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Integrating Aviation Database Use in Non-engineering Aviation Course Development

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Exploring the use of aviation databases in aviation courses

Abstract

Using real world data when learning new concepts is attractive to many students in engineering technology programs. Even more attractive is using real world data when learning how to address challenges. Statistics courses are usually required for aeronautical engineering technology and other aviation technology students to prepare them with data analysis skills for solving practical problems. Students who major in aviation technology programs are encouraged to practice the learned statistical knowledge with real life aviation data. In aviation public databases such as those available from the Federal Aviation Administration (FAA) and the International Civil Aviation Organization (ICAO), there is a wealth of data that has the potential to engage students in active learning and to inspire students to participate in research or even seek advanced degrees. The use of aviation databases can be expanded in undergraduate level courses, or incorporated into statistical applications in class. The goal of this paper is to encourage instructors to use aviation data in their courses by doing two things: 1) familiarize instructors with a selection of FAA databases and 2) propose a set of exercises that may be incorporated into existing courses, or become part of the exercises in a standalone data analysis course. This paper presents a preliminary course design that focuses on incorporating project based, analysis oriented exercises in undergraduate courses where the exercises use public aviation data. These exercises are intended to hone students' analytical skills and inspire students to learn by using aviation data in the exercises.

Introduction

Using real world data when learning new concepts is attractive to many students in engineering technology programs. Even more attractive is using real world data when learning more about local, national and global challenges. Statistics courses are usually required for aviation technology students to prepare them with data analysis skills for solving practical problems. Students who major aviation programs may be inspired to learn more in-depth statistical knowledge and skills if the problems use real aviation data. In aviation public databases, such as those available from the Federal Aviation Administration (FAA) and the International Civil Aviation Organization (ICAO), there is a wealth of data that has the potential to engage students in active learning and to inspire students to participate in research or even seek advanced degrees. The use of aviation databases could be expanded in undergraduate level courses, or incorporated into statistics exercises. The goal of this paper is to encourage instructors to use aviation data in their courses in two ways: 1) familiarize instructors with a selection of FAA databases and 2) propose a set of exercises that may be incorporated into existing courses, or become part of the exercises in a standalone data analysis course. This paper focuses on incorporating project based, analysis oriented exercises in undergraduate courses where the exercises use public data. These exercises are intended to hone students' analytical skills and inspire students to learn by using aviation data in the exercises.

Data retrieving and information collecting are critical skills for aerospace engineering technology or aviation technology students to practice and expand. While learning and mastering statistical tools and aviation technical knowledge, this paper proposes that students would benefit from projects that use real life data specific to their major, which in this case is aviation related. Access to a vast array of aviation data may be found in two ways: through University libraries that spend scarce resources to purchase access to online databases and through the numerous public databases that are freely available. Even if the data is available, there may be at least two barriers to using it. First, instructors and students are many times not familiar with these databases. Second, examples of using these databases may not be available that facilitate the incorporation of this data in to courses. In this exploratory paper, the two questions explored are:

1. What aviation-related databases are available?
2. How can these databases be used in courses?

Background on Data Analysis in Aviation Programs

Two of the accrediting bodies for aviation-related programs each have some requirement for data analysis. Initially founded in 1988, Aviation Accreditation Board International (AABI) is an autonomous institute that aims to advance the quality of worldwide aviation education program.[1] AABI accredits aviation education programs that meet certain standards.[2] Although there is no prescribed course specific for database utilization, the 2016 AABI accreditation criteria for both bachelor and graduate level programs requires that graduates must demonstrate data analysis and interpretation skills.[3] The ABET-Engineering Technology Accreditation Commission (ABET-ETAC) requirements for aeronautical engineering technology (AET) programs do not specify statistics or database coursework, but the student outcomes do include analysis and interpretation of experimental data, the application of mathematics, and use of graphical communication. Because of these requirements from AABI and ABET-ETAC, there are undergraduate aviation programs that require students to take an elementary statistics course and include data analysis in aviation courses.

The goal of an introductory undergraduate statistics course is to provide students with basic understanding of statistical theory and analysis techniques such as understand sample statistics, analyze data for one or more variables, test for significant differences for means and proportions, calculate the confidence interval for population parameters, and perform simple regression. The courses typically choose a standard statistical software product, such as SAS, Minitab, SPSS, R Project, Excel, among others. Use of a statistical software in introductory statistics courses focuses on learning the concepts in those courses such as estimation of population parameters and the use of graphical and statistical analytical tools. In these courses, students may perform data analysis using datasets provided by the instructor as these datasets are known to the instructor and are selected to be focused on the problem at hand.

Aviation technology programs typically include project based courses in which students work together in small teams to perform case study or group research over a several week period.

Students are required to analyze data from multiple sources provided by course instructor; for instance, airlines operation data, runway incursion and excursion data, airport operation data, maintenance management data, aircraft life cycle management data, meteorological data, aircraft emission data, and other data specific to the course. For similar reasons as in statistics courses, students may use datasets provided by the instructor as these datasets are known to the instructor and are selected to be focused on the specific project.

Introduction to Aviation Databases

There are numerous aviation databases available to the public via websites. The US Federal Aviation Administration (FAA) and the US Bureau of Transportation Statistics (BTS) have national databases that are available. When starting with FAA data, the aircraft registration list and certificated aviation school lists are easily located and searched. There are interesting datasets on on-time statistics, wildlife and aircraft collisions, accident data, and other areas on the www.faa.gov/data_research website. While not an exhaustive list of information available from the FAA, as a way to get started in this sea of freely available data, please see the FAA data source summary in Table 1. For information on aviation and the myriad of other transportation modes, the BTS website contains datasets and reports. The extensive BTS website has an entire section on transportation topics by mode of transportation and offers a wide selection of statistical products and data. For instance, on time statistics by flight number, tarmac times, and fuel consumption by air carrier are available.

Table 1: FAA data and research sources from www.faa.gov/data_research.

Area	Types of Data
Accident and Incident Reports	Preliminary Data, Final Data
Aviation Data and Statistics	Airline On-Time Statistics and Delay Causes, Airport Operations and Ranking, Operational Metrics, Airport Data and Contact Information, and many more data sets
Commercial Space Data	Upcoming and Recent Launch Data, Historical Launch Data
Forecasts	FAA Aerospace Forecasts FY 2016-2036
Passengers and Cargo	Unruly Passenger Statistics, Passenger Boarding and All-cargo Data
Safety	Aviation Safety Information Analysis and Sharing (ASIAS), National Wildlife Aircraft Strike Database
Funding and Grant Data	Airport Improvement Program, Procurement Forecast

Aviation is a global enterprise, and therefore, it is critical that students are exposed to aviation operations, issues and data in a global context. However, it can be more difficult to obtain data from other countries due to lack of availability via websites or due to language differences. Two of the numerous sources of aviation data that are readily available to English-speakers are the United Kingdom Civil Aviation Authority (CAA) and ICAO. On the CAA website available at www.ca.co.uk, there are data sources for the aviation market, safety and security, airspace and the environment, persons and organizations holding approved certificates, aircraft and airworthiness, and data for passengers. For instance, data on flight reliability, on-time flight performance, and aircraft noise and exhaust emissions are available. ICAO collects information on airlines and air travel from countries all over the world. ICAO is the United Nations specialized agency dedicated to aviation. ICAO sells access to databases such as the ones inside ICAO Data Plus that includes aviation data collected from its member states. ICAO Data Plus has financial data, fleet data, passenger-route data, and much more. The ICAO engine emissions databank is freely accessible and contains specific emissions indices for exhaust emissions for turbine engines from all over the globe. Downloadable as a csv file, the databank is easily imported into spreadsheet software. The databank includes information of emissions, fuel flow rates, and other engine parameters for engines such as the AE3007 series to the CFM56 series to the GE90 series. In addition to these databases, there are private companies that sell access to privately developed and maintained databases and are available through access purchase.

The information in Table 1 is not an exhaustive list of FAA data available, instead it is presented as a starting point for locating and using aviation data sources beginning with the FAA Aviation Safety Information Analysis and Sharing (ASIAS) System. For instance, the airport data and contact information database is not found in ASIAS, but is found under the Airports tab and also under Aviation Data and Statistics on the FAA website. This searchable database contains information on number of based aircraft, runway lengths and other airport data. In this paper, the FAA Aviation Safety Information Analysis and Sharing (ASIAS) data found in table 1 is introduced and highlighted for inclusion in aviation courses and exercises.

Table 2: Summary of available data sources in FAA ASIAS.[4]

Data Source	What's in the data source?	Acronym
FAA Accident and Incident Data System	Incident data for all categories of civil aviation operation	AIDS
Aircraft Registration Inquiry database	Fourteen categories of aircraft registration information	AR
Aviation Safety Reporting System	Voluntary reported safety issue or incident from related aviation personal	ASRS
FAA Near Mid Air Collision System	Incident data for possible collision and observed collision hazards	NMACS
NTSB Aviation Accident and Incident Data System	Incident and accident information under the definition of NTSB, in preliminary and final report format	NTSB
NTSB Safety Recommendations	Safety recommendations originated from aviation accident investigation	NTSFE
FAA Runway Safety Office - Runway Incursions	Detailed runway incursion metadata from FAA recorded runway incursion accidents and incidents	RWS
FAA UAS Accident and Incident Preliminary Reports	UAS accident and incident information such as sponsor information, date, location, aircraft type	N/A
World Aircraft Accident Summary	Brief information of major operational accidents worldwide	WAAS

Note. UAS = Unmanned Aircraft Systems; NTSB = National Transportation Safety Board.

Multiple sources of data are available through the FAA's ASIAS portal. A summary of data sources is shown in table 2. The ASIAS system is a joint initiative across government and industry that aims to analyze aviation safety concerns proactively.[5] Using data to inform decision-making is a critical skill in aviation, and in many other ASEE disciplines. ASIAS combines 185 voluntary safety data sources from commercial passenger and cargo air carriers (45), corporate and business operators (20), manufacturers (2), and maintenance, repair, and overhaul (MRO) organizations (2). ASIAS cooperates with Commercial Aviation Safety Team (CAST) and the General Aviation Joint Steering Committee (GAJSC), and specialized in risk monitoring, risk detection, and mitigations evaluation.[5]

The homepage of FAA ASIAS program is the portal to the data sources in Table 2. By selecting "Data & Information" tab on the top left, users can enter the list of all data sources from ASIAS presented in alphabetical order. The following example of retrieving data from this database is based on the FAA Runway Safety Office - Runway Incursions (RWS) database found on the ASIAS source databases (P-Z) tab.

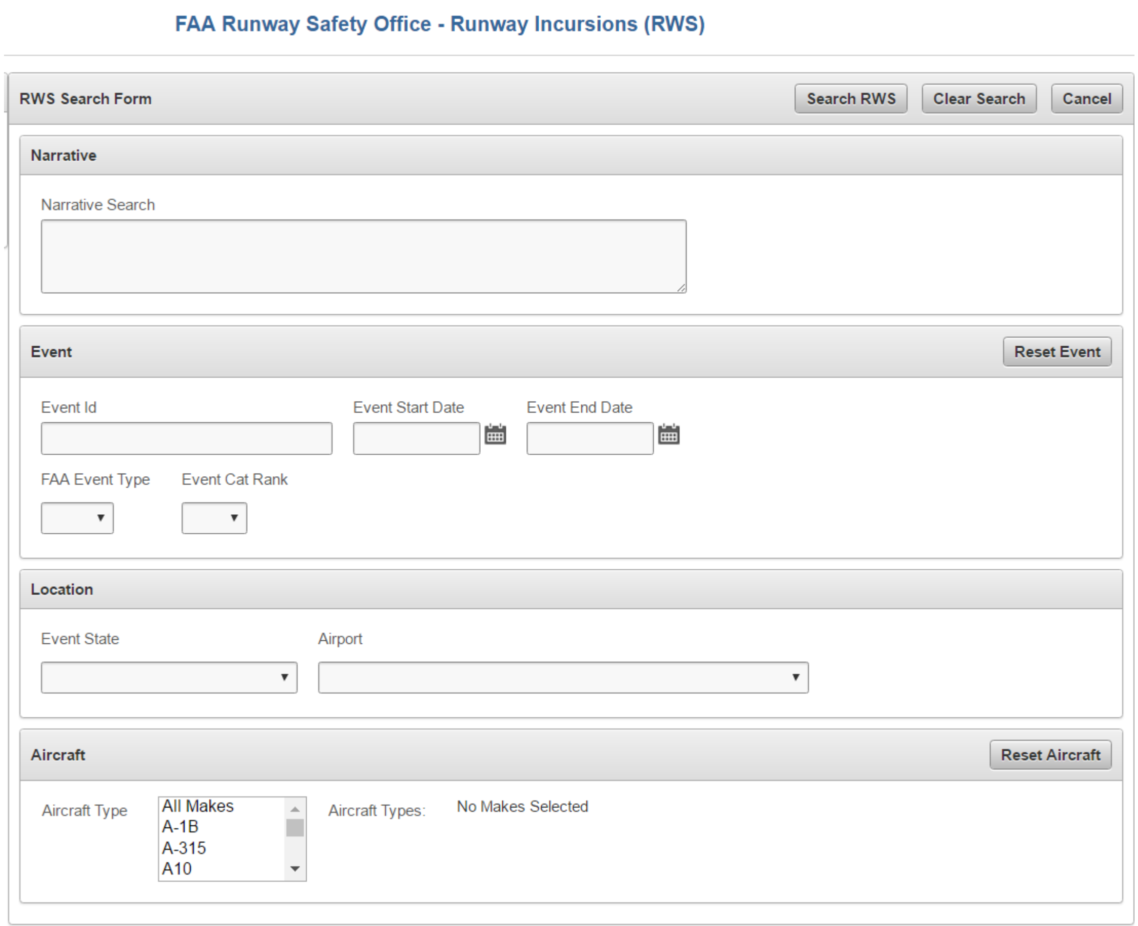

Figure 1: FAA Runway Safety Office - Runway Incursions (RWS) database search form.[6]

After entering the RWS database (figure 1), users can define their search parameters by entering information into the online search form. Runway incursion accidents and incidents can be searched through “Narrative”, “Event”, “Location”, and “Aircraft”. Throughout the “Narrative” searching box, keywords such as “Collision”, “Taxi”, and “Takeoff”, among others, can be used to search details of events such as accidents or incidents. The event can also be located through “Event ID” or the start and end date of the event. Parameters such as the IATA 3-Letter Airport Codes, the state where the event happened, and the type of aircraft can be used to filter the events.

One example of data output from the RWS database is shown in figure 2. This sample output was retrieved by specifying the time of events from January 1st, 2015 to January 1st, 2016, at Chicago O’Hare International Airport (ORD). The output of the search results allows users to sort the events by different parameters, such as FAA code for runway incident type, incursion aircraft type, weather condition, or type of operator. Conveniently for further data analysis, persons can select the “CSV Download” to retrieve the dataset in the format of comma separated value (as is shown in figure 2) that can be copied into many statistical software packages.

EVENT_ID	INCDNT_TYPE_FAA_CODE	EVENT_LCL_DATE	RWY_SFTY_RI_CAT_RNK_CODE	EVENT_ARPT_ID	ACFT_1_RWY_SFTY_TYPE	ACFT_2_RWY_SFTY_TYPE	ACFT_1_FLTCNDT_CODE	ACFT_2_FLTCNDT_CODE	WX_COND_DESC	EVENT_LCL_TIME	EVENT_TKOF_LNDG_DESC	ERROR_TYPE_CODE
17366	PD	30-Dec-15	C	ORD	H25B	A321	91	121	25008KT 2 1/2SM -SN BR BKN010 OVC014 M02/M04	940	RWY 27L	14
17365	UNK	30-Dec-15	N/A	ORD	B739		N/A		301341Z 25005KT 3/4SM R10L/4500VP6000FT -SN BR	742		0
17318	PD	27-Dec-15	N/A	ORD	C208		135	N/A	02019G30KT 10SM -DZ FEW014 BKN020 OVC026 03/(	1055		24
17317	PD	27-Dec-15	N/A	ORD	A320		121	N/A	271351Z 01015G25KT 10SM BKN010 OVC013 03/01 A	811		24
17246	OI	25-Dec-15	C	ORD	E190	CRJ2	121	121	35003KT 8SM SCT140 BKN220 01/M01 A3024	826	RWY 9L	1
17292	PD	11-Dec-15	N/A	ORD	A320		121	N/A	13006KT 10SM SCT170 BKN200 OVC250 08/01 A2983	1720		24
17265	OI	9-Dec-15	D	ORD			VEH	N/A	27008KT 8SM FEW250 07/04 A2971	1008	RWY 32L	3
17338	OI	5-Dec-15	C	ORD	B763	B739	N/A		052251Z 16008KT 10SM BKN250 02/M01 A3050	1742		0
18297	PD	15-Nov-15	D	ORD	B744		129	N/A	21012KT 10SM BKN100 13/01 A3017	2225	RWY 28C	16
17031	OI	30-Oct-15	D	ORD			VEH	N/A	19006KT 10SM BKN210 OVC230 09/04 A3005	1947	RWY 32L	3
16758	OI	24-Oct-15	N/A	ORD	A330		129	N/A	30016G24KT 10SM OVC019 14/11 A2990	1748	N/A	4
16986	OI	20-Oct-15	C	ORD	B738	B738	121	121	27004KT 10SM FEW080 SCT110 BKN140 BKN250 21/(	1750	RWY 27L	1
16934	PD	2-Oct-15	C	ORD	C208	A320	135	121	06017G26KT 10SM FEW035 BKN250 12/04 A3034	835	RWY 9R	16
16910	PD	1-Oct-15	N/A	ORD	A320		121	N/A	04021G27KT 10SM BKN035 14/06 A3030	1640	RWY 10C	24
16702	OI	29-Sep-15	C	ORD	CRJ2	E145	121	121	02016G26KT 10SM FEW020 SCT095 SCT130 BKN250 1	1820	RWY 10C	1
16684	PD	25-Sep-15	D	ORD	A320		121	N/A	02010KT 6SM BR FEW012 FEW200 BKN250 18/17 A3(	1905	RWY 4L	14
16661	PD	19-Sep-15	D	ORD	MD83	N/A		121	32007KT 10SM FEW060 FEW250 19/07 A3007	1842	RWY 28C	16
16605	PD	9-Sep-15	B	ORD	E145	E145	121	121	06006KT 10SM FEW025 SCT250 24/09 A2998	1528		28
16483	PD	12-Aug-15	C	ORD	B787	E170	129	121	08005KT 10SM SCT040 26/16 A3013	1612		16
16432	VPD	6-Aug-15	C	ORD	N/A	B744	VEH	129	08003KT 10SM BKN150 BKN250 22/17 A2994	2333	RWY 10C	30
16284	PD	13-Jul-15	D	ORD	MD11	N/A		121	27014G23KT 10SM -TSRA FEW034CB SCT075 OVC10(	2225	RWY 28R	16
16209	OI	27-Jun-15	C	ORD	CRJ7	A320	121	121	05005KT 10SM FEW250 18/09 A2995	2137	RWY 9R	1
16205	OI	27-Jun-15	D	ORD	A320	N/A		121	35007KT 10SM FEW150 BKN250 14/11 A2996	617	RWY 4L	7
16173	OI	23-Jun-15	C	ORD	C208	CRJ7	121	121	32006KT 10SM SCT060 SCT250 26/11 A3007	1820	RWY 10C	1
16111	OI	10-Jun-15	C	ORD	A320	B738	121	121	22010KT 10SM FEW250 26/16 A2972	1609	RWY 9R	1
16090	PD	6-Jun-15	C	ORD	CRJ7	B772	121	121	04011KT 10SM FEW065 SCT250 21/11 A3012	1434	RWY 9R	15

Figure 2: Data output from FAA Runway Safety Office - Runway Incursions (RWS) database.[7]

Example Exercises Using Aviation Data

In introductory statistics courses, the graphical and statistical analyses of data are introduced. In table 3, a sample of questions and datasets is presented to inspire educators to use aviation data in their statistics courses. The Graphical Summary skill listed is a command in Minitab software that produces a histogram with a Normal curve fitted on the data, box and whiskers charts for median and mean, and numerous sample statistics.

The sample questions in Table 3 are a starting point for the use of these datasets in statistics courses and in aviation courses related to airport management and aviation safety. Using real data that is applicable to real issues is a way to inspire students to learn more about statistics and data analysis.

Aviation Data Analysis Course

While some aviation programs include a statistics course and courses that use aviation data, there is a growing demand for aviation technologists who possess data analysis skills. These technologists may work in safety, operations, or revenue management at airlines, or in manufacturing, safety, quality or engineering at aircraft manufacturers or maintenance companies. Using aviation data is one way to engage students in the statistics theory and application. In this paper, an aviation data analysis course is introduced.

Introduction to Data Management

Statistical software packages are critical tools in managing data before performing the data analysis. In this module, example-based software instructions will be delivered to students in the classroom, and students will practice their software skills in the laboratory hours. Excel, SAS, Minitab, SPSS, and R project are among the prevalent commercial statistical packages in performing data management. The example-based learning modules will be designed to develop a set of focused skills, and to enhance students' practical skills in using those packages, but not develop a comprehensive knowledge of the full capabilities of the software.

After downloading datasets from online database, students are expected to be able to read the original data files, and identify the layout and type of data from the file. Students then will be assigned to transform the datasets into required data formats, using step-by-step guidance developed by the instructor. Additionally, students are expected to be able to manipulate the original datasets, such as combine two or more datasets, add or remove variable(s), transform numerical data to categorical (or vice versa), create new variable and assign value, and conditionally-screen output data. An in-class test will be graded.

Research Project and Presentation

The group project will be assigned to students during the fourth module of the curriculum. Each project team includes three students, and they will be either assigned a topic or propose their interested analytical research project. The objective of the project is to develop and answer an aviation-related question by using aviation databases and statistical software package(s). The team will develop a research question, a methodology, data collection plan, and analysis plan. Ideally, the project will require the use of multiple datasets. The results will be presented to the class, and delivered as a report and a one-page project summary. During class periods, students will discuss published research studies that used aviation databases, in order to increase their skills in developing research projects and in critical thinking. Grades for this module include the report, presentation, one-page summary, team participation input from peers, and participation in the class discussions.

Table 3: Sample of Questions and Datasets.

Sample Questions	Potential Statistical Skills	Datasets
How many 4-seater, single engine, piston aircraft are there in each state in the Great Lakes region?	Histogram, graphical summary, heat map	Aircraft Registration Inquiry database
How many UAS are there in each state in the Great Lakes region?	Histogram, graphical summary, heat map	Aircraft Registration Inquiry database
How many public airports are there in each state?	Histogram	Airport Data and Contact Information
What is the joint expectation of the numbers of UAS registered and public airports for Oregon, Washington and Colorado?	Chi-square Parameter estimation, confidence intervals	Aircraft Registration Inquiry database
What is the distribution of runway lengths in your state? Is this data from a Normal distribution? What distribution is it from?	Histogram, graphical summary Anderson-Darling tests for Normality Parameter estimation, confidence intervals.	Airport Data & Contact Information
How many take-offs and landings are there each month at Charlotte (CLT)? Is there a statistical difference by month?	Histogram, graphical summary, One-way ANOVA and potentially Tukey test, non-parametric tests	Airport Operations and Ranking
Are the number of runway incursions correlated with number of take-offs?	Matrix diagrams, Pearson's correlation, linear regression Correlation vs. causation	FAA Runway Safety Office - Runway Incursions. Airport Operations and Ranking
Are there more accidents in Maine or in Oklahoma? What other factors could be lurking?	Hypothesis tests Correlation vs. causation Parameter estimation, confidence intervals	FAA Accident and Incident Data System
Are there more incursions at airports with crossing runways?	Hypothesis tests Correlation vs. causation Parameter estimation, confidence intervals	FAA Runway Safety Office - Runway Incursions. Airport diagrams.
Are the number of accidents correlated with the number of based aircraft?	Matrix diagrams, Pearson's correlation, linear regression	FAA Accident and Incident Data System. Airport Data & Contact Information
Are unruly passengers correlated with flight delays?	Matrix diagrams, Pearson's correlation, linear regression	Unruly Passenger Statistics. Airline On-Time Statistics and Delay Causes

For instance, the class might discuss studies on runway incursions. Johnson, Zhao, Faulkner, and Young [8] demonstrated an example of runway incursion study that used multiple online databases. Three research questions were addressed in this study:

- "Is the presence of intersecting runways related to the rate of runway incursions at an airport?"
- "Do airport geometry factors contribute significantly to the prediction of the number of runway incursions per 100,000 operations at an airport?"
- "What are the most significant airport geometry factors that contribute to the number of runway incursions per 100,000 operations at an airport?" [8]

To answer the above research questions, this study utilized public available data from Air Carrier Activity Information System (ACAIS), Air Traffic Activity System (ATADS), Aviation safety information analysis and sharing system for runway incursions (ASIAS), AirNav, and FAA Airport Diagrams. From the data provided by Air Carrier Activity Information System (ACAIS), this study first identified the 30 busiest airports with intersected runway, and another 30 busiest airports without intersected runway. The number of incursions per 100,000 operations at the selected airports were retrieved from FAA Runway Safety Office's Runway Incursion database. Air Traffic Activity System (ATADS) provided the total number operations at selected airports from 2009-2013. The ratio of operations causing runway incursions to incursion-free operations were calculated for each airport. The airport configurations data (intersected runway vs. non-intersected runway) were retrieved from the examination of airport diagram available in AirNav. The first research question was examined by a one-sided test for two proportion. Under $\alpha = 0.05$, the statistical test rejected the null hypothesis that "the frequency of runway incursions at airports with intersecting runways is the same as at airports without intersecting runways" in favor of the alternative hypothesis that runway incursion frequency is higher for airports with intersecting runways.[8]

At the completion of the course, the student will have completed the four modules and associated assignments. As a percentage of the course grade, the expected weighting is:

- Introduction to Aviation Databases (5%)
- Laboratory Database Search (10%)
- Introduction to Data Management (25%)
- Research Project and Presentation (60%)

This course is under development and expected to be delivered in Spring 2018 as an experimental course. A set of the data management modules will be incorporated into a course in Fall 2017. The authors aim to encourage the use of aviation data in engineering technology and aviation technology courses. The purpose of this paper is to identify sources of aviation data and introduce how these data may be included in a separate course, or as exercises in an existing data analysis course.

Additional Databases

The ASIAS databases are introduced earlier in this paper as a place to start when looking for real aviation data to include in courses. Other collections of data are available. First, another FAA database is presented. Next, two sources of data from ICAO are presented.

The FAA Air Traffic Activity Data System (ATADS) contains the official public air traffic operations data that are available in National Airspace System (NAS). ATADS data can be accessed without login request.[9] The major data sub-database of ATADS system (see table 4) are: airport operations, tower operations, TRACON (Terminal Radar Approach Control Facilities) operations, total terminal operations, center aircraft handled, and information about air traffic control facility.

By accessing ATADS online, the user is directed to a main page. The airport operations is one of the choices available on the main page. After entering the main page of Airport Operations sub-system, there are six tabs for detailed searching customization. By specify the date, facility, filters and groupings, dataset will be automatically downloaded through click the "Run" button. Under the "Output" tab, user can define the scope of the report and the format of output data file.

Table 4: Available data sub-systems in ATADS.[9]

Data Sub-systems	What's in the data sub-systems?
Airport Operations	The number of IFR, VFR, itinerant operations (takeoff and landings), and local operations, reported by Air Traffic Control Towers (ATCTs)
Tower Operations	The number of IFR, VFR, itinerant operations (takeoff and landings), and local operations worked by the tower
TRACON Operations	The number of IFR and VFR itinerant operations (takeoff and landings), IFR and VFR overflights, and local operations worked by the TRACON
Total Terminal Operations	Combination of operations number worked by different facility
Center Aircraft Handled	All domestic and oceanic departures, overflights, and ARTCCs and CERAPs handled aircraft operations
Facility Information	Name, type, region, state, and the hours of operation for each air traffic control facility

Note. IFR = Instrument flight rules; VFR = Visual flight rules; TRACON = Terminal Radar Approach Control Facilities; ARTCC = Air Route Traffic Control Center; CERAP = Center Radar Approach Control.

Sample data output from Airport Operations sub-system is as shown in figure 3. The number of flights between January, 1990 and December, 2016 at Chicago O'Hare International Airport is used as a sample output in this example. The report used standard format, and the output dataset used MS Excel format. The flight statistics of VFR, IFR, itinerant and local flight were all selected to the output.

Calendar Year	Facility	State	Region	Class	Service Area	IFR Itinerant Air Carrier	IFR Itinerant Air Taxi	IFR Itinerant General Aviation	IFR Itinerant Military	IFR Itinerant Total	VFR Itinerant Air Carrier	VFR Itinerant Air Taxi	VFR Itinerant General Aviation	VFR Itinerant Military	VFR Itinerant Total
1999	ORD	IL	AGL	Combined TRACON & Tower with Radar	CT	712,614	150,764	17,404	632	881,414	1,714	2,520	11,476	166	15,876
2000	ORD	IL	AGL	Combined TRACON & Tower with Radar	CT	687,794	192,272	16,080	198	896,344	100	1,373	11,153	7	12,633
2001	ORD	IL	AGL	Combined TRACON & Tower with Radar	CT	648,007	235,644	13,099	579	897,329	2,012	1,585	10,918	17	14,532
2002	ORD	IL	AGL	Combined TRACON & Tower with Radar	CT	624,177	273,304	12,595	190	910,266	387	364	11,750	20	12,521
2003	ORD	IL	AGL	Combined TRACON & Tower with Radar	CT	543,551	357,611	12,249	225	913,636	2,932	2,733	12,082	39	17,786
2004	ORD	IL	AGL	Combined TRACON & Tower with Radar	CT	452,734	266,630	9,238	57	728,659	3,875	4,019	9,009	126	17,029
Sub-Total for Unknown						3,668,877	1,476,225	80,665	1,881	5,227,648	11,020	12,594	66,388	375	90,377
2004	ORD	IL	AGL	Towers with Radar	CT	159,713	80,768	2,990	66	243,537	146	140	2,959	1	3,246
Sub-Total for 2004						612,447	347,398	12,228	123	972,196	4,021	4,159	11,968	127	20,275
2005	ORD	IL	AGL	Towers with Radar	CT	620,311	325,053	11,543	121	957,028	564	612	13,933	109	15,218
2006	ORD	IL	AGL	Towers with Radar	CT	626,435	303,749	10,763	106	941,053	2,806	1,255	13,357	172	17,590
2007	ORD	IL	AGL	Towers with Radar	CT	617,086	299,211	9,844	142	926,283	49	145	464	32	690
2008	ORD	IL	AGL	Towers with Radar	CT	580,924	291,048	8,427	125	880,524	43	616	350	33	1,042
2009	ORD	IL	AGL	Towers with Radar	CT	544,820	275,633	6,545	126	827,124	24	404	312	35	775
2010	ORD	IL	AGL	Towers with Radar	CT	542,883	331,740	7,018	157	881,798	17	459	308	35	819
2011	ORD	IL	AGL	Towers with Radar	CT	518,217	352,636	7,372	89	878,314	17	229	221	17	484
2012	ORD	IL	AGL	Towers with Radar	CT	508,754	360,760	7,608	196	877,318	15	313	408	54	790
2013	ORD	IL	AGL	Towers with Radar	CT	512,919	362,435	6,785	97	882,236	15	260	757	19	1,051
2014	ORD	IL	AGL	Towers with Radar	CT	547,201	325,687	6,465	169	879,522	1,052	821	510	28	2,411
2015	ORD	IL	AGL	Towers with Radar	CT	597,730	270,074	6,476	114	874,394	20	36	665	21	742
2016	ORD	IL	AGL	Towers with Radar	CT	593,186	267,752	5,833	91	866,862	12	57	692	12	773
Sub-Total for CT						10,639,056	5,322,771	178,334	3,480	16,143,641	15,800	17,941	101,324	943	136,008
Sub-Total for Unknown						6,970,179	3,846,546	97,669	1,599	10,915,993	4,780	5,347	34,936	568	45,631
Sub-Total for AGL						10,639,056	5,322,771	178,334	3,480	16,143,641	15,800	17,941	101,324	943	136,008
Sub-Total for IL						10,639,056	5,322,771	178,334	3,480	16,143,641	15,800	17,941	101,324	943	136,008
Sub-Total for ORD						10,639,056	5,322,771	178,334	3,480	16,143,641	15,800	17,941	101,324	943	136,008
Total:						**10,639,056**	**5,322,771**	**178,334**	**3,480**	**16,143,641**	**15,800**	**17,941**	**101,324**	**943**	**136,008**

Figure 3: A partial sample data output from ATADS Airport Operations Sub-system.[10]

The ICAO Data Plus database is an innovative tool that dynamically and graphically presents airline data. The database helps users to visualize data characteristics and enable them to perform data analysis more competently.[11] The ICAO Data Plus database covers over a 30-year period and allows users to conduct longitudinal research based on historical data. The database also incorporates forward forecasting until the year of 2030. The database covers 7 modules, which are: air carrier finances, air carrier fleet, air carrier traffic, traffic by flight stage, air carrier personal, on flight origin and destination, and airport traffic. See table 5 for more information.

The ICAO Aircraft Engine Emission Databank contains certain aircraft engine emission data from engine manufacturers.[13] The measurement procedures for engine emission data are compliance with ICAO Annex 16, Vol II, and engine manufacturers are responsible for the data accuracy. The ICAO Annex 16, Vol II contains the standards that limit the emission of smoke, hydrocarbons (HC) residual, carbon monoxide (CO) and oxides of nitrogen (NOx), and it also provides standardized test procedures for measuring emissions from aircraft turbine engine exhaust. The Engine Emissions Databank contains emissions information on newly certified engines that entered the production phase, and older engines which are not necessarily compliant with the current emission standards.

Directly downloadable as a single compressed file from the ICAO website (see figure 4), the databank currently incorporates engine emissions data from 15 engine manufacturers worldwide. The data are easily downloaded to an Excel file as a large workbook, and then may be imported to other database software for analysis. In addition, the datasheets are also available. The measurement data files from the same manufacturer are included in one folder and all the required results are divided into different reports based on engine model and engine variations.

For instance, under the "GE Aero Engines" folder, there are thirty-three (33) measurements data files for different variations of CF-6 engine, ranging from CF6-6D to CF6-80E1A2.

Table 5: Available data sub-systems in ICAO Data Plus.[12]

Data Sub-system	What's in the data sub-systems?
Air Carrier Finances	Financial data for international scheduled airlines (revenues, expenditures, assets, liabilities, etc.)
Air Carrier Fleet	Fleet information for both international and domestic scheduled/unscheduled operators (fleet size, type of aircraft, aircraft capacity and utilization)
Air Carrier Traffic	Visualized operational, traffic, and capacity data for international and domestic scheduled/unscheduled operators
Traffic by Flight Stage	Air traffic data categorized by international flight stage (air carrier, aircraft type, operation number, aircraft capacity, and traffic carried)
Air Carrier Personal	Personal information from both international and domestic scheduled/un-scheduled operators (number of airline personnel by job title and their expenditures per year)
On Flight Origin and Destination	Total number of passengers, freight, and mail on scheduled services between all international city-pairs (can only show 6 months after each quarterly reporting period)
Airport Traffic	Monthly and annually air traffic data for major international airports (aircraft movements, passenger enplanements/deplanements, and freight and mail loaded/unloaded information)

The databank contains general engine specifications such as engine bypass ratio, pressure ratio, and rated engine output. The emissions measurements are based on an ideal Landing-and-takeoff (LTO) cycle, under the International Standard Atmosphere (ISA) conditions. The measurement of HC, CO, NO_x, and smoke number are recorded based on the ideal LTO cycle. The report also includes local atmosphere conditions and fuel utilization, along with other information.

Engine Identification	Combustor Description	Eng Type	B/P Ratio	Press Ratio	Rated Output (kN)	---------------EI HC------------- T/O	C/O	App	Idle	LTO Total mass (g)	-------------Fuel Flow---------- T/O	C/O	App	Idle	Fuel LTO Cycle (kg)
						---------------g/kg-------------					-------------kg/sec-----------				
AE3007C2	Type 2	MTF	4.99	17.44	32.73	0.00	0.01	0.22	2.57	1747	0.3263	0.2714	0.0985	0.0472	147
BR700-710A2-20		MTF	4.19	24.16	65.61	0.02	0.02	0.05	1.12	4239	0.714	0.595	0.214	0.089	299
BR700-710C4-11	Annular	MTF	4.05	24.95	68.77	0.02	0.02	0.05	2.29	4449	0.747	0.617	0.215	0.083	294
CFM56-7B27/3	Tech Insertion	TF	5.1	29.00	121.4	0.03	0.02	0.05	1.54	5320	1.293	1.031	0.343	0.110	444
CFM56-7B27AE	Tech Insertion	TF	5.1	29.00	121.4	0.03	0.02	0.05	1.54	5320	1.293	1.031	0.343	0.110	444
CFM56-7B27E	Tech Insertion	TF	5.1	29.00	121.4	0.03	0.02	0.05	1.54	5320	1.293	1.031	0.343	0.110	444
CFM56-7B27E/B1	Tech Insertion	TF	5.1	29.00	121.4	0.03	0.02	0.05	1.54	5320	1.293	1.031	0.343	0.110	444
CFM56-7B27E/B1F	Tech Insertion	TF	5.1	29.00	121.4	0.03	0.02	0.05	1.54	5320	1.293	1.031	0.343	0.110	444
CFM56-7B27E/B3	Tech Insertion	TF	5.1	29.00	121.4	0.03	0.02	0.05	1.54	5320	1.293	1.031	0.343	0.110	444
CFM56-7B27E/F	Tech Insertion	TF	5.1	29.00	121.4	0.03	0.02	0.05	1.54	5320	1.293	1.031	0.343	0.110	444
CF34-10A16	2253M21	TF	5.7	25.1	76.9	0.06	0.08	0.14	6.96	7014	0.765	0.632	0.219	0.083	298
CF34-10A18	2253M21	TF	5.4	26.5	82.1	0.05	0.08	0.13	5.67	6589	0.826	0.684	0.232	0.086	315
CF34-8E5A1	LEC	TF	5.13	24.12	62.49	0.02	0.02	0.06	0.13	2026	0.691	0.563	0.188	0.066	251
GEnx-2B67B	TAPS	TF	8.0	42.4	299.8	0.02	0.02	0.06	0.57	6890	2.451	2.012	0.701	0.216	874
GEnx-2B67/P	TAPS	TF	8.0	43.6	299.8	0.02	0.02	0.04	0.41	5201	2.453	2.009	0.642	0.219	864
PW4060	Phase III	TF	4.7	29.7	266.9	0.08	0.06	0.1	11.63	14815	2.567	2.036	0.696	0.206	865
PW4062	Phase III	TF	4.6	31	275.8	0.08	0.07	0.09	10.86	14475	2.725	2.125	0.718	0.21	894
PW4170	Talon IIB	TF	4.86	33.8	311.4	0.00	0.00	0.05	0.83	5896	3.019	2.450	0.833	0.255	1048
PW6122A	Talon II	MTF	4.8	25.7	98.31	0.00	0.001	0.001	0.006	4602	1.047	0.86	0.304	0.109	401
PW6124A	Talon II	MTF	4.8	28	105.87	0.00	0.002	0.001	0.002	4901	1.169	0.939	0.325	0.114	429
Trent XWB-79B	Phase5 Tiled	TF	9.15	38.81	355.2	0	0	0	1.11	10227	2.601	2.129	0.755	0.280	1008
Trent XWB-84	Phase5 Tiled	TF	9.01	41.09	379.0	0	0	0	0.94	9760	2.819	2.306	0.801	0.291	1069

Figure 4: A partial sample data output from ICAO Aircraft Engine Emission Databank.[14]

Conclusion

In this paper, the authors presented an introduction to the numerous aviation databases available and presented a way to incorporate these databases in courses. Many of these databases can be used free of charge; some require subscription or purchase. After familiarizing the reader with a selection of FAA databases, the authors proposed a set of exercises that may be incorporated into existing courses, or become part of the exercises in a standalone data analysis course. In addition, this paper presented a preliminary course design that focuses on incorporating project based, analysis oriented exercises in undergraduate courses where the exercises use publicly available aviation data. These exercises are intended to hone students' analytical skills and inspire students to learn by using aviation data in the exercises. It is the aim of the authors to inspire others to use these databases so that future generations of engineering technologists are familiar with the challenges facing the global aviation industry and have the skills to help solve them.

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