraft in the registry has a unique ID (i.e., N-number or tail number), which could be used to link aircraft registry records to aircraft operations in other data sets to estimate fleet mix information.

### **4.1.2 TxDOT Planning Airports**

The TASP prepared by TxDOT helped identify the airports and heliports that play a significant role in Texas's economic and social development [16]. A total of 295 facilities are included in the TASP. Airports with international customs facilities are flagged in the data.

### **4.1.3 Bureau of Transportation Statistics**

The Bureau of Transportation Statistics (BTS) is a part of the U.S. DOT. It was established to provide comprehensive, relevant, and timely statistical information and analysis to inform transportation decision-making. Here are some key points about BTS. The BTS plays a crucial role in supporting evidence-based policy-making and fostering a better understanding of the transportation system in the US.

The following subsection lists the BTS dataset used.

#### *4.1.3.1 Airline Service Quality Performance*

Airline Service Quality Performance (ASQP) provides air carriers with quality of service information. The U.S. certificated air carriers within 1% or more of the total domestic scheduled service passenger revenues (about 17 carriers) are required to report data for flights involving any airport in the 48 contiguous states accounting for 1% or more of

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<sup>7</sup> A Part 135 operator provides commercial, non-scheduled aircraft operations, such as private air charter and air taxi flights.

the domestic scheduled service passenger enplanements. Some of the data elements included are gate departure, gate arrival, wheels-off and wheels-on times, and aircraft tail number.

#### 4.1.4 Texas Facilities

Multiple Texas facilities are tracking aircraft activities and other information such as emission control measures at their facilities. They play a crucial role in providing input data for airport EI development. In the AERR23, major Texas facilities reviewed the inputs prepared by TTI and provided revisions to these inputs. The details are discussed in sections 3.3 and 4.2.1.

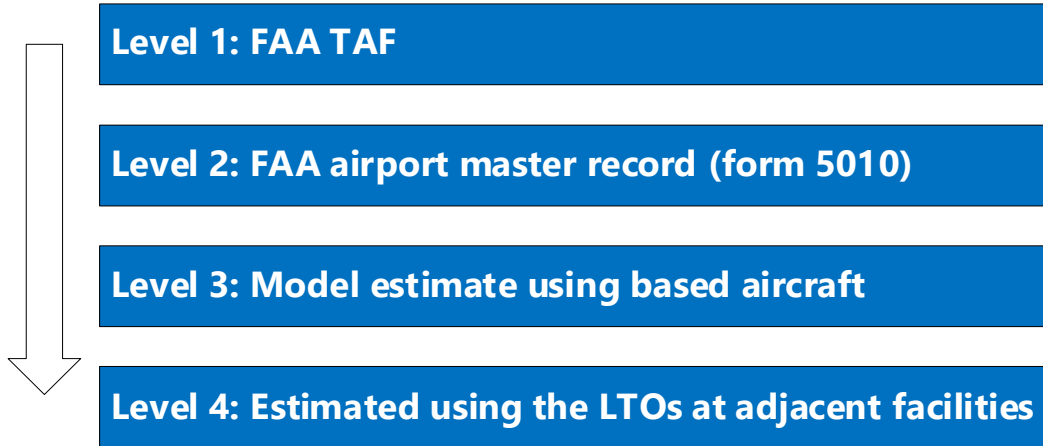
## 4.2 ACTIVITY DATA DEVELOPMENT

The 2023 aircraft operations, taxi times, fleet mix, and projection factors with respect to 2023 operations for each facility group are presented in this section. Due to limited data on APU operating time and GSE activity, default values from AEDT were used for modeling.

### 4.2.1 Aircraft Activity— LTO

The hierarchal approach developed in the study [1] was utilized to estimate the LTOs at facilities.

Figure 4 shows the four levels in the hierarchy, with level one data sources being the most preferred and level four being the least preferred choice for LTO data for a facility. In the first level, LTOs obtained from the TAF have precedence over other sources. In the second level, for airports where TAF data is not available, flight operation data from FAA's AMR is used to generate LTOs. In the third level, for landing facilities where neither TAF nor FAA's AMR provides LTOs, LTOs are estimated using base aircraft and the LTO rate: number of LTOs per aircraft. Base aircraft counts are from FAA's AMR and the LTO per aircraft is from FAA's GA survey data. In the fourth level, for landing facilities that are not captured in the above three sets of sources, LTOs are estimated as the average of the adjacent landing facilities (within a radius) of the same category.



**Figure 4. Methods hierarchy for developing LTOs.**

Table 11 summarizes the landing facilities count within each facility group, whose LTOs were available or were estimated by each data source. About 78% of the total 2023 LTOs are directly from FAA's TAF.

**Table 11. LTOs Generated by Data Source or Method.**

Facility category	LTOs by L 1 (TAF)	LTOs by L 2 (AMR)	LTOs by L 3 (Estimated using based aircraft)	LTOs by L 4 (filled using adjacent facilities)
Commercial	1,641,279	0	0	0
Farm/Ranch	0	28,311	17,785	18,313
Medical	0	1,721	7,088	28,430
Military	0	0	20,012	300,178
Other Private Airports	0	73,925	114,282	49,762
Other Private Heliports	0	2,028	15,903	30,543
Other Public Airports	26,370	271,237	3,277	11,289
Other Public Heliports	0	9	0	3,759
Reliever	1,253,043	0	0	0
TASP	1,201,601	179,633	0	0
<b>Total</b>	<b>4,122,293</b>	<b>556,863</b>	<b>178,346</b>	<b>442,274</b>
<b>Percent of Total</b>	<b>77.78%</b>	<b>10.51%</b>	<b>3.37%</b>	<b>8.35%</b>

Since aircraft operations at commercial airports have a higher impact on the EI, further research was done on commercial airports' websites for their 2023 operational data. Seven airports were found to have their 2023 LTO data reported on their websites. The reported LTOs and their ratios to TTI's LTO estimates for these airports are summarized

in Table 12. The LTOs by air carriers accounted for the majority of the total LTOs, and the reported LTOs by air carriers were slightly higher than TTI's estimates (i.e., LTOs from TAF). For each user class, TTI's 2023 LTO estimates were adjusted by applying the ratio to match the 2023 LTOs reported on the airports' websites.

**Table 12. LTOs by User Class Collected from Airport Website and Adjustment Ratios Applied to LTO Estimates.**

Airport	AC LTO	AT LTO	GA LTO	Mil LTO	AC Ratio	AT Ratio	GA Ratio	Mil Ratio
DFWIA	333,880	8,210	2,625	71	1.027	0.827	0.979	1.195
AUS	100,271	11,911	23,066	2,637	1.019	1.003	0.981	1.073
DAL	74,872	26,508	24,246	368	1.036	0.999	0.988	0.980
CRP	NA	9,331	8,164	26,916	NA	2.698	1.178	1.167
ELP	22,969	6,960	14,680	3,550	1.005	0.946	0.990	1.030
IAH	180,699	26,242	3,985	76	1.024	0.972	0.946	1.126
HOU	59,485	23,937	15,272	284	1.037	1.675	0.612	0.951

AC: air carrier, AT: air taxi, GA: General Aviation, Mil: Military

Table 13 summarizes the 2023 LTOs by facility group.

**Table 13. 2023 LTOs by Facility Group.**

Facility Group	2023 LTO	2023 LTO Percentage
Commercial	1,641,279	30.97%
TASP Airports	1,381,234	26.06%
Reliever	1,253,043	23.64%
Military	320,190	6.04%
Other Public Airports	312,172	5.89%
Other Private Airports	237,968	4.49%
Farm/Ranch	64,410	1.22%
Other Private Heliports	48,473	0.91%
Medical	37,239	0.70%
Other Public Heliports	3,768	0.07%
<b>Total</b>	<b>5,299,776</b>	<b>100.00%</b>

The LTOs developed by TTI in the AERR23 and AERR20, and ERG in the AERR17 were compared. Table 14 shows the differences between the ERG and TTI EI's 2017 LTOs [13]. The total percent difference in LTOs between the studies is within two percent.

**Table 14. 2017 LTOs Comparison among AERR17, AERR20, and AERR23**

Facility Group	2017 AERR17	2017 AERR20	Percent Difference*	2017 AERR23	Percent Difference*
Commercial	1,596,760	1,560,809	-2.25%	1,516,400	-5.03%
Reliever	1,021,636	1,056,668	3.43%	989,296	-3.17%
TASP	1,281,547	1,282,092	0.04%	1,387,202	8.24%
Other	657,227	625,522	-4.82%	705,165	7.29%
<b>All</b>	<b>4,557,171</b>	<b>4,525,110</b>	<b>-0.70%</b>	<b>4,598,062</b>	<b>0.90%</b>

\*Percent difference is calculated by comparing with ERG 2017 LTOs

Table 15 presents the differences of the 2020 and 2023 LTOs between the AERR20 and AERR23. The 2020 (backcasted) and 2023 LTOs in the AERR23 and trend inventories are higher than those in AERR20 and trend inventories. While the difference can be a result of different LTO estimation methods used in the two studies, other factors may also contribute to the difference. Specifically, the 2023 LTOs in AERR23 are 25.9% higher than the 2020 LTOs in AERR20. The increase could also be partially due to the recovery and/or demand growth in air travel from 2020 to 2023. The 2023 LTOs in AERR23 are 15.8% higher than the forecasted 2023 LTOs in AERR20. The difference may be due to the 2023 LTO forecast in AERR20 having been given more weight to the potential impact of COVID-19 on the future air travel demand.

**Table 15. 2020 and 2023 LTOs Comparison between AERR 2020 and 2023.**

Facility Group	2020 AERR20	2020 AERR23	Percent Difference	2023 AERR20	2023 AERR23	Percent Difference
Commercial	1,231,989	1,329,246	7.89%	1,500,834	1,641,279	9.36%
Reliever	1,043,392	1,083,971	3.89%	1,115,564	1,253,043	12.32%
TASP	1,266,325	1,350,002	6.61%	1,292,692	1,381,234	6.85%
Other	669,301	722,392	7.93%	668,511	1,024,221	53.21%
<b>All</b>	<b>4,211,007</b>	<b>4,485,611</b>	<b>6.52%</b>	<b>4,577,601</b>	<b>5,299,776</b>	<b>15.78%</b>

Appendix C shows the 2023 LTOs.

## 4.2.2 Taxi-In and Taxi-Out Times

Taxi-in and taxi-out data sets are dependent on airport traffic, runway alignments, and other airport-specific operational factors. During the previous activity data collection study for the airport EI AERR20, many of the airports contacted did not track this information. For this reason, the TTI study team utilized a hierarchical process of using the airport-reported data as the primary source of information for taxi times, when

available, and employed FAA’s ASPM taxi time dataset for the airports that don’t track taxi times [25]. This study used updated taxi times, based on those used in the AERR20, with the reported values from facilities and the 2023 taxi times in FAA ASPM. Table 16 shows the taxi-in and taxi-out times for commercial and reliever airports. For the facilities where taxi-in and taxi-out times were not available, the defaults in the latest AEDT were used.

**Table 16. Taxi-In and Taxi-Out Times for Commercial/Reliever Airports.**

Facility ID	Facility Name	County	Taxi-out (min)	Taxi-in (min)
ABI	ABILENE RGNL	TAYLOR	12.75	4.15
ACT	WACO RGNL	MC LENNAN	15.1	4.31
AMA	RICK HUSBAND AMARILLO INTL	POTTER	13.69	5.06
AUS	AUSTIN-BERGSTROM INTL	TRAVIS	14.7	8.2
BPT	JACK BROOKS RGNL	JEFFERSON	16.68	5.25
BRO	BROWNSVILLE/SOUTH PADRE ISLAND INTL	CAMERON	14.66	4.93
CLL	EASTERWOOD FIELD	BRAZOS	13.65	4.7
CRP	CORPUS CHRISTI INTL	NUECES	13.94	4.46
DAL	DALLAS LOVE FIELD	DALLAS	12.32	5.27
DFWIA	DALLAS-FORT WORTH INTL	TARRANT	19.67	12.34
DRT	DEL RIO INTL	VAL VERDE	11.14	4.7
ELP	EL PASO INTL	EL PASO	13.77	4.46
GGG	EAST TEXAS RGNL	GREGG	15.74	5.14
HOU	WILLIAM P HOBBY	HARRIS	11.63	5.79
HRL	VALLEY INTL	CAMERON	12.08	3.49
IAH	GEORGE BUSH INTERCONTINENTAL/HOUSTON	HARRIS	19.4	9.41
ILE	SKYLARK FIELD	BELL	12.45	5
LBB	LUBBOCK PRESTON SMITH INTL	LUBBOCK	14.08	4.74
LRD	LAREDO INTL	WEBB	14.03	5.07
MAF	MIDLAND INTL AIR AND SPACE PORT	MIDLAND	13.08	3.95
MFE	MC ALLEN MILLER INTL	HIDALGO	13.71	4.61
SAT	SAN ANTONIO INTL	BEXAR	12.96	4.6
SJT	SAN ANGELO RGNL/MATHIS FIELD	TOM GREEN	11.07	3.83
SPS	SHEPPARD AFB/WICHITA FALLS MUNI	WICHITA	18.02	7.3
TYR	TYLER POUNDS RGNL	SMITH	16.96	4.46
VCT	VICTORIA RGNL	VICTORIA	11.54	4.85
ADS	ADDISON	DALLAS	14.1	5
AFW	FORT WORTH ALLIANCE	TARRANT	12.06	5.52

Facility ID	Facility Name	County	Taxi-out (min)	Taxi-in (min)
AXH	HOUSTON-SOUTHWEST	FORT BEND	17.89	5
CXO	CONROE-NORTH HOUSTON RGNL	MONTGOMERY	13.82	5
DTO	DENTON ENTERPRISE	DENTON	14.21	5
DWH	DAVID WAYNE HOOKS MEMORIAL	HARRIS	14.27	5
EFD	ELLINGTON	HARRIS	14.34	5.01
FTW	FORT WORTH MEACHAM INTL	TARRANT	14.63	5
FWS	FORT WORTH SPINKS	TARRANT	14.32	5
GKY	ARLINGTON MUNI	TARRANT	14.7	5
GLS	SCHOLES INTL AT GALVESTON	GALVESTON	13.05	5
GPM	GRAND PRAIRIE MUNI	TARRANT	11	5
GTU	GEORGETOWN MUNI	WILLIAMSON	14.68	5
HQZ	MESQUITE METRO	DALLAS	14.02	5
HYI	SAN MARCOS RGNL	CALDWELL	13.75	5
IWS	WEST HOUSTON	HARRIS	12.55	5
LBX	TEXAS GULF COAST RGNL	BRAZORIA	13	5
LNC	LANCASTER RGNL	DALLAS	16.25	5
LVJ	PEARLAND RGNL	BRAZORIA	17	5
RBD	DALLAS EXECUTIVE	DALLAS	14.35	5
SGR	SUGAR LAND RGNL	FORT BEND	14.56	5
SKF	KELLY FLD	BEXAR	13.53	5.01
SSF	STINSON MUNI	BEXAR	13.78	5
T41*	LA PORTE MUNI	HARRIS	0	5
TKI	MCKINNEY NATIONAL	COLLIN	8	2

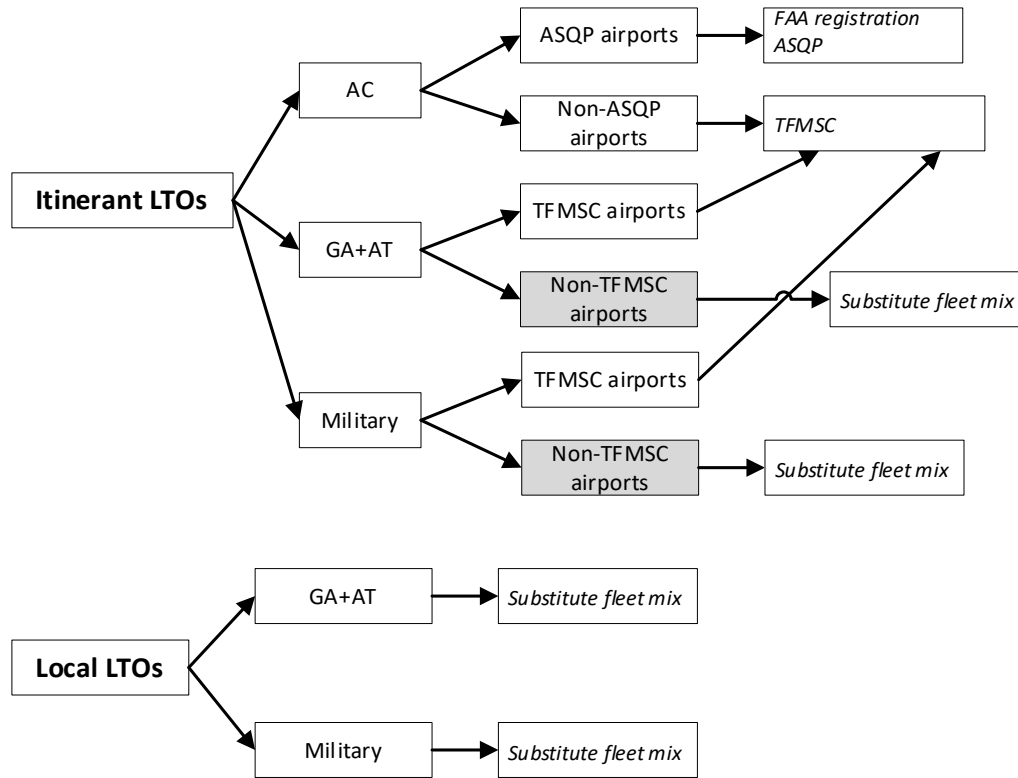
\*T41's average taxi-out time in AERR20 is 13.84 minutes; however, its average taxi-out time is reported as 0 minutes in FAA's 2023 ASPM.

### 4.2.3 Fleet Mix Development

In TTI's previous data collection study [3], the study team found that airports do not track the aircraft fleet mix as it depends on the technical capability of the airport. In the AERR20, a hierarchical process of using the airport-reported data as the primary source of information for the fleet mix was utilized along with the FAA's TFMSC dataset for the airports that did not provide the fleet mix.

For the AERR20, airports DFWIA, IAH, EFD, and HOU provided their fleet mix data. For the current study, only DFWIA provided their 2023 flight operation data which can be used to develop DFWIA's fleet mix for air carrier operations. TTI further improved upon the fleet mix estimation method previously used in the AERR20 by developing new

methodologies and using new data sets. This study adopted the methods in [1] to develop the fleet mix for airports other than DFWIA. An overview of the fleet mix development process is shown in Figure 5. Different approaches are used to develop a fleet mix for itinerant and local LTOs, respectively as most of the local flight operations are performed by single-engine aircraft. The following presents a summary of the methods and data used.



**Figure 5. An Overview of the Fleet Mix Process.**

#### 4.2.3.1 Air carrier LTOs

Air carrier LTOs are mostly itinerant. The following method is used to estimate the fleet mix of the LTOs by air carriers:

- For facilities that are covered by ASQP, the fleet mix is estimated using ASQP data.
- For facilities that are not covered by ASQP but are covered by TFMSC, the fleet mix is estimated using TFMSC data in a way similar to the one used in the 2020 AERR airport EI. Specifically, a mapping between aircraft types in TFMSC and AEDT equipment is developed. The fleet mix at a facility is then estimated by

converting the aircraft type counts from TFMSC into AEDT equipment percentages using the mapping.

- For DFWIA, the fleet mix of air carrier LTOs was developed from the operation data provided by the airport.

Table 17 summarizes the usage of ASQP and TFMSC datasets in the development of fleet mix for commercial, reliever, and TASP airports.

**Table 17. Fleet Mix Development for Air Carrier LTOS by Landing Facility Category.**

Facility Category	ASQP	TFMSC
Commercial*	23	1
Reliever	0	13
TASP	1	3

\* The fleet mix for DFWIA’s Air carrier LTOs is developed from the data provided by DFWIA. Skylark Field Airport (ILE) has 0 LTOs by the air carrier in 2023 in TAF.

#### 4.2.3.2 Itinerant GA and AT LTOs

The following methods are used to estimate the fleet mix of the itinerant GA and AT LTOs:

- For facilities that are covered by TFMSC, the fleet mix is estimated using TFMSC data in a way similar to the one used to develop the 2020 AERR airport EI.
- For other facilities, a substitute fleet mix is created using the FAA’s registry records with assigned AEDT equipment. Aircraft are selected based on their frequencies in the registration record. For itinerant LTOs, aircraft of all engine types are eligible to be selected. For heliports, only helicopters are selected to develop the substitute fleet mix. An example of selected AEDT equipment is presented in Table 18. The LTOs are assigned to each AEDT equipment proportional to their frequencies.

**Table 18. Selected Aircraft (AEDT Equipment) for Substitute Fleet Mix.**

AEDT Equipment ID	Airframe Name	Engine Name	Engine Type	Frequency
2102	Piper PA-28 Cherokee Series	IO-360-B	P	5,937
1887	Piper PA-28 Cherokee Series	O-320	P	4,331
779	Piper PA-31 Navajo	TIO-540-J2B2	P	1,669
3171	Cessna 206	TIO-540-J2B2	P	1,532

AEDT Equipment ID	Airframe Name	Engine Name	Engine Type	Frequency
1262	Cessna 182	IO-360-B	P	1,233
1856	Northrop F-5E/F Tiger II	J85-GE-5F	J	100,865
1824	Lockheed Martin F-16 Fighting Falcon	F100-PW-229	J	76,574
1401	Boeing C-17A	PW2041	J	30,238
2024	Raytheon Beechjet 400	JT15D-5, -5A, -5B	J	25,675
4218	Boeing KC-135A Stratotanker	J57-P-420	J	21,427
6310	Beechcraft T-6 Texan 2 (FAS)	PT6A-64	T	82,425
1483	Raytheon Super King Air 200	PT6A-42	T	44,100
1489	Pilatus PC-12	PT6A-67B	T	34,273
20	Sikorsky SH-60 Sea Hawk	T700-GE-401 -401C	T	19,839
1468	Raytheon King Air 100	PT6A-28	T	17,996
20	Sikorsky SH-60 Sea Hawk	T700-GE-401 -401C	T	19,839
4126	Bell 430	250B17B	T	4,440
4125	Bell 429	TPE331-1	T	713
4113	Sikorsky S-92	T700-GE-700	T	230
4093	Bell 214B-1	T53-L-11D	T	53

Table 19 summarizes the number of facilities to which each method is applied. The fleet mix of itinerant GA and AT LTOs at almost all commercial and reliever airports is developed using the TFMSC data.

**Table 19. Fleet Mix Development for Itinerant GA and AT LTOs by Facility Category.**

Facility Group	GA		AT	
	Substitue	TFMS	Substitue	TFMS
Commercial	0	26	0	24
Farm/Ranch	100	27	4	0
Medical	178	9	186	0
Other Private Airports	474	87	13	0
Other Private Heliports	333	7	95	0
Other Public Airports	35	53	5	4
Other Public Heliports	3	0	0	0
Reliever	0	25	1	20
TASP Airports	7	223	8	26

#### 4.2.3.3 Local GA and AT LTOs

ASQP and TFMSC usually do not contain many local flight operations. Therefore, a substitute fleet mix is created for all local LTOs. According to TTI’s study [1], local operations are mostly performed by aircraft with piston or turboprop engines. The same approach as the one used to create a substitute fleet mix for itinerant GA and AT LTOs is applied here but with jet-engine aircraft excluded from the selection.

#### 4.2.3.4 Military LTOs

Approaches similar to those used to create the itinerant and local LTOs are used to develop the fleet mix of military LTOs. Since there can be many local military flight operations by aircraft with jet engines for training purposes, aircraft with jet engines are included in the substitute fleet mix for local operations.

Table 20 summarizes the number of landing facilities by facility category to which each method is applied. The fleet mix for the majority of commercial and reliever airports was developed using the TFMSC data.

**Table 20. Fleet Mix Development for Military LTOS by Landing Facility Category\*.**

Facility Category	Substitute	TFMSC
Commercial	0	26
Medical	10	0
Military	16	0
Other Private Heliports	38	0
Other Public Airports	4	2
Reliever	2	20
TASP	24	57

\*There are military LTOs at non-military landing facilities.

Table 21 summarizes the LTOs by SCC in this study for the years 2020 and 2023 and the comparison of the corresponding statistics in the AERR20. LTOs by commercial and GA account for about 80% of the total LTOs. Significant differences can be observed in the LTOs of commercial and GA between the two studies. As has been shown in the study [1], the differences are mainly due to the different methodologies used to estimate aircraft activity.

**Table 21. LTOs by SCC and Comparison with AERR20.**

SCC Description	2020 LTOS-AERR20	2020 LTOS-AERR23	Percent Difference	2023 LTOS-AERR20	2023 LTOS-AERR23	Percent Difference
Commercial Aviation	1,088,066	610,023	-43.94%	1,294,548	879,777	-32.04%
Air Taxi: Piston	0	1,055	-	0	1,187	-
Air Taxi: Turbine	96,720	246,416	154.77%	108,743	285,837	162.85%
General Aviation: Piston	1,464,790	1,850,678	26.34%	1,502,499	2,266,674	50.86%
General Aviation: Turbine	1,208,331	993,045	-17.82%	1,285,425	1,153,849	-10.24%
Military	353,101	784,394	122.14%	386,386	712,452	84.39%
Total	4,211,007	4,485,611	6.52%	4,577,601	5,299,776	15.78%

The detailed fleet mixes of all facilities from 2011 to 2050 are provided in Appendix D.

#### 4.2.4 Forecasting Factors

The calendar year 2023 activity and EI were combined with projection factors to backcast and forecast aircraft activity and estimate the trend EI from 2011 through 2050. This study primarily used FAA’s most recent TAF dataset (issued January 2024) to develop the projection factors because of the following reasons:

- 1) TAF is one of the major data sets used to develop the estimation of aircraft activity in the base year. TAF provides the projection of flight operations by flight type (i.e., commercial, itinerant and local air taxi, itinerant and local general aviation, itinerant and local military), which are the same as the flight types used in the estimation of LTOs and fleet mix. Using TAF to develop projection factors would help maintain consistency between the aircraft activity in the base year and those in the other years.
- 2) TAF provides forecasts of flight operations for all commercial and reliever airports in Texas. An airport’s forecast of aviation demand in its airport master plan is expected to be consistent with the forecast in the TAF.

The dataset included historical flight operations and projections of flight operations from 1990 to 2050. This study used flight operations by flight type to obtain the projection factors for 2011 through 2050. Projection factors of a flight type were

developed by calculating ratios of the base year (2023) operations (or LTOs) by the flight type to each projection year's operations.

TAF data provided operations for 211 airports in Texas, including all commercial and reliever airports. These airports account for about 78% of the total 2023 LTOs. TAF does not cover many smaller facilities in the other facility groups. Generic growth-rate projection factors were developed for these facilities. Table 22 presents the missing data handling methodology used for these facility groups.

**Table 22. Projection Factors – Reconciling Data Gaps.**

Facility Group	Missing Data Handling	Comments
TASP airports	Used TAF projections for TASP airports to develop generic projection factors.	Only TAF airports of this facility group in Texas are used.
Other Public Airports	Used TAF projections for other public airports in Texas to develop generic projection factors.	Only TAF airports of this facility group in Texas are used.
Medical and heliports	Used heliports in TAF to develop generic projection factors.	All TAF airports of this facility group are used because no TAF airports in Texas belong to this facility group.
Military	Used military-owned airports in TAF to develop generic projection factors.	All TAF airports of this facility group are used because no TAF airports in Texas belong to this facility group.
Farm/Ranch and Other Private Airports	Used the TAF airports with the basic, unclassified, and local roles in NPIAS to develop generic projection factors.	All TAF airports of this facility group are used because no TAF airports in Texas belong to this facility group.

The activation year in the FAA AMR dataset was used to determine the start year of a facility. Projection factors for all years before the activation year were set to zero. The projection factor in the activation year is prorated based on the number of months the facility is operational. The summary statistics for the projection factor development are presented in Table 23.

**Table 23. Summary Statistics for Projection Factor Development.**

Facility Group	TAF	TAF Other Public Airports	TAF Heliports	TAF Military	TAF NIPAS
Commercial	26	0	0	0	0
Farm/Ranch	0	0	0	0	438
Medical	0	0	190	0	0
Military	0	0	0	20	0
Other Private Airports	0	0	0	0	584

Facility Group	TAF	TAF Other Public Airports	TAF Heliports	TAF Military	TAF NIPAS
Other Private Heliports	0	0	343	0	0
Other Public Airports	1	91	0	0	0
Other Public Heliports	0	0	3	0	0
Reliever	25	0	0	0	0
TASP Airports	159	0	0	0	0
Total 2023 LTO	4,122,293	285,745	89,567	320,190	302,349
LTO Percentage	77.78%	5.39%	1.69%	6.04%	5.70%

Figure 6 illustrates the total LTOs by facility type from 2011 to 2050 and the average annual growth rates of the total LTOs at commercial airports are presented in Table 24.

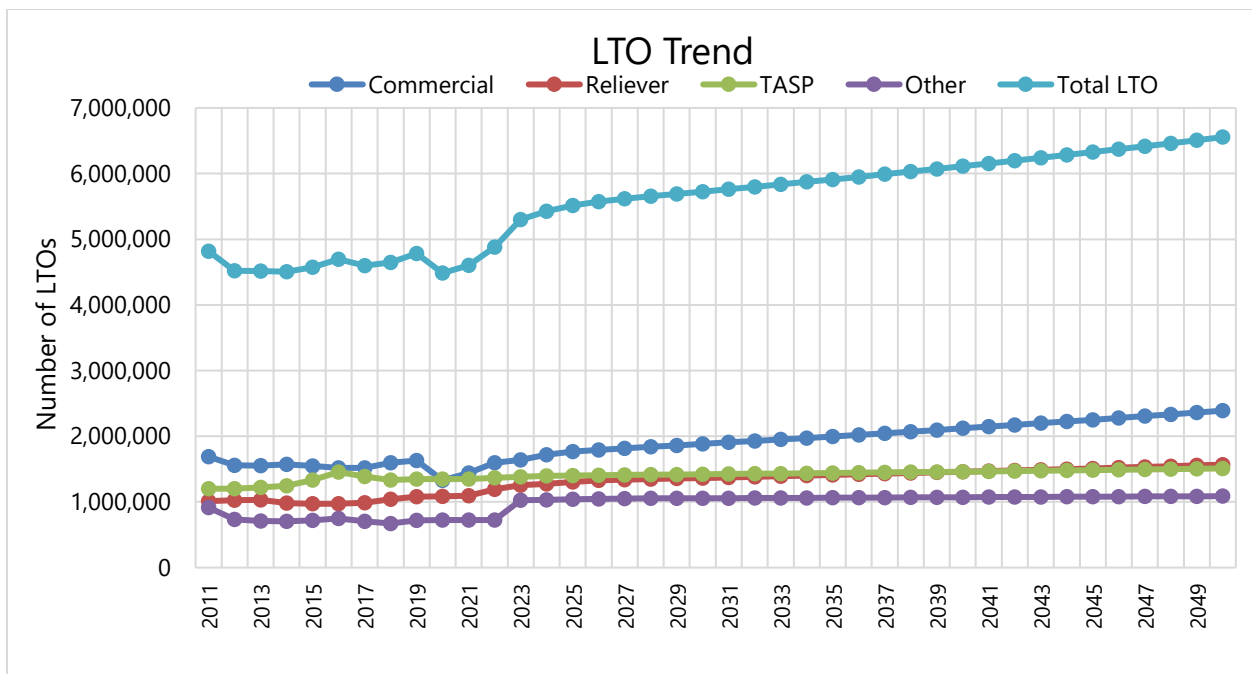


Figure 6. LTOs Trend by Facility Type.

**Table 24. Average Annual Growth Rate for Commercial Airports.**

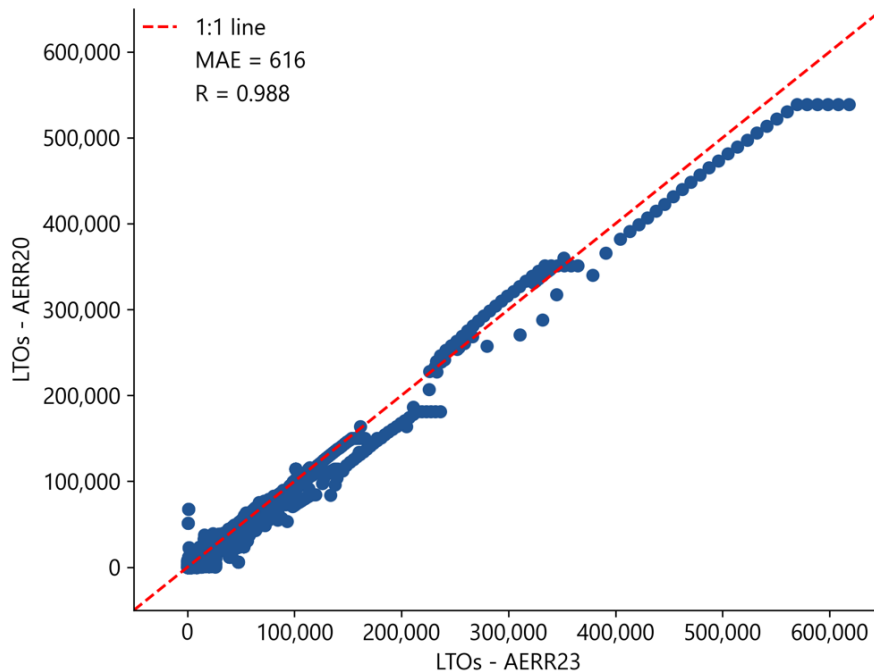
County	Facility ID	Facility Name	2023 LTO	LTO Percentage	Average Annual Growth Rate 2011-2023	Average Annual Growth Rate 2024-2050 (Forecasted)
Taylor	ABI	Abilene Rgnl	20,373	1.24%	-2.31%	0.54%
McLennan	ACT	Waco Rgnl	44,531	2.71%	9.13%	0.85%
Potter	AMA	Rick Husband Amarillo Intl	20,148	1.23%	-5.13%	1.24%
Travis	AUS	Austin-Bergstrom Intl	137,884	8.40%	5.18%	2.02%
Jefferson	BPT	Jack Brooks Rgnl	7,957	0.48%	-1.27%	0.98%
Cameron	BRO	Brownsville/South Padre Island Intl	11,704	0.71%	-4.53%	1.59%
Brazos	CLL	Easterwood Fld	32,109	1.96%	3.14%	0.13%
Nueces	CRP	Corpus Christi Intl	48,701	2.97%	-1.99%	0.49%
Dallas	DAL	Dallas Love Fld	125,994	7.68%	2.63%	0.40%
Tarrant	DFW	Dallas-Fort Worth Intl	344,785	21.01%	0.50%	2.20%
Val Verde	DRT	Del Rio Intl	10,933	0.67%	3.50%	0.00%
El Paso	ELP	El Paso Intl	48,158	2.93%	0.20%	1.14%
Gregg	GGG	East Texas Rgnl	40,136	2.45%	1.80%	0.34%
Harris	HOU	William P Hobby	98,978	6.03%	-0.07%	1.94%
Cameron	HRL	Valley Intl	23,791	1.45%	0.64%	0.74%
Harris	IAH	George Bush Intl/Houston	211,002	12.86%	-1.59%	2.05%
Bell	ILE	Skylark Fld	14,183	0.86%	23.08%	0.00%
Lubbock	LBB	Lubbock Preston Smith Intl	43,247	2.63%	2.51%	0.55%
Webb	LRD	Laredo Intl	23,805	1.45%	0.32%	0.96%
Midland	MAF	Midland Intl Air and Space Port	27,851	1.70%	-2.39%	1.45%
Hidalgo	MFE	McAllen Miller Intl	36,579	2.23%	1.21%	0.34%
Bexar	SAT	San Antonio Intl	80,327	4.89%	-0.81%	1.62%
Tom Green	SJT	San Angelo Rgnl/Mathis Fld	41,167	2.51%	-2.20%	0.22%
Wichita	SPS	Sheppard AFB/Wichita Falls Muni	101,017	6.15%	3.50%	0.00%
Smith	TYR	Tyler Pounds Rgnl	18,758	1.14%	-0.77%	0.23%
Victoria	VCT	Victoria Rgnl	27,168	1.66%	3.35%	0.06%

The projected LTOs and fleet mix from 2011 to 2050 are in Appendix E.

### 4.2.5 Comparison with Aircraft Activities in AERR20

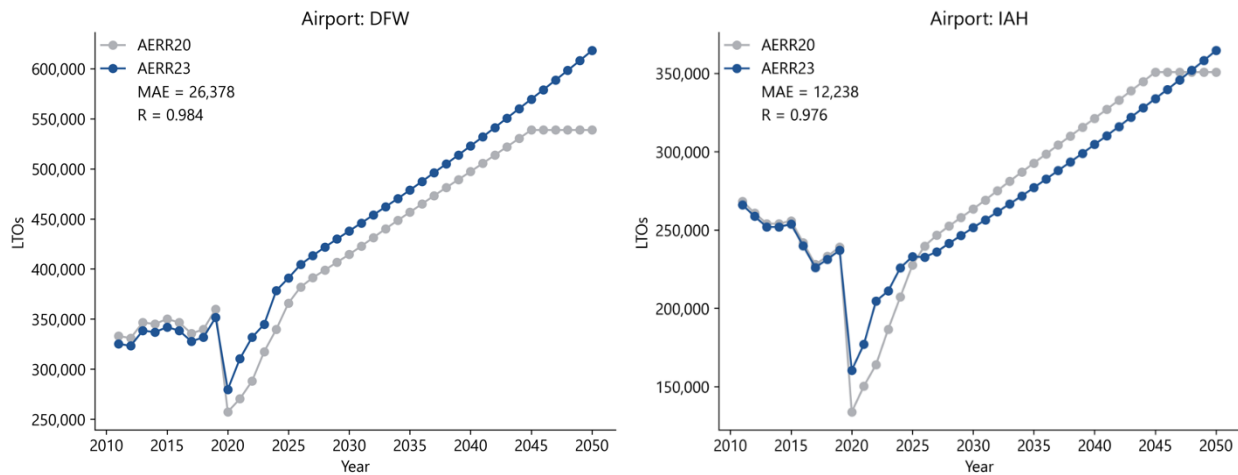
A comparison between the AERR20 and AERR23 studies revealed a difference in the number of facilities (airports) included in each study. The AERR20 lists a total of 2,032 facilities, while the AERR23 includes 1,947 facilities. Of these, 1,790 facilities are common to both studies. This difference is related to the fact that some small airports or heliports were closed in the previous study. For the following sections, the comparison between the AERR20 and AERR23 study results when considering all airports (statewide) refers to a total of 1,790 facilities.

One of the main inputs to calculate emissions is the LTO data, with a comparison shown in Figure 7 below. In general, there is a high correlation between the LTOs from both studies, with a coefficient of correlation of 0.988 and Mean Absolute Error (MAE) of 616. There is, however, a small difference for the large number of LTOs when it exceeded 400,000 from which the AERR23 shows values greater than AERR20. In addition, there is a noticeable difference (drift) in the LTOs from the AERR23 since, when the AERR20 study was conducted, it was assumed that the LTOs from 2045 to 2050 were constant.



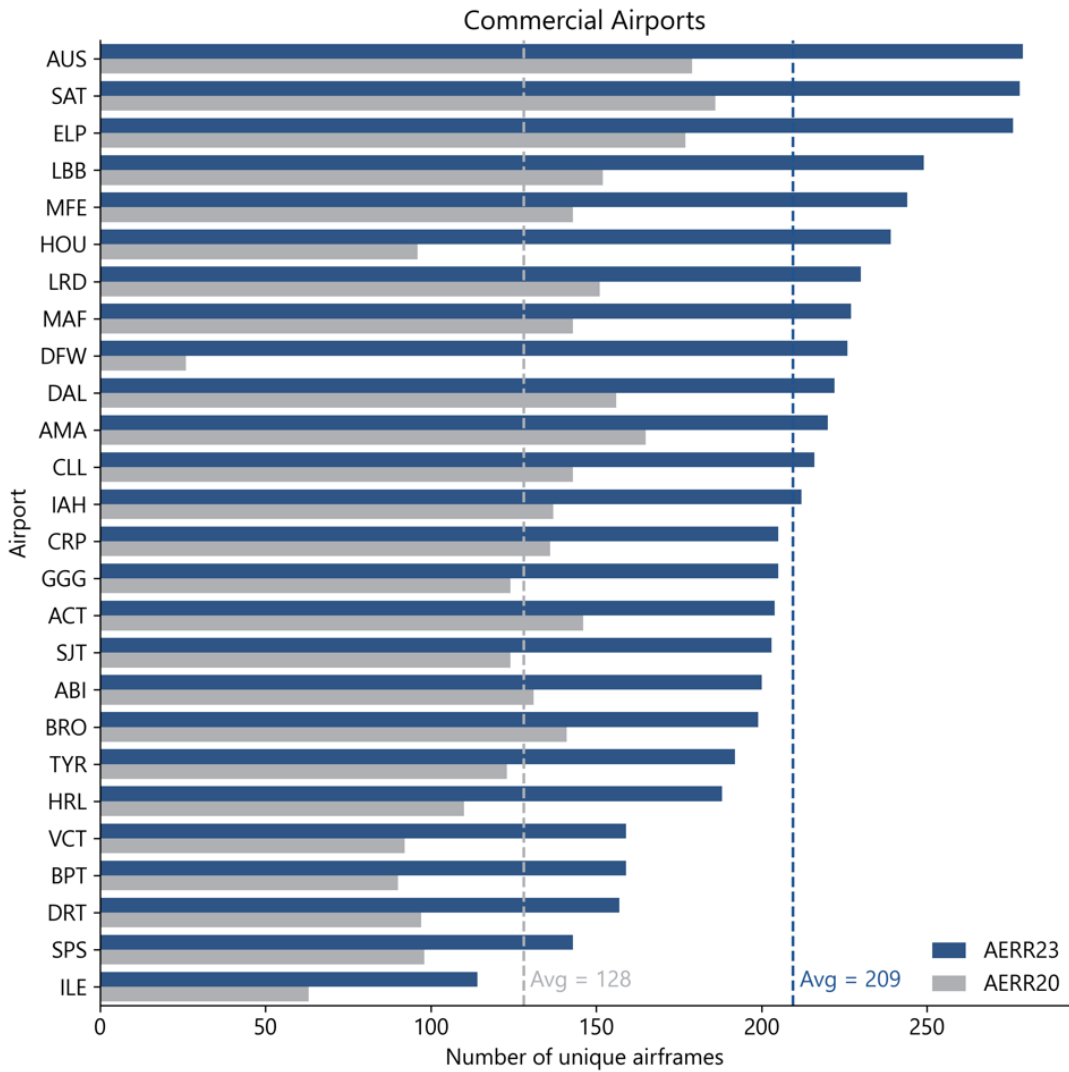
**Figure 7. LTO comparison between AERR20 and AERR23**

The drift mentioned before is more evident when comparing the LTOs for each airport, as illustrated for DFW and IAH airports in Figure 8. LTO trend from 2011 to 2050 for DFW and IAH airports.. For both airports, it is possible to observe a significant decrease in LTO in 2020 due to the COVID-19 pandemic. Another fact observed for these two airports is that LTO trends were underestimated for DFW and overestimated for IAH when comparing the AERR20 and AERR23 study results.



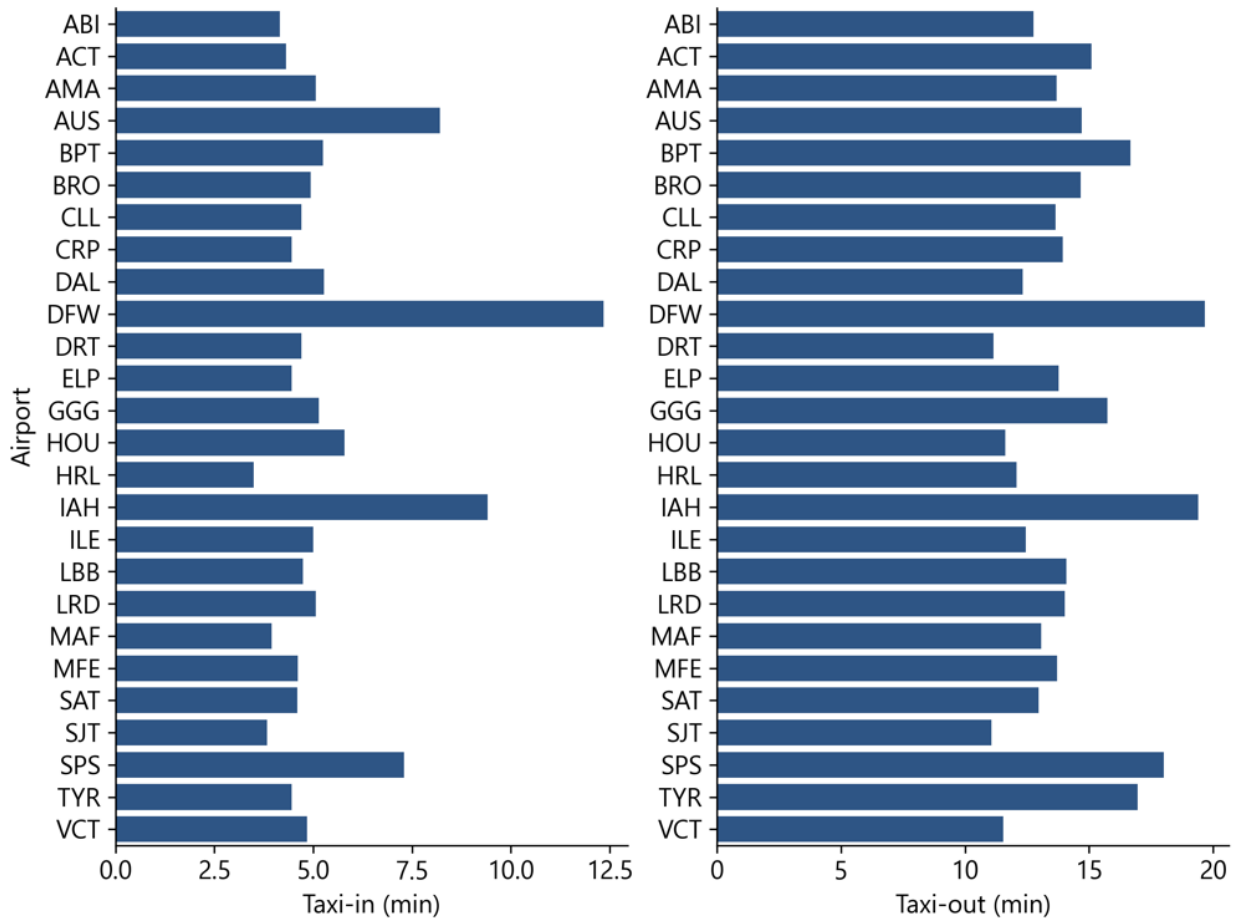
**Figure 8. LTO trend from 2011 to 2050 for DFW and IAH airports.**

The number of unique airframes in the AERR23 was significantly higher compared to the AERR20, as shown in Figure 9. On average, commercial airports in the AERR20 had 128 unique airframes, whereas in the AERR23, the average increased to 209. One of the most notable changes was observed at DFWIA Airport, which had fewer than 50 unique airframes in the AERR20. However, this number exceeded 220 in the AERR23 as DFWIA provided detailed 2023 flight records to TTI for the AERR23. This increase in detailed airframe information allows AEDT to conduct more detailed emission simulations, providing a more comprehensive representation of airport activities.



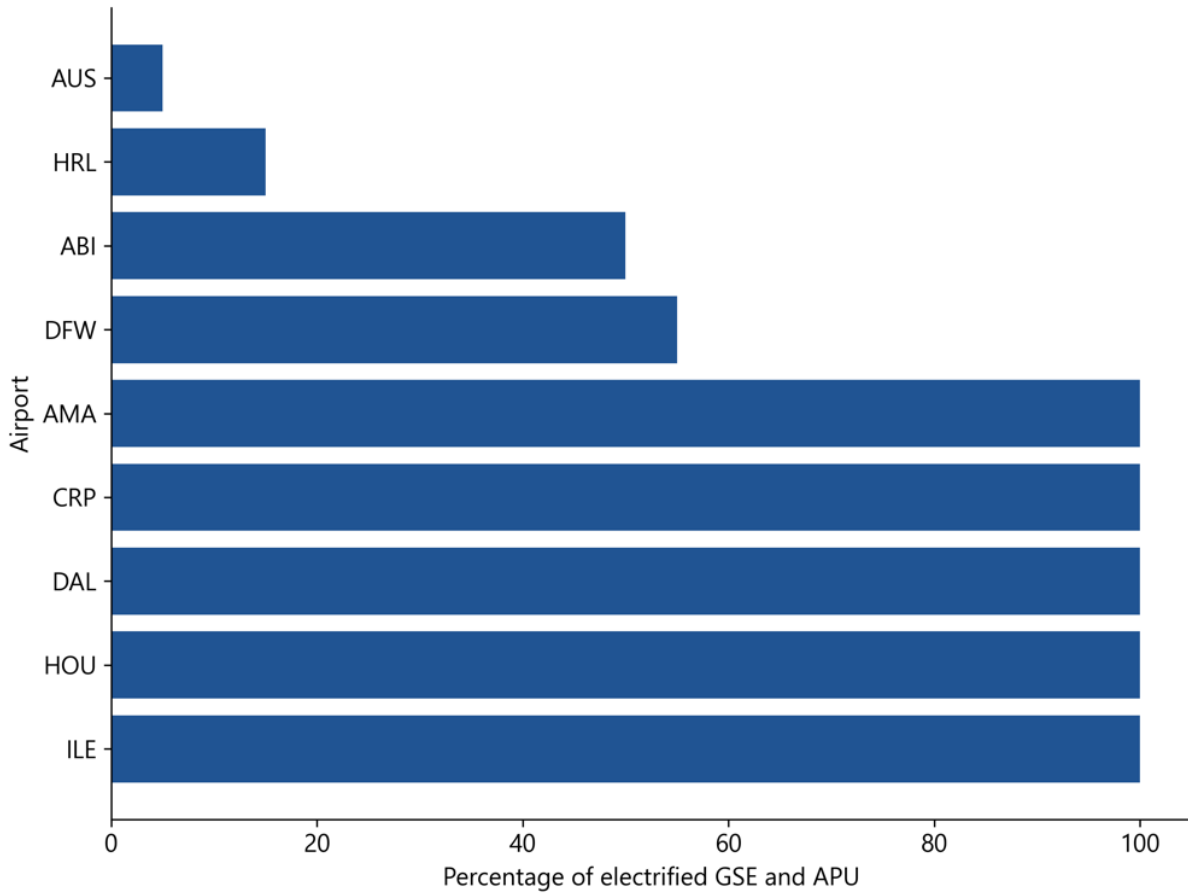
**Figure 9. Number of unique airframes for commercial airports from AERR20 and AERR23**

Figure 10 shows the average taxi-in and taxi-out times, in minutes, for commercial airports. Taxi times vary by airport, depending on factors such as runway length, the number of takeoffs and landings, and the distance from the gates. The goal is not to compare the AERR20 and AERR23 study results, but to illustrate the variation across airports. For most commercial airports, the taxi-in time is approximately half of the taxi-out time. Among these airports, DFW has the highest taxi times, with an average of about 12 minutes for taxi-in and 20 minutes for taxi-out.



**Figure 10. Taxi-in and out time for the commercial airports**

The percentage of electrified GSE and APU for the airports that have the information available is shown in Figure 11 for the base year of 2023. Only nine airports have information about electrified GSE and APU, and among these airports, five are reported to have 100% electrified GSE and APU. The AUS airport has the lowest percentage of electrified GSE and APU, at 5%.



**Figure 11. Percentage of electrified GSE and APU for the base year of 2023**

### 4.3 CONTROL STRATEGIES

Similar to the AERR20, the AERR23 primarily considered two control measures: gate electrification and GSE electrification. The control strategies used in this study are developed by updating those used in the AERR20 with the latest data received from facilities.

Table 25 and Table 26 present the gate and GSE electrification details from 2023 to 2050<sup>8</sup>, respectively. The facilities included in these tables are not exhaustive and thus do not capture all facilities in Texas that use these control measures. Only the facilities where control measure information was available in this study are included. Moreover, a

<sup>8</sup> Different facilities have different starting date for the control measures. The time span 2023-2050 is a common period shared by all facilities in the two tables.

conservative approach was used in that the controls should have been implemented and their effective year in the EI calculation is the year the information was collected.

Gate electrification allows the aircraft to use electricity hookups instead of the APUs while docking at the gates. GSE electrification consists of turning over the conventional fuel-powered GSE vehicles to use electric-powered vehicles. The APU and non-electric GSE emissions were reduced based on the gate and GSE electrification percentages.

**Table 25. Gate Electrification.**

Facility ID	Facility Name	County	Facility Group	2023 – 2050
ABI	ABILENE RGNL	TAYLOR	COMMERCIAL	50%
AMA	RICK HUSBAND AMARILLO INTL	POTTER	COMMERCIAL	100%
AUS	AUSTIN-BERGSTROM INTL	TRAVIS	COMMERCIAL	5%
BBD	CURTIS FIELD	MC CULLOCH	TASP	20%
CRP	CORPUS CHRISTI INTL	NUECES	COMMERCIAL	100%
DAL	DALLAS LOVE FIELD	DALLAS	COMMERCIAL	100%
DFW	DALLAS-FORT WORTH INTL	TARRANT	COMMERCIAL	55%
HOU	WILLIAM P HOBBY	HARRIS	COMMERCIAL	100%
ILE	SKYLARK FIELD	BELL	COMMERCIAL	100%
PWG	MC GREGOR EXECUTIVE	MC LENNAN	TASP	100%
SAT	SAN ANTONIO INTL	BEXAR	COMMERCIAL	100%
TFP	MCCAMPBELL-PORTER	SAN PATRICIO	TASP	100%

**Table 26. GSE Electrification.**

Facility ID	Facility Name	County	Facility Group	2023 – 2050
AFW	FORT WORTH ALLIANCE	TARRANT	RELIEVER	5%
BBD	CURTIS FIELD	MC CULLOCH	TASP	30%
CRP	CORPUS CHRISTI INTL	NUECES	COMMERCIAL	4%
DFW	DALLAS-FORT WORTH INTL	TARRANT	COMMERCIAL	34%
HRL	VALLEY INTL	CAMERON	COMMERCIAL	15%
SAT	SAN ANTONIO INTL	BEXAR	COMMERCIAL	100%
TKI	MCKINNEY NTL	COLLIN	RELIEVER	38%

## 5 EMISSIONS MODELING

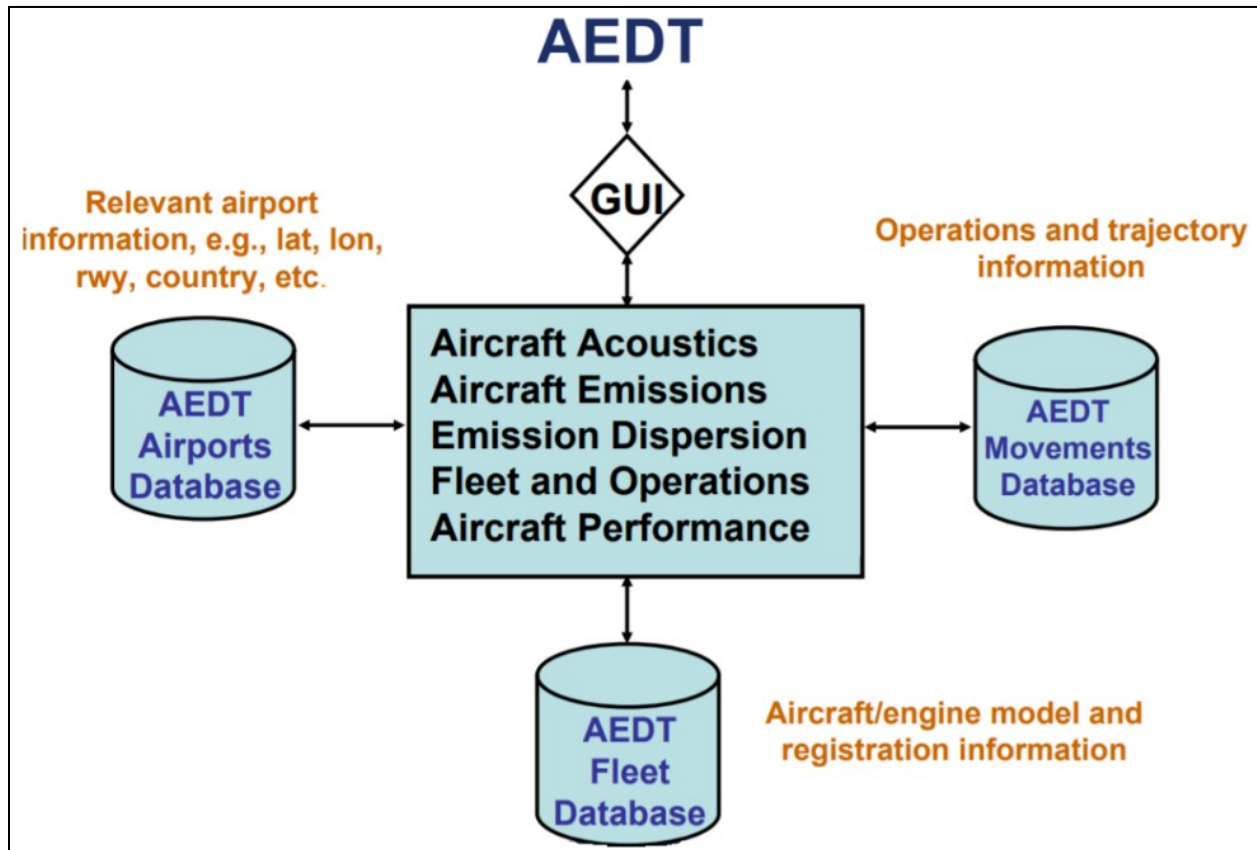
The aircraft, GSE, and APU emissions were modeled using AEDT. The following section provides an overview of AEDT and presents the modeling approach used in this study.

### 5.1 AEDT OVERVIEW

AEDT is a software system that models aircraft performance in space and time to estimate fuel consumption, emissions, noise, and air quality consequences. AEDT is a comprehensive tool that provides information to FAA stakeholders on each of these specific environmental impacts. AEDT facilitates environmental review activities required under NEPA by consolidating the modeling of these environmental impacts in a single tool [25]. AEDT version 3f was the latest version of this software when this study was conducted.

AEDT is designed to model individual scenarios ranging in scope from a single flight at an airport to regional, national, and global scenarios. AEDT leverages geographic information system (GIS) and relational database technology to achieve this scalability and offers rich opportunities for exploring and presenting results. The U.S. government actively uses versions of AEDT for domestic aviation system planning as well as domestic and international aviation environmental policy analysis [25].

AEDT accepts data from a variety of sources with varying spatial and temporal resolutions. The key input to estimating aircraft emissions is the aircraft activities which can be categorized into (a) planned flight data and (b) observed flight data. The planned flight data at the airport level consists of planned arrival and departure information of aircraft along specific routes. The observed flight data obtained from the sensor observations of aircraft activity contains information on the aircraft's three-dimensional position, speed, and direction. In addition to aircraft activity, AEDT can model emissions from APUs and GSEs operating in the airports. Users have two options to incorporate input information, (i) user-defined inputs through the graphical user interface (GUI) and (ii) extensive databases maintained by AEDT on the aircraft, fleet, and operations information required to estimate emissions. Key components of the AEDT model are presented in Figure 12 [25].



**Figure 12. Key Components of the AEDT Model.**

The critical databases within AEDT are described as follows:

- The study database provides the baseline template for creating a new study. This database references external data sources such as weather, and terrain, as well as map layers, including input and run configuration, intermediate data, and output results for the AEDT application. The study database contains all input parameter types and units, control settings, table structure (grouping of parameters), and the relationship between tables.
- The airport database consists of data pertinent to the airports considered in the study. The database contains information corresponding to airport codes, historical averages of meteorological data extracted from the weather sensors stationed at the airports, details of airport surface structures (e.g., runways, taxiways, gates, buildings, etc.), and airspace geographical content on procedures (e.g., ground-tracks, altitude controls, etc.). Additional information about airports can be imported using the GUI.

- The AEDT fleet database contains information pertaining to aircraft and non-aircraft equipment for AEDT modeling. The fleet database contains over 4,000 aircraft (airframe/engine combinations) and approximately 400 non-aircraft emissions sources (GSE, stationary power and fuel equipment, and APUs) [26]. AEDT provides the option to assign non-aircraft data either as a stand-alone operation or defined in association with aircraft operations.
- The AEDT movement database provides two options to incorporate operations information. The first option, where the minimum information required from the user to be incorporated, is the equipment to be used, the time at which the operation is to take place, and the location of the operation. AEDT models this as an explicitly scheduled operation. In the second option, in addition to the user's required information on the equipment and location of operation, the incorporation of activity profiles is required by AEDT to form a detailed schedule. The different inputs required by the AEDT<sup>9</sup> model to estimate emissions from various sources are presented in Table 27.

**Table 27. Input data parameters for emissions sources as required by AEDT.**

Emission Sources	Input Parameters
Aircraft operation	<ul style="list-style-type: none"> <li>• Airport layout (for departures and arrivals, required for delay and sequencing modeling)                             <ul style="list-style-type: none"> <li>○ Runway locations</li> <li>○ Gate locations</li> <li>○ Taxiway locations</li> <li>○ Taxi path definitions</li> </ul> </li> <li>• Aircraft operation schedule                             <ul style="list-style-type: none"> <li>○ Date and time</li> <li>○ Operation type (e.g., departure, arrival, touch and go, etc.)</li> <li>○ Airframe model and Engine model</li> <li>○ Flight profile</li> <li>○ Runway</li> <li>○ Flight track</li> <li>○ Gate (for departures and arrivals)</li> </ul> </li> <li>• Meteorological conditions                             <ul style="list-style-type: none"> <li>○ Mean sea level pressure and Temperature</li> <li>○ Relative humidity and Wind (speed and direction)</li> </ul> </li> </ul>

<sup>9</sup> Since the AEDT model is resource intensive, an emission rates look-up table was developed for all aircraft types in a single run, or a group of runs based on the region or airport category. In addition, due to lack of fuel formulation data availability from the airports, AEDT defaults on fuels were used for the analysis.

Emission Sources	Input Parameters
APU	<ul style="list-style-type: none"> <li>• Duration of operation</li> <li>• Emission rates (ERs) for pollutants (default ERs are available for system APUs)</li> <li>• As APU operation occurs only when an APU is installed on an aircraft, hence its operation is considered in conjunction with aircraft operation</li> </ul>
GSE	<ul style="list-style-type: none"> <li>• GSE emissions can be characterized in two ways, (a) "aircraft-assigned GSE" in which case emissions are estimated in conjunction with aircraft operations, and (b) "GSE population," in which case GSE emissions are estimated based on total annual GSE operation time independent of aircraft operation</li> <li>• Emissions are defined by the GSE type (e.g., air conditioner), and fuel type</li> <li>• Duration (minutes) (default values are available)</li> <li>• Horsepower (power rating) (default values are available)</li> <li>• Load factor (percent)</li> <li>• Emission rates (ERs) for pollutants (default ERs are available for system GSEs)</li> </ul>

## 5.2 MODELING PARAMETERS

Landing and takeoff emissions in AEDT are affected by a multitude of parameters. The following is a discussion of the key parameters that influence emissions and their values in this study.

- **Spatial scope:** In AEDT, the three-dimensional spatial scope is defined by selecting the airport for which the EI is being developed and the mixing height. TTI has used the default AEDT mixing height of 3,000 feet. Only landing and takeoff emissions below the mixing height are considered for the EI.
- **Temporal scope:** Temporal scope consists of the arrival and departure times. For this inventory, all operations are assigned to January 1<sup>st</sup>, 2023, at 8 am. This approach is similar to the approaches used in the AERR20 and the HAS's approach used for developing EIs for IAH, EFD, and HOU [27].
- **Airport layout:** Airport layout consists of runway locations, gate locations, taxiway locations, and taxi path definitions. For this study, TTI used the default airport layout.
- **Ground tracks:** Each runway end can have an arrival and departure track associated with it. They are a trace of the flight path on the horizontal plane and are represented by an ordered series of 2-D surface locations. This study generally uses four tracks for assigning aircraft and helicopter arrivals and

departures; one track for assigning aircraft arrivals, one for assigning aircraft departures, one for assigning helicopter arrivals, and one for assigning helicopter departures.

- **Landing and takeoff profiles:** These are a set of points that model the geometrical and physical characteristics of an aircraft flight operation in the vertical profile. This study uses the default profiles provided by AEDT for different aircraft and helicopters.
- **Number of arrivals and departures:** The 2023 LTOs and the fleet mix are used to obtain the number of operations for different aircraft. Operations for each aircraft are split equally between arrivals and departures.
- **APUs:** All commercial and reliever airport aircraft are assigned an APU based on the default APU and airframe mapping provided in the AEDT Fleet database. For the aircraft with APU, a default APU operating duration of 13 minutes is used.
- **GSE:** All commercial and reliever airport aircraft are assigned AEDT default GSEs and default GSE operating durations.
- **Weather information:** This study uses the 2013-2022 average airport weather for each facility modeled in AEDT.
- **Startup Emissions:** Startup emissions are included in the total emissions.

### 5.2.1 Facility Modeling using AEDT

In the AERR20, commercial and reliever airports were modeled individually using the AEDT. For other facilities, representative facilities were used to calculate emission rates with AEDT, which were then applied to estimate the EI for each facility.

In the AERR23, all facilities are modeled individually using AEDT. Specifically, AEDT Standard Input Files (ASIF) were developed for all the facilities considered in this study. However, the ASIFs for 255 facilities could not be imported into AEDT due to either not being defined in AEDT or issues with the AEDT airport database. For each of these facilities, the TTI research team used a nearby facility (within 50 nautical miles and with the closest elevation to the original facility) that can be modeled in AEDT to calculate the emissions of the aircraft activity at the original facility. Table 28 shows the summary statistics of the facilities directly modeled by AEDT and facilities modeled using their nearby facilities in AEDT. The total number of LTOs at the 255 facilities accounts for about 2.5% of the total LTOs.

**Table 28: Summary Statistics for Facility Modeling in AEDT**

Facility Group	All facilities		Facilities directly modeled in AEDT 3F			Facilities modeled by their nearby facilities in AEDT 3F		
	Count	LTO	Count	LTO	LTO percent	Count	LTO	LTO percent
Commercial	26	1,641,279	26	1,641,279	100.00%	0	0	0.00%
Farm/Ranch	438	65,489	354	57,361	87.59%	84	8,128	12.41%
Medical	190	36,399	174	33,837	92.96%	16	2,562	7.04%
Military	16	320,190	16	320,190	100.00%	0	0	0.00%
Other Private Airports	584	236,860	490	212,960	89.91%	94	23,900	10.09%
Other Private Heliports	343	49,399	298	43,649	88.36%	45	5,751	11.64%
Other Public Airports	92	312,115	83	294,808	94.46%	9	17,306	5.54%
Other Public Heliports	3	3,768	0	0	0.00%	3	3,768	100.00%
Reliever	25	1,253,043	24	1,204,162	96.10%	1	48,881	3.90%
TASP Airports	230	1,381,234	227	1,358,869	98.38%	3	22,365	1.62%
Total	1947	5,299,776	1692	5,167,115	97.50%	255	132,661	2.50%

All the ASIFs and AEDT outputs are in Appendix F.

## 6 EMISSION INVENTORIES

This study included the development of the 2023 EI and 2011 through 2050 trend EIs for aircraft, APU, and GSE non-road mobile sources. Based on the methodology described in Section 3, the summary of the 2023 EI, 2011 through 2050 trend EIs, TexAER XML format output, and EPA EIS XML files were prepared for the required SCC listed in Table 4.

### 6.1 STATE-LEVEL RESULTS COMPARISON

Table 29 compares the aggregated controlled criteria pollutant emissions for calendar year 2017 in the AERR23 with those from the AERR20 and AERR17 studies for reasonableness [13], while Table 30 summarizes the comparison of controlled criteria emissions for calendar years 2020 and 2023 between the AERR20 and AERR23. The emissions differences among these studies can be attributed to differences in the input data used, activity estimation methods, and the AEDT version used.

**Table 29. Comparing the 2017 Controlled Emissions Among AERR17, 20, and 23.**

Pollutant	2017 AERR17 (tons/year)	2017 AERR20 (tons/year)	2017AERR23 (tons/year)	Percent Difference* AERR17	Percent Difference* AERR20
VOC	3,962	5,536	4,789	20.86%	-13.49%
NO <sub>x</sub>	14,463	13,779	12,276	-15.12%	-10.91%
CO	37,506	48,776	50,140	33.68%	2.80%
PM <sub>10</sub>	759	194	236	-68.89%	21.69%
PM <sub>2.5</sub>	661	194	236	-64.35%	21.48%
SO <sub>2</sub>	1,497	1,393	1,317	-12.01%	-5.42%
Pb	18	15	16	-10.52%	9.68%

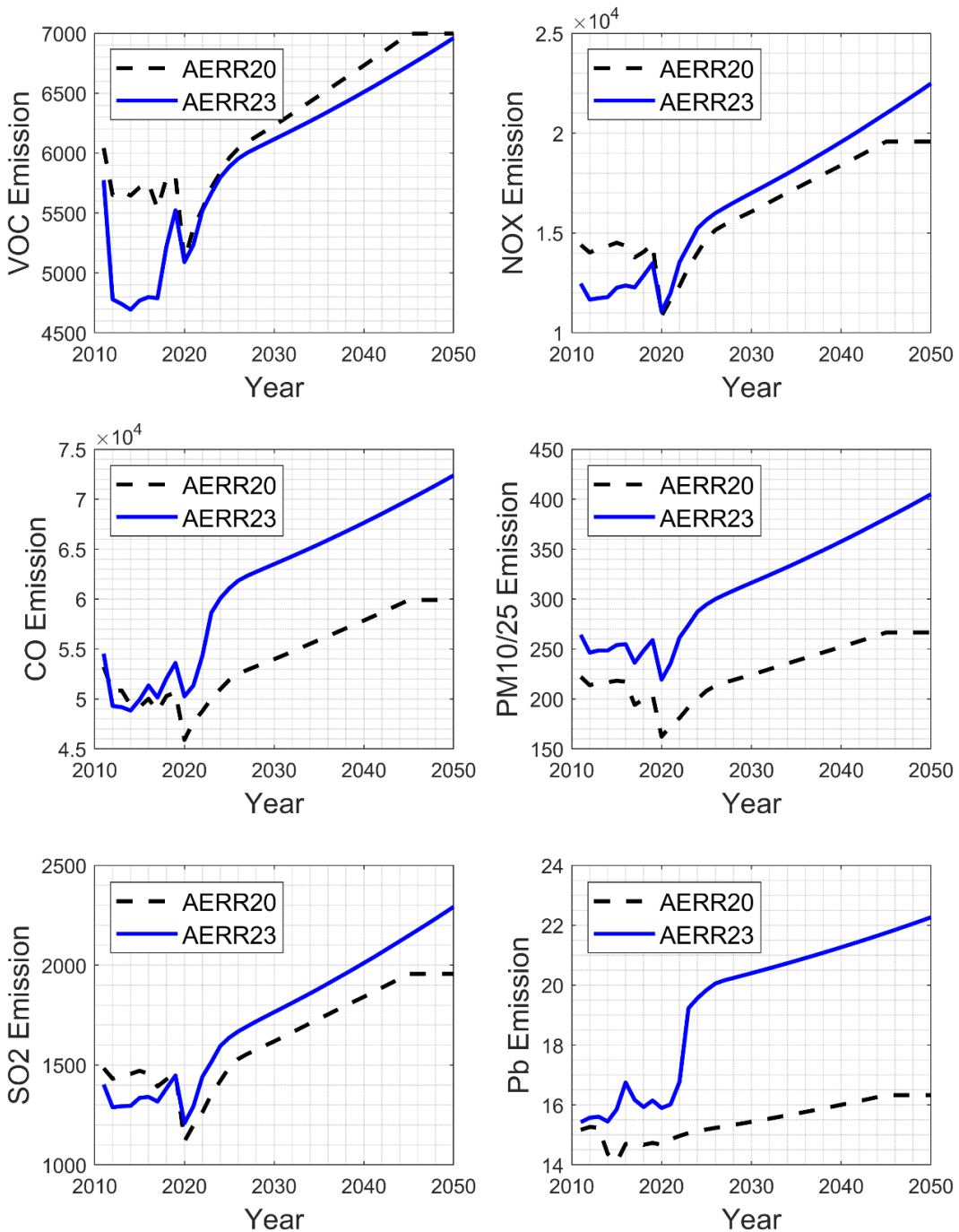
\*The differences are calculated by comparing AERR 2023 results with those from AERR 2017 and 2020.

**Table 30. Comparing the 2020 and 2023 Controlled Emissions between AERR20 and 23.**

Pollutant	2020 AERR20 (tons/year)	2020 AERR23 (tons/year)	Percent Difference	2023 AERR20 (tons/year)	2023 AERR23 (tons/year)	Percent Difference
VOC	5,103	5,091	-0.23%	5,713	5,666	-0.81%
NO <sub>x</sub>	10,857	11,068	1.95%	13,282	14,379	8.26%
CO	45,903	50,255	9.48%	50,043	58,630	17.16%
PM <sub>10</sub> or PM <sub>2.5</sub>	162	219	35.18%	192	274	42.94%
SO <sub>2</sub>	1,118	1,208	8.10%	1,352	1,515	12.03%

Pollutant	2020 AERR20 (tons/year)	2020 AERR23 (tons/year)	Percent Difference	2023 AERR20 (tons/year)	2023 AERR23 (tons/year)	Percent Difference
Pb	15	16	8.38%	15	19	27.67%

Figure 13 shows the trend of controlled criteria emissions in the AERR23 and those from the AERR20. The future trends in the two studies share a similar pattern to the pattern of the emissions in the base year.



**Figure 13: AERR23 and AERR20 Trend Controlled Emissions.**

## 6.2 RESULTS COMPARISON AT THE COUNTY AND AIRPORT LEVEL

This section presents the outcomes of the comparison between the AERR20 and AERR23 at both the airport and county levels.

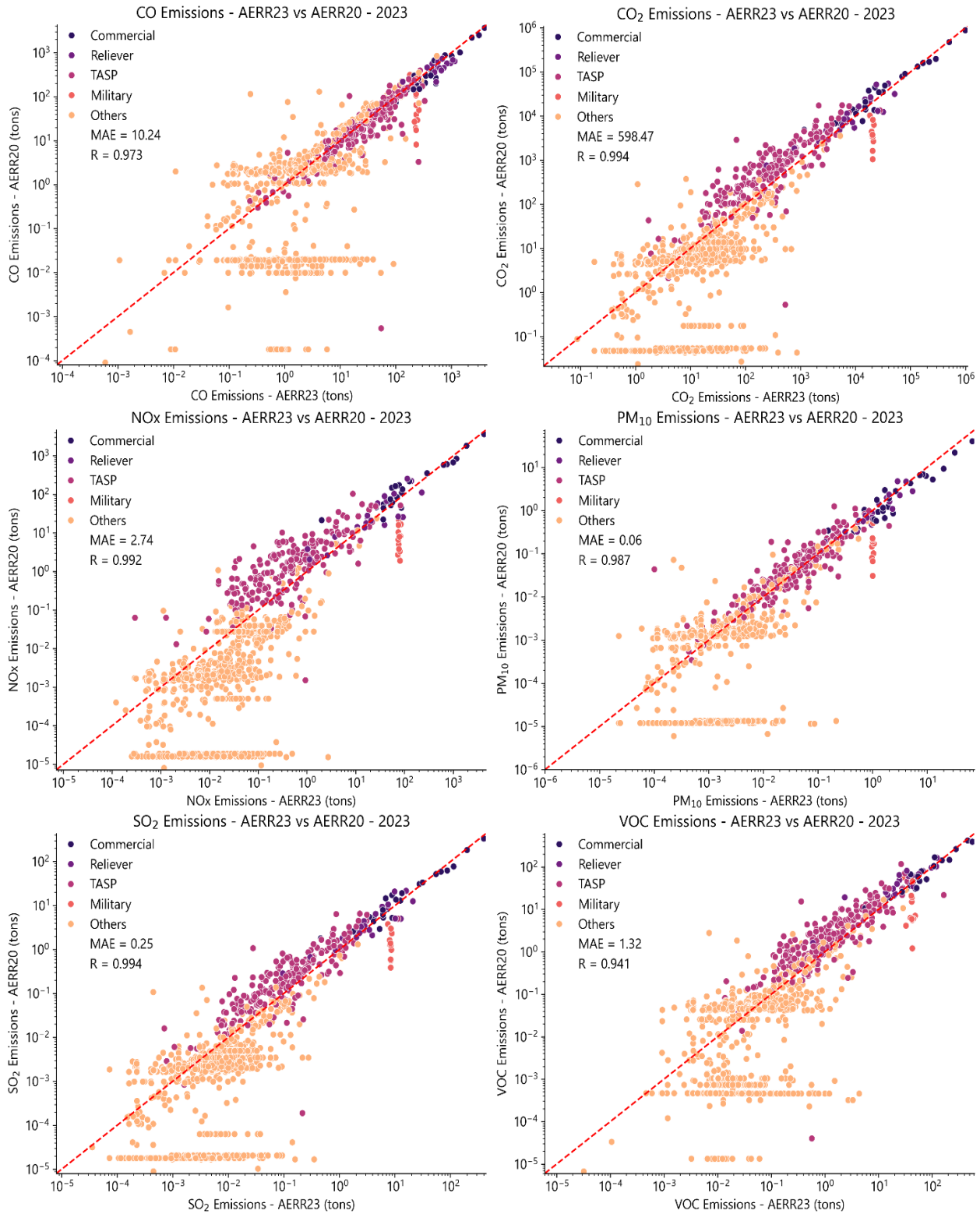
A summary of the difference in emissions represented by the ratio between the AERR20 and AERR23 is presented in Table 31 for the key pollutants (CO, CO<sub>2</sub>, NO<sub>x</sub>, PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>2</sub>, and VOC) for the top five airports in the commercial and reliever groups in calendar year 2023. In most cases, the emission ratio (AERR20/AERR23) reveals that airport emissions were lower in the AERR20 compared with the AERR23. For example, in DFW, all the selected pollutants were underestimated in the AERR20 with the range varying between 0.60 for PM<sub>10</sub> (as well as PM<sub>2.5</sub>) and 0.93 for CO. In other airports such as TKI, the emissions estimated in the AERR23 were lower than in the AERR20, which resulted in a ratio higher than 1.

**Table 31. Ratio between emissions from AERR20 and AERR23 for base year 2023**

Facility Name	Group	County	AERR20 and AERR23 ratio						
			CO	CO <sub>2</sub>	NO <sub>x</sub>	PM <sub>10</sub>	PM <sub>2.5</sub>	SO <sub>2</sub>	VOC
DFW	Commercial	Tarrant	0.93	0.89	0.84	0.60	0.60	0.84	0.92
IAH	Commercial	Harris	0.94	0.94	0.97	0.68	0.68	0.92	0.95
AUS	Commercial	Travis	0.71	0.68	0.72	0.46	0.46	0.68	0.70
DAL	Commercial	Dallas	0.83	0.77	0.68	0.41	0.41	0.72	0.94
SPS	Commercial	Wichita	0.80	1.13	2.51	0.89	0.9	1.06	0.70
DTO	Reliever	Denton	0.56	1.24	1.55	0.79	0.79	1.29	1.19
FTW	Reliever	Tarrant	0.64	1.37	1.61	1.14	1.14	1.36	1.33
DWH	Reliever	Harris	0.60	1.60	2.3	1.08	1.09	1.6	1.23
TKI	Reliever	Collin	1.06	2.16	2.22	1.65	1.66	2.1	2.4
GTU	Reliever	Williamson	0.84	0.96	1.06	0.63	0.63	0.89	1.06

In general, there is a tendency for the emission ratio to be lower in the commercial airports and higher than 1 in the reliever airports, with average ratios of 0.82 and 1.28, respectively. As mentioned before, these differences were expected because the research team acquired more detailed 2023 LTO and aircraft information (fleet mix), and the AEDT software is a newer version compared with the version used for the AERR20.

The comparison of total emissions between the AERR20 and AERR23 for all airports in the base year of 2023 is shown in Figure 14. The coefficient of correlation was high for all pollutants, being higher than 0.94. As expected, the commercial airports (dark colors) sum the highest emissions, followed by reliever and TASP airports.



**Figure 14. Comparison of total emissions between AERR23 and AERR20 for the base year of 2023 and all airports.**

As shown in Figure 14, in terms of magnitude, CO<sub>2</sub> is the pollutant most generated, with some airports reaching 1,000,000 tons of CO<sub>2</sub> per year. NO<sub>x</sub> and CO have a similar range, with maximum values of around 1,000 tons per year. This is followed by SO<sub>2</sub> with 100 tons per year, and PM<sub>10</sub> and VOC with 10 tons per year. The maximum and minimum values are similar between the AERR20 and AERR23 across all airports. Figure 14 also reveals high dispersion for the airports in the group “Others”. The emissions estimated for airports in the AERR20 remained largely constant at 0.02 tons of CO, whereas in the AERR23, there were slight variations.

Figure 15 and Figure 16 show the emissions trend from 2011 to 2050 for both the AERR20 and AERR23 for DFWIA and IAH, respectively. In general, the emissions follow the same trends as the LTOs (Figure 8) where DFW was underestimated, and IAH was overestimated compared with AERR20. However, for IAH, this behavior changed from PM<sub>10</sub>, with the AERR23 results indicating higher PM<sub>10</sub> emissions.

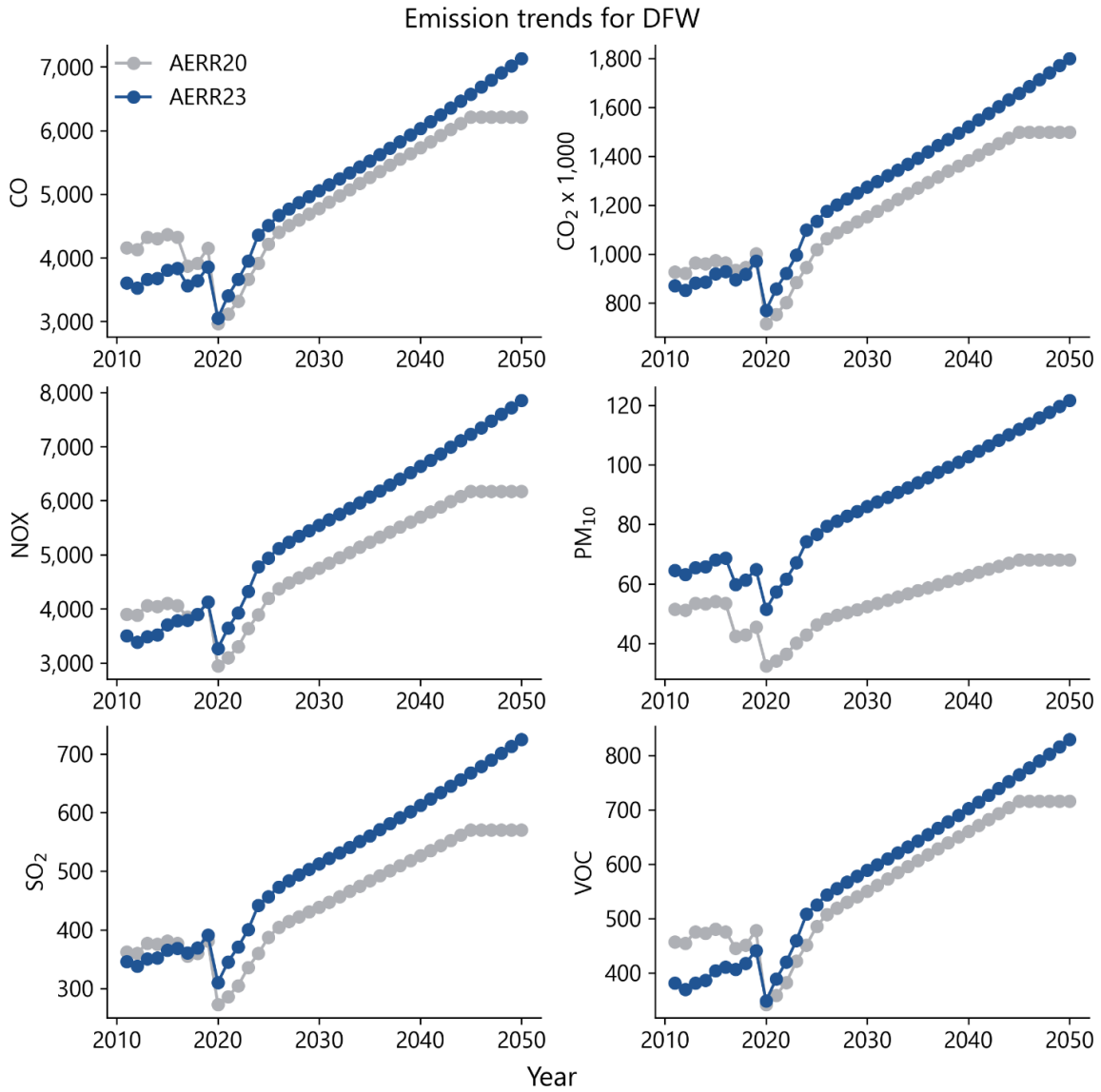
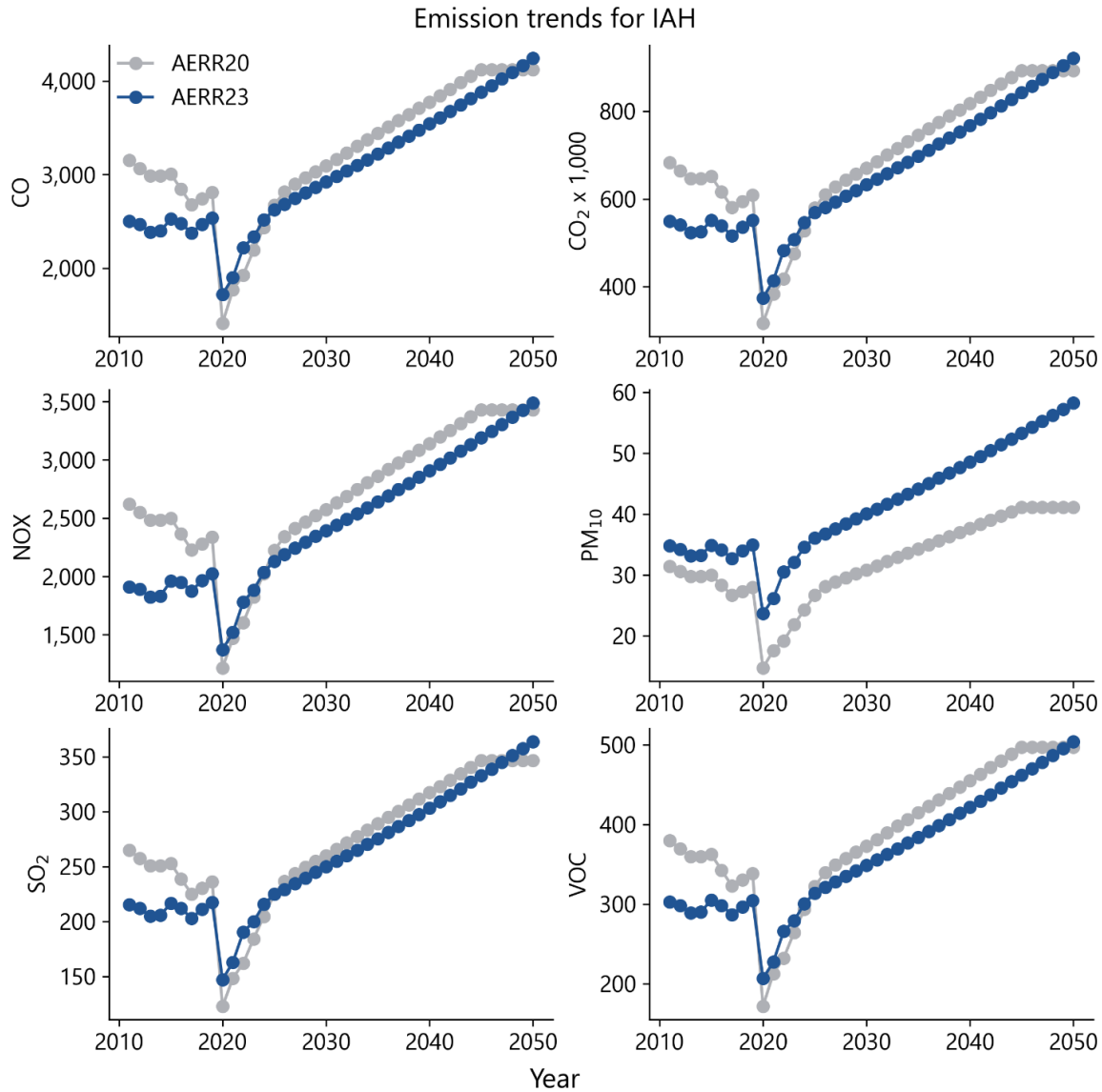
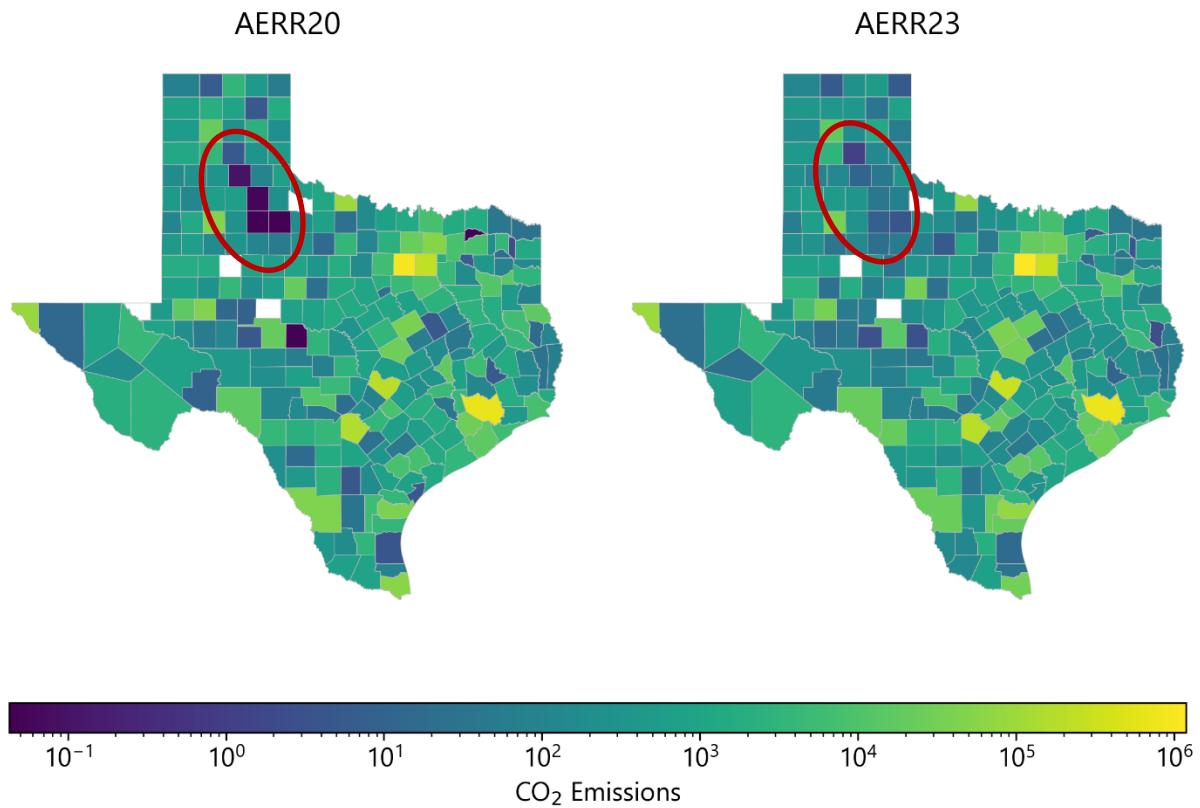


Figure 15. Total emission (in tons) trend from 2011 to 2050 for DFWIA.



**Figure 16. Total emission (tons) trend from 2011 to 2050 for IAH airport.**

The CO<sub>2</sub> emissions at the county level for the AERR20 and AERR23 in the base year of 2023 are shown in Figure 17. Tarrant, Harris, Travis, Dallas, and Bexar Counties are the top five counties with the highest CO<sub>2</sub> emissions in the AERR23, with total CO<sub>2</sub> emissions ranging from 100,000 to over 1,000,000 tons/per year. This rank also remains the same for other pollutants such as PM<sub>10</sub>, NO<sub>x</sub>, and SO<sub>2</sub>. Comparing the maps in Figure 17, it is noticeable that there was an increase in emissions for the counties of Motley, Dickens, Delta, Briscoe, King, and Concho (counties highlighted on the maps).



**Figure 17. CO<sub>2</sub> emission (tons) at the county level for the base year of 2023**

The differences found are related to the fact that the current study used improved methodologies and the latest input data compared to the previous studies. In addition, the simulations were performed using the latest version of AEDT.

Appendix G and Appendix H show the county-level uncontrolled and controlled emissions respectively. The detailed EI results are included electronically as a zipped folder with comma-delimited file format in Appendix I. Statewide controlled annual and average summer weekday emissions are included in the executive summary.

## 7 QUALITY ASSURANCE AND QUALITY CONTROL

Analyses and results were subjected to appropriate internal review and QA/QC procedures, including independent verification and reasonableness checks. All work completed was consistent with the applicable elements of the American Society for Quality, American National Standard ASQ/ANSI: E4:2014: *Quality Management Systems for Environmental Information and Technology Programs – Requirements with Guidance for Use*, February 2014, and the TCEQ Quality Management Plan.

The Quality Assurance Project Plan (QAPP) category and project type most closely matching the intended use of this analysis are QAPP Category II (for important, highly visible Agency projects involving areas such as supporting the development of environmental regulations or standards) and modeling for NAAQS compliance. Internal review and quality control measures consistent with the QA category and project type-specific requirements provided in Guidance for Quality Assurance Project Plans for Modeling, EPA QA/G-5M [28], along with appropriate audits or assessments of data and reporting of findings, were employed. These include but were not limited to the elements outlined, per EPA Requirements for Quality Assurance Project Plans (EPA QA/R-5) [29], in the following description.

### 7.1 PROJECT MANAGEMENT

The definition and background of the work addressed by this project, the project/task description, and project documents and records are as described in the Purpose and Background sections of the Grant Activity Description (GAD). No special training or certification was required. The TTI project manager ensured project personnel used the most current, approved version of the QAPP.

According to guidance and methods documents as referenced, the objective was to produce EIs of the quality level required for air quality modeling and in consultation with the TCEQ project manager.

Basic criteria were used to ensure the acceptable quality of the product, including:

- The product met the purpose of the emissions analysis;
- The full extent of the modeling domain was included;
- Agreed methods, models, tools, and data were used;
- The output data sets were produced in the required formats;

- Any deficiencies found were corrected; and
- Aggregate results were comparable with available, similarly produced emissions estimates.

## 7.2 ASSESSMENT AND OVERSIGHT

The following assessments were performed.

- Verified that the overall scope was met (i.e., consistent with the intended purpose, for specified temporal resolution and geographic coverage, for specified sources, pollutants, and emissions processes).
- Checked that input data was prepared according to the plan; and
- Checked that correct output data was produced. Records were kept of the checks performed.

If any inconsistency or deficiency was found, the issue was directly communicated to the responsible staff for correction (or outside agency staff involved, if any). After any correction, QA checks were repeated to ensure that the additional work resulted in the intended result and was noted in the QA record. The project manager ensured that all QA checks performed were compiled and maintained in the project archives.

## 7.3 DATA VALIDATION

Erroneous or improper inputs at any point during the EI development process may produce inaccurate emissions estimates. QA checks were performed at each step of the analysis to ensure data quality.

Any data products required for the emissions analysis were subjected to the appropriate QA checks. Any issues found needing resolution were corrected, and appropriate QA checks were performed until satisfied, ensuring the project results met the TCEQ requirements, i.e., as outlined in the GAD and QAPP.

The data validation work conducted by the TTI study team includes:

- Comparison of the LTOs between those developed in this study and those developed by TTI and ERG in previous studies. The comparison is shown in Section 4.

- Comparison of the fleet mix between those developed by TTI in this study and those developed by TTI for the AERR20. The comparison is shown in Section 4.
- Comparison of the emissions between those developed by TTI in the AERR23 and those developed by TTI in the AERR20 and ERG in the AERR17. The comparison is shown in Section 6.
- Verification that the final EI data converted into TCEQ's TexAER format meets the TCEQ reporting purposes.

The following sections describe the specific methods the TTI team followed for the data validation.

### 7.3.1 Data Quality Metrics

To evaluate the data quality, the following metrics were used:

- Correlation Coefficient ( $r$ ): Measures the strength and direction of the linear relationship between two variables, such as emissions from 2022 compared to the current study. A coefficient closer to 1 indicates strong agreement.
- Mean Absolute Error (MAE): Quantifies the average error between paired observations without considering their direction. Lower MAE values indicate closer alignment between observations, such as when comparing emissions across different studies.
- Regression Analysis: Linear regression was employed to compare variables between the AERR20 and AERR23. Ideally, the slope should be close to 1, and the intercept close to 0, if the variables from both studies align well.

### 7.3.2 Data Quality Assurance

The quality of the datasets and inputs for the EI were carefully evaluated. Discrepancies were investigated, such as ensuring consistency in airport activity data (both historical and forecasted) between the previous and current studies. Additionally, the data provided by the airport administration was compared against what was collected from airport websites and other sources.

### 7.3.3 Data Analysis

The data analysis involved aggregating AEDT outputs at both airport and county levels and comparing them with previous studies, particularly the AERR20, for the base year

and trend periods (2011 to 2050). The project numbers associated with prior studies are 582-1882508-19, 582-19-95489-01, 582-21-11196-018, and 582-22-32383-005.

Visualizations such as time series plots, bar charts, scatter plots, and heat maps were created to illustrate emission data. These plots were critical in identifying trends, comparing emissions across airports and counties, and detecting potential outliers.

Key pollutants, including NO<sub>x</sub>, CO, CO<sub>2</sub>, PM<sub>2.5</sub>, PM<sub>10</sub>, SO<sub>2</sub>, and VOC, were analyzed using the metrics described earlier. Percentage changes relative to the AERR20 were calculated to assess trends and highlight significant variations over time. All findings from the data analysis are documented in subsequent sections.

### 7.3.4 Tools and Implementation

The QA and data analysis steps were executed using Python, with libraries such as NumPy, pandas, and matplotlib for data analysis and visualization. The scripts were developed in Jupyter notebooks, facilitating easy report generation, auditing of the code, and verification of the results. The developed code is available for sharing with TCEQ upon request, ensuring full transparency and reproducibility.

## 8 SUMMARY AND RECOMMENDATIONS

The report describes the development of aircraft, GSE, and APU source category EIs for the state of Texas for AERR23.

The AERR23 includes 1,947 facilities in Texas. In contrast, the AERR20 has a total of 2,032 facilities. Of these, 1,790 facilities are common to both studies. This difference is related to the fact that some small airports or heliports were closed in the previous study.

The development of the aircraft activities for the AERR23 EI were based on the methodologies developed by improving those used in AERR20. The activity estimates for the AERR23 EI were further revised based on the review by airports.

In the AERR23, all facilities are modeled individually using AEDT. In the AERR20, commercial and reliever airports were modeled individually using the AEDT. For other facilities, representative facilities were used to calculate emission rates with AEDT, which were then applied to estimate the EI for each facility.

Comparisons of results indicate that the 2023 controlled emissions in AERR23 are generally higher than the projected 2023 emissions in AERR20. Apart from differences in

data and methodologies, the faster recovery of air travel post-COVID may also be a significant contributing factor.

TTI recommends the following future work

- 1) Exploring the potential of using Automatic Dependent Surveillance-Broadcast technology to estimate aircraft activity by General Aviation.
- 2) Improve the estimates of GSE fleet and activity
- 3) Develop temporal profiles of the airport emission

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## LIST OF APPENDICES

The appendix for this report includes the following:

Appendix	Title	Description
A	TOG speciated pollutants	This appendix contains an Excel Spreadsheet that lists the HAPs and other TOG-speciated gases included in AERR23 and their mass fraction. This appendix is only available electronically.
B	Airport Contacts	This appendix contains an Excel Spreadsheet that lists the contact information collected. This appendix is only available electronically.
C	2023 LTOs	This appendix contains an Excel Spreadsheet that lists the LTOs from Texas Airports in 2023. This appendix is only available electronically.
D	Fleet Mix	This appendix contains a series Excel Spreadsheet containing the airport LTO and fleet mix from 2011 to 2050. Each analysis year is in its own Excel Spreadsheet. This appendix is only available electronically.
E	Projected LTOs and Fleet Mixes from 2011 to 2050	This appendix contains an Excel Spreadsheet that lists the LTOs from Texas Airports from 2011 through 2050. This appendix is only available electronically.
F	ASIF and AEDT Results	This appendix contains 6 files: 3 XML and 3 CSV for each of commercial reliever TASP, noncommercial reliever TASP, and unsimulated airport. This appendix is only available electronically.
G	Uncontrolled Annual and Daily County-Level Emissions for Texas	This appendix contains 2 CSV file representing the annual and daily uncontrolled emissions inventory for 2011 through 2050 by county. This appendix is only available electronically.
H	Controlled Annual and Daily County-Level Emissions for Texas	This appendix contains 2 CSV file representing the annual and daily controlled emissions inventory for 2011 through 2050 by county. This appendix is only available electronically.
I	Uncontrolled and Controlled Emission Raw Data	This appendix contains the raw uncontrolled and controlled emissions data. This appendix is only available electronically.

## APPENDIX A. TOG SPECIATED POLLUTANTS (ELECTRONIC ONLY)

Available from the TCEQ upon request.

## APPENDIX B. AIRPORT CONTACTS (ELECTRONIC ONLY)

Available from the TCEQ upon request.

## APPENDIX C. 2023 LTOS (ELECTRONIC ONLY)

Available from the TCEQ upon request.

## APPENDIX D. FLEET MIX (ELECTRONIC ONLY)

Available from the TCEQ upon request.

## APPENDIX E. PROJECTION OF LTOS AND FLEET MIX FROM 2011 TO 2050 (ELECTRONIC ONLY)

Available from the TCEQ upon request.

## APPENDIX F. ASIF AND AEDT RESULTS (ELECTRONIC ONLY)

Available from the TCEQ upon request.

## APPENDIX G. UNCONTROLLED ANNUAL AND DAILY COUNTY-LEVEL EMISSIONS FOR TEXAS (ELECTRONIC ONLY)

Available from the TCEQ upon request.

## APPENDIX H. CONTROLLED ANNUAL AND DAILY COUNTY-LEVEL EMISSIONS FOR TEXAS (ELECTRONIC ONLY)

Available from the TCEQ upon request.

## APPENDIX I. UNCONTROLLED AND CONTROLLED EMISSION RAW DATA (ELECTRONIC ONLY)

Available from the TCEQ upon request.