# A Data Collection Scheme to Support Applications for Capacity Enhancements at Small Airports

Danae Zoe Mitkas
Department of Civil and Environmental Engineering, and
Institute for Systems Research
University of Maryland
College Park, MD, USA
dmitkas@umd.edu

David J. Lovell (Adviser)
Department of Civil and Environmental Engineering, and
Institute for Systems Research
University of Maryland
College Park, MD, USA
lovell@umd.edu

*Abstract*—This paper describes a proposed a data collection scheme to support capacity estimation at small airports that serve primarily general aviation aircraft. Such airports do not have automated data collection systems, nor are they well represented in the existing suite of capacity estimation tools. Capacity estimation is an essential tool for applying for capacity enhancement funding. This paper describes the types of data that are necessary to participate in this process, as well as a scheme based on local, portable installations of Automatic Dependent Surveillance-Broadcast receivers to collect the raw aircraft type and trajectory data that would be necessary to generate these more refined data. The paper also outlines data processing steps that can be taken to deduce more sophisticated insights from the raw data.

*Keywords-airport capacity, general aviation, flight trajectories, ADS-B*

## I. Introduction

Air traffic management can be a very complex procedure but remains a vital element of good performance. An airport's major goal is to meet but not exceed operational capacity. Therefore, an airport must be able to satisfy traffic demand at any given time. This procedure becomes more challenging with increasing air traffic and each airport's capacity constraints. Airside capacity can be affected by various factors, such as weather conditions, local topography or runway configuration [1][2].

Capacity estimation is even more important and must be calculated cautiously when it comes to small airports, with multiple limitations. Small airports can be more sensitive to minor changes in traffic demand. Also, capacity estimation can provide support to airports that seek funding for the construction of a new runway or for the maintenance of existing ones. In general, in order for an airport to qualify for federal funding for infrastructure improvements, it must provide accurate capacity data and future demand data that support the claim for expansion. For accuracy purposes, it is best to avoid self-reported data from informal empirical techniques; however, small airports generally do not have the same automated data collection mechanisms that larger airports can rely on. Also, existing capacity models were calibrated to reflect the much larger scale features that dominate large airports; they do not provide meaningful results when it comes to small airports, since small aircraft and the discriminating features of small airports have low impact on the final result. This can be an important problem for airports that operate mainly with small aircraft. Therefore, the main challenge is to create a method that will provide precise data for small airports that operate mainly with small single or twin engine aircraft [1][2][3].

The need to update airfield capacity models is even greater for small airports. The existing capacity estimation methods proposed by the "ACRP Report 79: Evaluating Airfield Capacity" are inadequate for small airports or small aircraft. These airports may encounter capacity issues only during the peak hour, which may not be reflected in the available analysis techniques. The "ACRP Report 79" and the "Airfield Capacity Spreadsheet" are mostly effective for large airports [3]. Additionally, the Advisory Circular (AC) 150/5060-5 contains only one short section (4-5) which refers to capacity estimation for single runway airports or airports used by small aircraft (class A and B). This technique takes into account only:

- Runway configuration and
- Percent of touch-and-go activity

and provides results of hourly capacity for Visual Flight Rule (VFR) and Instrumental Flight Rule (IFR) conditions. Since we have the means to collect and analyze more data, these methods ought to be revised and updated, especially for small airports [4].

## II. Previous Attempts

Detecting and counting small aircraft can be challenging. Visual detection or radar sensors may not always be effective with small size and low velocity aircraft. Therefore, other techniques must be investigated for data collection in small airports.

Attempts have been made and patents have been filed for automated aircraft counting with acoustic technology. The first related patent was filed in Dec. 2005, which refers to an automated acoustic data collection system using an Unmanned Aerial Vehicle (UAV) equipped with an antenna array. The UAV can collect data while in flight. However, the challenges encountered include wind noise and the UAV's engine noise. Also, this system can only detect the appearance of something (e.g. aircraft) in the environment, with no additional data [5].

Another related patent, filed in Nov. 2011, refers both to a method and the apparatus to detect aircraft in an airport environment. This sensing system is able to detect, track and classify aircraft using the acoustic data. This sensing system can be used by airports that do not have ground surveillance radars. Aircraft can be detected and, in some cases, identified by their acoustic emissions. They cannot, however, be fully identified, nor can any part of their geometric trajectory be determined. [6]

The aforementioned methods may be effective in detecting small aircraft, since they are not related to the size of the aircraft, but only with the noise of their engine. Their main and mutual drawback is that they can only provide gross information regarding the position and in some cases the type of the aircraft. To calculate the capacity of an airport, additional data are needed that either need further procedures to be extracted, or cannot be collected by these methods. The data needed for capacity estimation will be presented in the following sections.

## III. PROPOSED PLAN

### *A. Data Needed for Capacity Estimation*

As proposed by the "ACRP Report 79: Evaluating Airfield Capacity" and the "Airfield Capacity Spreadsheet", which can be used for the evaluation of existing and future capacity for airports, certain input/data are needed to extract results. These data include:

- Aircraft fleet mix
- Percentage of Visual Meteorological Conditions (VMC) and Instrumental Meteorological Conditions (IMC) occurrence
- Arrival runway occupancy time
- Average aircraft approach speeds
- Runway exit availability
- Type of parallel taxiway (full, partial, or none)
- ATC tower availability
- Runway crossings
- Percent of touch-and-go activity
- Length of common approach
- Departure-arrival separation
- Arrival gap spacing buffer
- Departure hold buffer
- Arr-Arr separation requirements
- Dep-Dep separation requirements

The inputs related to the airport's geometry and characteristics can be easily found in the airport records. Data related to aircraft must be collected and processed. As already mentioned, there is a need for an automated data collection method [1].

### *B. External data sources*

Existing databases may contain all the data needed for larger airports; however, they are inadequate for small airports. For example, the number of based aircraft at a small airport is generally known, but quite often a significant percentage of the based aircraft do not participate in many flying operations per year, so they do not represent a significant load on the airport. Moreover, flight schools are often located in small airports, and these tend to have aircraft that are utilized more often and contribute more to the airport's traffic.

Existing databases were considered before moving to the proposed plan. After investigating the Aviation System Performance Metrics (ASPM) database it was found that it contains information only for 77 ASPM airports and for ASPM carriers. This led to the conclusion that it will not contain complete records for small airports [7].

Next, the System Wide Information Management System (SWIM) was examined. It can be considered a useful database since it provides real-time, relevant aeronautical, flight and weather information. However, it also proved to be insufficient for small airports and small aircraft [8].

Finally, the Traffic Flow Management System (TFMS) was considered, which contributes data to both ASPM and SWIM. TFMS provides Aircraft Situation Display (ASDI) data, which include aircraft scheduling, routing, and positional information. As in the previous cases, TFMS also lacks data on small aircraft [9].

### *C. Data Collection using ADS-B Receivers*

Automatic Dependent Surveillance – Broadcast (ADS-B) is an integral part of air transportation. It is a technology intended to supplement ground-based radars by enabling participating aircraft to broadcast their own kinematic data (position, altitude, and speed vectors), as well as other relevant data. According to the FAA, all aircraft that want to fly in controlled airspace must be equipped with ADS-B out [10][11]. As of January 1, 2020, 84,317 General Aviation (GA) aircraft have been equipped, according to the FAA. Specifically, 77% have the 1090ES transponders at 1090 MHz frequency, 22% have a Universal Access Transceiver (UAT) at 978 MHz frequency and 1% have a dual transponder. These numbers may seem small (38%), compared to the approximately 220,000 total registered GA aircraft. However, an aircraft is required to be equipped only when it is flying in controlled airspace. It is often the case that aircraft are registered but do not fly [12]. ADS-B 1090ES is required for aircraft flying above 18,000 ft., or for locations outside the USA. UAT transponders are limited to use within the United States. Ground stations receive and repeat messages both in 978 MHz (UAT) and 1090 MHz (1090ES). Flight schools tend to have more modernized fleets with more interest in maintaining the newest level of technology for the purposes of instructing new pilots. Hence, these airports would likely host a greater percentage of ADS-B equipped aircraft.

ADS-B receivers can collect aircraft data from any equipped aircraft that is detected within range. Thus, ADS-B can help in automated data collection and accurate numbers.

ADS-B messages contain the following information:

- Aircraft Identification: 24 bit address assigned by the International Civil Aviation Organization (ICAO).
- Position: aircraft report their position twice per second. Aircraft position is provided in geodesic frame (WGS84). Position information includes latitude,

longitude, Pressure Altitude and NUC, which indicates the integrity of the associated horizontal position data.

- Velocity: in east-west and north-south velocity and vertical rate.
- Some aircraft may broadcast status messages (e.g. emergencies, priority, capability, navigation accuracy category, operational modes etc.) [13].

ADS-B messages are broadcast using pulse-position modulation (PPM) on a known, fixed frequency; hence, this is an open communication protocol that can be understood by any appropriately configured receiver. The most common configuration used in practice is a software-defined radio (SDR), which uses digital signal processing to complete all the necessary steps of tuning, demodulation, etc. [14]. Many hobbyists have ADS-B receivers and feed their results to consolidators like OpenSky or FlightAware, who use the agglomerated data to produce useful applications for purposes such as flight tracking.

UAT allows aircraft equipped with ADS-B out to be seen by any other aircraft using ADS-B technology and ground stations (receivers). UAT uses a 978 MHz channel to support ADS-B, FIS-B (Flight Information Service – Broadcast) and TIS-B (Traffic Information Service – Broadcast) broadcasts. The UAT channel has two basic types of messages:

- ADS-B messages: these messages are broadcast by an aircraft. Also TIS-B data are broadcast by ground station and use the same message type.
- Ground Uplink messages: these messages are used by ground stations to uplink the FIS-B data.

Aircraft equipped with ADS-B in technology receive altitude and vector information by other equipped aircraft and FIS-B and TIS-B broadcasts. TIS-B contains real-time position information and ground track of nearby aircraft. FIS-B contains weather text and weather graphs [15]. The ADS-B in feature is not relevant for the purposes of this study.

### *D. Data Collection Apparatus*

The ADS-B technology is explained in the following figure. An aircraft receives its position information from a constellation of GPS (Global Positioning System) satellites. Using its ADS-B transponder, it feeds the position information along with other data to ADS-B receivers. Receivers feed their collected raw data to larger databases (Fig.1).

ADS-B receivers can be set up easily, with off-the-shelf hardware. The receiver is composed of the antenna (the analog section) and a software-defined radio (SDR, the digital section). To ensure high quality ADS-B reception, the antenna must have good line-of-sight. The proposed plan is to set up at each airport two antennae, one for 1090 MHz (1090ES) and one for 978 MHz (UAT), and a processor system, to collect transmissions. Even though 1090ES and UAT downlinks have the same architecture, for this study the plan is to use two separate antennae and two separate processors to handle the incoming data, both of which will then feed the data to a common server.

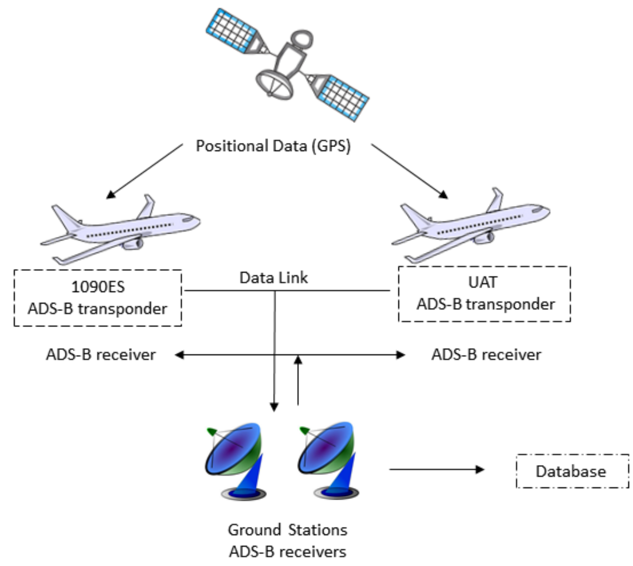


Figure 1: ADS-B system architecture

The next step after setting up a receiver is to start collecting, filtering, and decoding the data received. The state vector of each aircraft comprises all the data mentioned in the previous section. These data will be decoded using the Software Defined Radio (SDR).

After a message has been received, the individual bits need to be identified for message decoding. If the bits have been received successfully, then they will be decoded based upon the type and the format of the message. Each message is 112 bits, of which 24 bits are the unique ICAO aircraft identification number (actually the ID of the transponder) and 56 bits are the ADS-B data. The remaining bits are used for parity checking and other communications details.

To be able to extract useful data, the raw data received must be decoded. The java-adsb library is a decoder library for ADS-B messages, which provides a convenient interface. The supported ADS-B message formats are the following: Identification messages, Velocity over ground messages, Airborne Position messages in compound position reporting (CPR) (including global and local), Surface Position messages in compound position reporting (CPR) (including global and local), Operational status reports (airborne and surface), and Aircraft status reports (emergency/priority, TCAS RA). [16] [17], [18], [19]

### *E. Data Processing Steps*

Once the previous steps have been completed and the data have been collected, the big challenge is to make use of these large quantities of data. The ADS-B messages are stored in .csv (comma separated values) files, and both 1090ES and 978 UAT are saved in the same format. Each file contains a timestamp, the Downlink Format (DF), the ICAO address and the ADS-B message. The timestamp has to be added by the downstream data collection process, because raw ADS-B messages do not contain any inherent timing information. The relevant DFs for this study are 17 and 18, because they contain the necessary data (e.g.

position, velocity etc.). Each aircraft performs differently in each flight phase and produces multiple different messages. The messages are stored in 1-hour long files and then decoded using the python library pyModeS. The decoded .csv files contain the following columns: Timestamp, ICAO address, latitude, longitude, groundspeed, track, rate of climb and callsign; for all the aircraft detected within 1 hour. These messages must be organized in small sets based on the ICAO address and then be connected to create single flight trajectories. To create the trajectories, the decoded files are run through a python script which reads the data and splits them based on ICAO into flights. If an aircraft is detected in more than one file and the time gap between consecutive messages is small, then the messages are combined into one flight. If the aircraft signal is lost for more than 50 secs (a number selected after tests on collected and decoded data) then a new flight with a different flight ID is created. The ICAO address is also used to collect information about the aircraft type, number of engines, weight etc., information important to determine the fleet mix which is needed for capacity estimation. This method can be very useful for organizing raw data in groups that can give meaningful information. Most of the data mentioned in Section A are now collected and can be used for capacity estimation. The flight data groups can also be used to map the aircraft activity using available software tools and provide a visual representation of the actual traffic in the airport where the receivers are set [20].

The outcome provides sets of continuous flight data representing trajectories of flights. Through these trajectories, the following information will be retrieved: number of aircraft departing, number of aircraft landing, phase of aircraft movement (e.g. ground, climb, descend, and cruise), runway occupancy time, velocity and separation.

## IV. CHALLENGES EXPECTED

Factors that may influence the procedure and alter the course of this study include missing or corrupted data and the sheer size of the data. Non-equipped small aircraft (missing data): it is possible that not all aircraft have been equipped with ADS-B transponders. Therefore, even if the data are self-collected directly at the airports, there is a risk that they may not depict reality. Also, processing large amounts of data can be time consuming and lead to errors. Lastly, apart from the problems with message loss that might occur, ADS-B messages are sensitive to radio frequency (RF) attacks, which can lead to message corruption.

## V. CONCLUSIONS

In this study, a data collection and a data processing method are proposed, to support capacity estimation at small airports. Capacity estimation is crucial for airports, and the existing techniques have been proven inadequate for small airports. A capacity model needs proper input to provide a satisfying result. ADS-B technology can be the key to this challenge and if properly utilized, it can produce the desired results. Another significant step of this study is the selection of the appropriate locations for data collection, based on high traffic, mixed activity, runway configuration and line-of-sight. The method proposed with the potential to assess capacity estimation, can provide guidance to airport planners and managers.

## ACKNOWLEDGMENT

The authors wish to acknowledge the Federal Aviation Administration, sponsors of FAA NEXTOR II Award #693KA919F00139 "Small Aircraft Capacity Modeling Factors", the motivation for this research.

## REFERENCES

[1] B. Bubalo and J. R. Dadun, "Airport capacity and demand calculations by simulation—the case of Berlin-Brandenburg International Airport", *Netnomics*, 2011, 12: pp.161.

[2] E. Fernandes and R.R. Pacheco, "Efficient use of airport capacity", in Elsevier, *Transportation Research Part A: Policy and Practice*, vol. 36, issue 3, pp.225-238.

[3] National Academies of Sciences, Engineering, and Medicine 2012, "ACRP Report 79, Evaluating Airfield Capacity", Washington, DC: The National Academies Press, 2012.

[4] Federal Aviation Administration, "Airport Capacity and Delay", Advisory Circular AC: 150/5060-5, 1983.

[5] A.M. Zelnio, "Detection of Small Aircraft Using an Acoustic Array", Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Engineering, Wright State University, 2009.

[6] J.S. Lee, R.O. Nielsen, H.H. Davis and P.H. Dunholter, "Acoustic Airport Surveillance System", Patent No. US 8,059,489 B1, United States Patent, 2011.

[7] Federal Aviation Administration, "Aviation System Performance Metrics (ASPM)", last update 5.10.19.

[8] Federal Aviation Administration, "System Wide Information System (SWIM)", last update 10.18.19.

[9] Federal Aviation Administration, "Traffic Flow Management System (TFMS)", last update 7.5.18.

[10] "Automatic Dependent Surveillance-Broadcast (ADS-B) Out equipment and use", Title 14 of the Code of Federal Regulations (CFR) § 91.225.

[11] "Automatic Dependent Surveillance-Broadcast (ADS-B) Out equipment performance requirements", Title 14 of the Code of Federal Regulations (CFR) § 91.227.

[12] Duffy, K. (FAA Airports Planning and Environmental Division), in conversation with the authors, January 2020.

[13] RTCA, Inc., "Minimum aviation system performance standards for Automatic Dependent Surveillance – Broadcast (ADS-B)," Report DO242A, 2004.

[14] E.G. Piracci, G. Galati and M. Pagnini, "ADS-B signals reception: a Software Defined Radio approach", in 2014 IEEE Metrology for Aerospace (MetroAeroSpace), Benevento, Italy, 2014.

[15] International Civil Aviation Organization, "Manual for the Universal Access Transceiver (UAT)", 2003.

[16] M. Schafer, M. Strohmeier, V. Lenders, I. Martinovic and M.Wilhelm, "Bringing up OpenSky: A Large-scale ADS-B Sensor Network for Research", In: IPSN-14 Proceedings of the 13th International Symposium on Information Processing in Sensor Networks, Berlin, Germany, 2014.

[17] International Civil Aviation Organization, Asia and Pacific Office, "ADS-B Implementation and Operations Guidance", Edition 11.0, 2018.

[18] M. Strohmeier, M. Schäfer, V. Lenders, and Ivan Martinovic, "Realities and Challenges of NextGen Air Traffic Management: The Case of ADS-B", *IEEE Communications Magazine*, Vol: 52, Issue: 5, May 2014.

[19] "Mode S and ADS-B Decoder for Java", OpenSky network project, retrieved from https://opensky-network.org/community/projects/20-java-adsb, January 2020

[20] J. Sun, H. Vu, J. Ellerbroek & J.M. Hoekstra, "pyModeS: Decoding Mode-S Surveillance Data for Open Air Transportation Research", IEEE Transactions on Intelligent Transportation Systems, 2019.