Appendix A

# Prototype
# Airfield Capacity
# Spreadsheet Model

# User's Guide

## INTRODUCTION

The Prototype Airfield Capacity Spreadsheet Model (Airfield Capacity Spreadsheet Model) was developed for ACRP Project 03-17, "Evaluating Airfield Capacity," and is intended to serve as a prototype modeling tool to help airport planners understand and determine airfield capacity. Airfield capacity is the estimated number of total operations that a given airfield configuration can facilitate in a given period of time and under a given set of assumptions regarding fleet mix, separation minima rules, weather conditions and technological aides.

For many years the ability to quickly estimate an airfield's potential operational capacity has been limited to rules of thumb for simple configurations and a lookup table provided in the 1983 FAA Advisory Circular 150/5060-5, *Airport Capacity and Delay* (the AC). Varying levels of sophistication from spreadsheet models to full simulation modeling continue to advance and provide additional tools for planners to assess the existing and future airfield capacity under varying scenarios. The Airfield Capacity Spreadsheet Model can serve as an intermediary between the existing lookup tables available in the current AC (some of which are replicated utilizing new calculations on this spreadsheet model) and full simulation modeling.

The Airfield Capacity Spreadsheet Model is built on base calculations following the theory in the FAA Airfield Capacity Model (ACM) and applies variable separation, spacing and clearance standards following the guidelines included in FAA JO 7110.65, *Air Traffic Control,* and FAA EM-78-8A, *Parameters of Future ATC Systems Relating to Airport Capacity/Delay*. The FAA ACM referenced is discussed in detail in FAA RD-76-128, Reference 1.

The new spreadsheet model is designed to function as a working planning tool and is sensitive to most input changes that will dynamically represent real conditional changes on most simple to moderately complex airfield configurations.

This spreadsheet modeling tool is intended to serve as a beginning-level capacity calculation option. The model is not intended for complex airfield calculations or for use when a higher degree of specificity is required when supporting large-scale airfield redevelopment projects or highly controversial capacity projects. As outlined in the model selection criteria in Chapter 5 of the guidebook, large-scale and expensive capacity-related projects can support and should require the use of more detailed simulation efforts. The checklists provided in Chapter 5 will help to determine if sufficient data is available or can be assumed to provide enough of the necessary inputs to run the various models. In the absence of specific input parameters, the model can, in many cases, still be used, as many of the base default parameters can be used for simple single or dual runway airfields without significant unique restrictions. The Airfield Capacity Spreadsheet Model can be used to generate average or high level hourly capacity metrics depending on the data available and depth of knowledge.

Model worksheet areas have been formatted to print out on two sheets of legal paper for each of the three working models.

The Airfield Capacity Spreadsheet Model calculates average hourly capacity levels for the following general airfield configurations:

Single runway
Dual parallel runways
Dual intersecting runways

Each general configuration can be uniquely adjusted to closely fit the conditions of the user's specific airfield through selected input parameters.

The flowchart in Exhibit 1 provides a process overview of the steps involved in using the spreadsheet model with the necessary inputs to estimate airfield capacity.


Source: Landrum & Brown.

***Exhibit 1. Prototype Airfield Capacity Spreadsheet Model flowchart.***

Determination of airfield capacity is essentially based on the average time of separation between arriving aircraft and/or departing aircraft, which allows for a certain number of arrivals or departures to occur in an hour. The Airfield Capacity Spreadsheet Model attempts to model the interactions of different aircraft classes in a given fleet mix that follow all of the inputs regarding minimum spacing and air traffic rules. When sufficient spacing occurs between successive arrivals or departures, often one or more departures or arrivals can be released between the pairs, allowing for true mixed operations on the airfield. The optimal capacity is typically a balanced mix of arrivals and departures or a 50:50 mix.

## DISCLAIMER

Significant research has been undertaken to prepare these analysis models for ACRP and much precaution has been taken to ensure that the models provide useful and applicable results to the area of airfield capacity planning. Neither ACRP, LeighFisher, nor Landrum and Brown Inc. assume any responsibility for errors or omissions of components in the development of this model, or for any damages resulting in the use of results from the spreadsheet model analysis. The developing group shall in no event be liable for any financial implications or loss of opportunity alleged to the use of resulting information assumed from use of this model.

## SYSTEM REQUIREMENTS

The Airfield Capacity Spreadsheet Model runs in Excel and suitable for all versions of Microsoft Office Excel 2003 or newer. If the user's computer is currently successfully running Excel 2003 or newer, the spreadsheet model file should operate without any additional complication or issue.

The Airfield Capacity Spreadsheet Model does contain some simple macros for resetting many standard inputs and therefore require the macro function to be enabled. In Excel 2007 or Excel 2010, the "Enable Macros" button should appear in the ribbon at the top of the spreadsheet when the file is opened. Excel versions typically suggest not allowing all macros to run without authorization; therefore, most configurations are set to ask before running a macro or to disable any macros upon opening the file and prompt the user to change the security settings if necessary. To access the security settings in Excel 2007 and 2010, select the "File" tab or the "Windows Office" icon and navigate to "Options\Trust Center\Trust Center Settings" to change the security settings to enable the use of macros. In Excel 2003, navigate to the security settings by selecting the "Tools" menu and choosing "Macro\Security" to change the settings to "Medium." With the macros enabled, the functions in the Airfield Capacity Spreadsheet Model can perform as intended. If you encounter difficulty getting the "RESET INPUTS" button to work, more information is available on the "INTRO" tab on the spreadsheet.

The model's viewing area fits better on a wide screen monitor with a resolution of at least 1680 x 1050, but any monitor will suffice. Lower resolution monitors may not fully display the output section to the right without shifting the screen view more to the right.

# OVERVIEW

The Airfield Capacity Spreadsheet Model consists of a macro-enabled Excel file (workbook) with several user tabs (spreadsheet tabs) that contain the operating configuration models, calculation worksheets, and supporting information on using the models and understanding the inputs and their individual effects on the output. The calculated output is the hourly airfield capacity determined by the combinations of the input data entered and model selections chosen as specific parameters for the airfield under consideration.

The workbook contains an introduction tab, labeled "INTRO," which contains some helpful definitions useful in navigating the model (see Exhibit 2). Note: A supplemental tab, labeled "Separation Layout" (not visible in the exhibit), provides a visual reference for understanding the determination of the arrival to arrival separation and interleaved departure time requirements described in the INTRO tab.


*Exhibit 2. INTRO tab.*

The INTRO tab also contains a legend, or "key" to the cell contents to help users identify the data associated with the fill and text colors used throughout the model (see Exhibit 3).

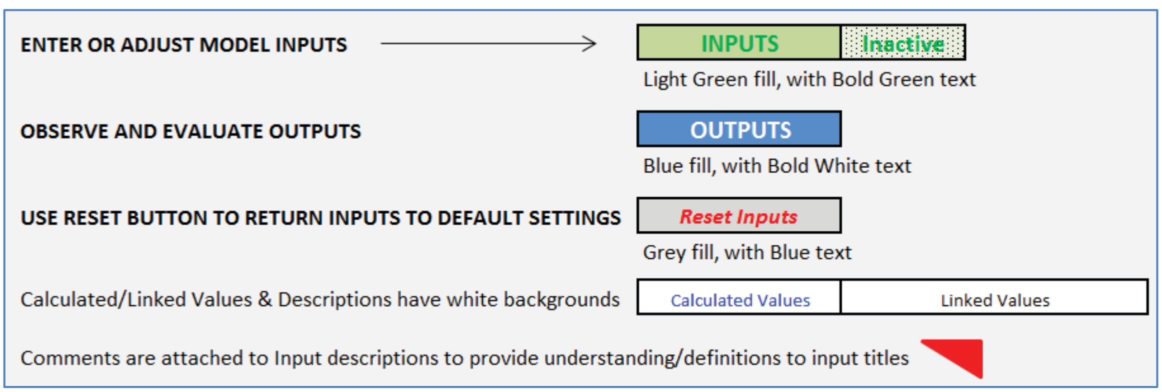


*Exhibit 3. Cell contents key.*

Next to the INTRO tab, a "Runway Layouts" tab has been included to graphically depict some of the terms and configurations illustrated within the models to help the user get a better understanding of the interaction involved in the models and the overall process involved in the calculations of the separation between aircraft (Exhibit 4).


*Exhibit 4. Runway Layouts tab.*

To protect the integrity of the Airfield Capacity Spreadsheet Model's information and formulas, *all of the worksheets have been protected;* however, the user can unprotect them as needed. There is no set password for the ancillary tabs, and for the model tabs the password is set as "**pass**". Caution: Do NOT change the password if you choose to unlock the models as the password is embedded in the macro codes.

The next tab in the workbook is labeled "Lookup Table" (Exhibit 5). This tab opens a sheet containing a lookup table in the format of the AC's Figure 2-1. This lookup table is just a sample of new lookup table results based on iterations performed using the default settings and assumptions that are in line with those expressed in the AC.


***Exhibit 5. Lookup Table tab.***

Of the original 19 configurations presented in the AC, five have been populated which best represent the usable outputs from the three configuration models included in the Airfield Capacity Spreadsheet Model tool. Exhibit 6 shows the results of the Single Runway Model.

| General Runway-Use Configurations | New Aircraft Group Mix Percentages A S-S | B S-T | C S+ | C L-TP | C L-J | C L-757 | D H | Hourly Capacity Operations/Hour VFR | IFR | Annual Service Volume Operations/Year |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.) Single Runway | | | | | | | | | | |
| | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 90 | 66 | 223,000 |
| | 25% | 50% | 25% | 0% | 0% | 0% | 0% | 74 | 62 | 213,000 |
| | 5% | 20% | 20% | 25% | 25% | 5% | 0% | 63 | 56 | 206,000 |
| | 0% | 5% | 10% | 10% | 65% | 5% | 5% | 62 | 50 | 209,000 |
| | 0% | 0% | 5% | 5% | 55% | 5% | 30% | 60 | 48 | 225,000 |

***Exhibit 6. Portion of Lookup Table showing single runway configurations.***

Three runway configuration tabs can be employed by the user to estimate hourly airfield capacity—"Single Model," "Dual Model," and "Intersecting Model" (Exhibit 7). Each tab opens a separate, but comparable, spreadsheet model as designed for a single runway, dual parallel runway, or intersecting runway configuration.


***Exhibit 7. Single Model, Dual Model, and Intersecting Model tabs.***

Selection of a model that reflects the user's airfield operating conditions is the first choice that must be made by the user. Default values are supplied in other sections of the model, but selection of the runway configuration is the first requirement in utilizing the Airfield Capacity Spreadsheet Model.

The next sections of the User's Guide provide explanations for use of the models reflecting the three airfield operating conditions provided in the Airfield Capacity

Spreadsheet Model, including details of the inputs that the user may enter or adjust to arrive at the hourly capacity output. It is assumed that the user will have limited knowledge of air traffic control rationale or FAA rules and guidelines on air traffic and pilot procedures regarding approach and departure routines. The explanations are intended to provide sufficient understanding to successfully use the capacity model, but not in such detail as to act as a tutorial on airfield capacity planning. The user is advised to become familiar with the spreadsheet tool as presented for the Single Runway Model (Single Model) before moving on to the Dual Parallel Runways Model (Dual Model) or the Dual Intersecting Runways Model (Intersecting Model), as the inputs and instructions for the latter two models build on information presented in the explanation of the Single Model.

## SINGLE RUNWAY MODEL

The Single Runway Model (Single Model) is the simplest base configuration and will have the smallest number of variables, conditions and potential airfield conflicts. Having selected the Single Model, the user must then consider other inputs or choice selections.

Defaults (a standard set of inputs) are provided as a starting point for using each model. The Dual Model and Intersecting Model have additional configuration possibilities and will therefore have some additional input parameters to select or enter. There are basically two main areas for making inputs or choosing selections; General Inputs and Advanced Inputs. The general inputs allow the user to set up the conditions of the airfield and the fleet mix. These general inputs should be modified by the user, since the defaults that exist in the base model are unlikely to reflect the specific airfield and fleet mix conditions of the user's airport. While these general inputs are not requirements, they are essential to the production of a reasonable and relevant hourly airfield capacity. Beyond the general inputs are the advanced inputs, which allow for further refinement of data such as separation minima requirements that can also be modified. The advanced inputs, or advanced features, can be either shown in the spreadsheet model or left hidden by the user with the use of Excel radio buttons. The advanced features incorporate standardized separation minima requirements between pairs of arrivals and pairs of departures for both VMC and IMC weather conditions. It should be noted that if a user does not provide inputs in the advanced features section, the defaults reflect those included in FAA's EM-78-8A report on airport capacity and delay.

Cells within the runway configuration tabs are identified in a consistent manner to help the user quickly follow the flow of inputs, intermediate calculated values and outputs.

A "RESET INPUTS" button is available in each runway configuration model near the top of the INPUTS section (Exhibit 8).


***Exhibit 8. RESET INPUTS button.***

The user can change all of the input settings while customizing the conditions of a given airfield, and then return all of the standard (default) settings back to the original values by clicking the RESET INPUTS button.

The only settings that do not change back to default values when the RESET INPUTS button is clicked are the fleet mix share allocations, the VMC % occurrence under meteorological conditions, the operations assumption on touch-and-goes and the Runway Exit Availability and Full Parallel Taxiway selections.

## General Inputs, Section 1

In the first section of general inputs the user makes selections regarding the specific operating conditions and air traffic control (ATC) practices for the airfield under consideration (Exhibit 9).

**At a minimum in Section 1,** the user must make an assumption regarding the percentage of total operations that consist of touch-and-go operations (see **Operations Assumption on Touch-N-Go's,** in Exhibit 9). This percentage is likely to be 0 if there isn't a flight training school or military airbase onsite. If the user has specific information on departure-arrival separation or the length of the common approach, the user **can** modify this information or rely on the defaults that are provided based on standard operating conditions as identified by FAA in ATC procedures.

| INPUTS | | | | | |
|---|---|---|---|---|---|
| Meteorological Conditions | VMC, % Occurrence | 90% | IMC, % Occurrence | | 10% |
| VMC-Departure-Arrival Separation | 2.0 | nm | Arrival - Arrival Std. Dev. | 18.0 | sec |
| IMC-Departure-Arrival Separation | 2.0 | nm | Departure ROT Std. Dev. | 6.0 | sec |
| Length of Common Approach | 7.0 | nm | Z-Value, 95% Confidence | 1.645 | ------------ |
| Operations Assumption on Touch -N- Go's | | 0% | T-Factor (Touch-N-Go's) | | 1.00 |

***Exhibit 9. Single Model General Inputs Section 1.***

Another key adjustment within Section 1 is the percentage of time the airfield operates under visual meteorological conditions (**VMC, % Occurrence**) and instrument meteorological conditions (**IMC, % Occurrence**). The basic criteria for determining VMC or IMC is a cloud ceiling of at least 1,000 feet above the ground and visibility of at least 3 statute miles. VMC is assumed when exceeding the minimum requirement, and IMC is therefore assumed when below the minimum FAA guidelines. VMC and IMC can be determined from ASPM data sets available from FAA or determined from local weather history for the airport vicinity while following some general FAA guidelines. There are more conditional types, such as Marginal (MMC) and Poor Visual (PVC), but VMC and IMC are the two major conditions commonly used in determining an airfield's capacity.

Other inputs in Section 1 include the following:

- Departure-arrival separations (for both VMC and IMC conditions)
- The length of common approach
- Arrival-arrival standard deviation
- Departure runway occupancy time (DROT, abbreviated as Departure ROT in the spreadsheet) standard deviation

**Departure-Arrival Separations** are defined as the minimum spacing between an arriving aircraft and the runway threshold for a departure to receive clearance to occupy the runway and take off. This value can range from as little as 1 to 5 nautical miles (nm, also noted as "nmiles" on some spreadsheet pages) or more, depending on the surrounding conditions. Even though the default values have both been set at 2.0 nm in this model, the values for VMC and IMC are not always the same.

The **Length of Common Approach** is the distance from the outer marker (the point at which the aircraft is on final approach) to the runway threshold. During this phase of flight, aircraft traveling at different speeds can possibly get closer or further apart as they descend on final approach to the runway. This value is typically between 5 and 10 nautical miles.

**Arrival-Arrival Standard Deviation** and **Departure ROT Standard Deviation** inputs are determined from actual ATC tower datasets or field observations at specific airfields. The input reflects the variance in consistency of pairs of arriving and departing aircraft in terms of seconds (sec.). This variance helps to sufficiently buffer the necessary separation spacing desired. These are default values that reset when the RESET INPUTS button is clicked, and can be used as a common starting point if data are not available for more detailed analysis. The **Z-value** input is not colored in green like the other inputs as it is a standard statistical value used to achieve a 95 percent confidence level. By using this set value, it is assumed that no more than 5 percent of operations will fail to remain within the assigned separations.

### General Inputs, Section 2

The second section of general inputs is focused on the aircraft fleet mix and associated operating specifications, as well as selections regarding the availability and use of runway and taxiways. The Airfield Capacity Spreadsheet Model has expanded the traditional four-category aircraft classification into a seven-category classification system to allow for more specificity of aircraft types and possible interactions with a more diverse fleet mix. The new categories have been discussed for some time, but are not formally agreed upon or used by FAA or the aviation consulting industry. The expanded classification system is used in the model to give the user more variability in identifying the specific fleet mix at the airfield under consideration. A summary of selected aircraft types and their corresponding fleet mix categories which are used in the Airfield Capacity Spreadsheet Model appears separately on the worksheet's "Fleet Mix" tab (Exhibit 10).

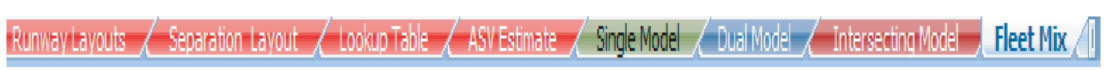


**Exhibit 10.** Fleet Mix tab.

Exhibit 11 illustrates the second section of general inputs as organized for the Single Runway Model.

**At a minimum** in Section 2, the user must enter share allocations for the **Operating Fleet Mix** and make selections pertaining to the **Runway, Taxiway** and **Airport Traffic Control Tower** availability. The other inputs can be left as common defaults for a baseline determination of the hourly airfield capacity.

| Aircraft Classification<br>New Category | Small - S | Small - T | Small + | Large-TP | Large-Jet | Large-757 | Heavy |
|---|---|---|---|---|---|---|---|
| Previous FAA Category | A | B | C | C | C | C | D |
| Maximum Gross Takeoff Weight (MTOW) | Less than 12,500 lbs (Single Engine) | Less than 12,500 lbs (Twin Engine) | Between 12,500 lbs and 41,000 lbs | Between 41,000 lbs and 255,000 lbs | Between 41,000 lbs and 300,000 lbs | Boeing 757 Series | More than 300,000 lbs |
| Operating Fleet Mix<br>Share Allocations | Enter the actual or expected % share for each aircraft class | | | | | | |
| | 5.0% | 0.0% | 10.0% | 20.0% | 60.0% | 2.0% | 3.0% |
| Arrival Runway Occupancy Time<br>Time in *Seconds* | Enter the estimated time from touchdown to runway exit | | | | | | |
| | 32 | 40 | 42 | 45 | 46 | 51 | 55 |
| Average Approach Speeds<br>*Velocity in Knots* | Enter the average suggested manufacturers final approach speed under normal conditions | | | | | | |
| | 90 | 100 | 120 | 130 | 135 | 140 | 150 |
| Runway Exit Availability OR | Excellent or Default | | 100% | Runway Crossing Delay ? | | Yes | 90 |
| Full Parallel Taxiway | Full Taxiway | | 100% | Average Crossing Delay | | 30 | sec |
| Airport Traffic Control Tower | Yes | | Availability | Crossings during Peak Hour | | 3 | Frequency |

***Exhibit 11. Single Model General Inputs, Section 2.***

Explanations of the other inputs in Section 2 are provided below.

The **Operating Fleet Mix** inputs are set up with conditional formats to shade out the aircraft class options that are not selected and to highlight the aircraft classes that are included. The cell values are conditionally formatted to alert the user if the sum does not equal to 100 percent. This alert shows up as a message stating (ADJUST VALUES), and a red summary total percentage appears to the right of the last column, as seen in Exhibit 12.

| Fleet Mix<br>Share Allocations | Enter the actual or expected % share each aircraft class | | | | | | (ADJUST VALUES) | |
|---|---|---|---|---|---|---|---|---|
| | 9.6% | 0.0% | 0.0% | 0.0% | 80.0% | 9.5% | 9.3% | 108.4% |

***Exhibit 12. ADJUST VALUES alert message.***

Fleet mix determinations can be made with FAA ASPM data, airport traffic control tower (ATCT) counts, radar data, or some other available flight-log type data. For those airports without ATCTs, an operational fleet mix should be estimated that considers the airport's based aircraft as well as the itinerant aircraft that operate at the airport.

The goal is to best represent the operational proportions of each aircraft class for use in a probability matrix that determines the likely pairing matches between each possible pair of aircraft classes. The average operational fleet mix probabilities, by aircraft class, are used by the Airfield Capacity Spreadsheet Model for calculations.

For example: if a fleet mix has 50% Small-S aircraft operations and 50% Large-Jet aircraft operations, the probabilities for aircraft pairing would be as follows:

- 25% Small-S leading a Small-S
- 25% Small-S leading a Large-Jet
- 25% Large-Jet leading a Small-S
- 25% Large-Jet leading a Large-Jet

A sample set of aircraft for each aircraft class is provided in Exhibit 13. Aircraft weights are based on manufacturers' suggested Maximum Take Off Weight (MTOW), which can be determined from the manufacturers' specification sheets, www.airliners.net/aircraft-data website, or other sources.

The **Arrival Runway Occupancy Time (AROT)** is specific to each individual aircraft, as is the **Approach Speed**. For purposes of the Capacity Spreadsheet Model, averages of these inputs have been selected as defaults, but the data can be modified if the user has specific information on either of these two inputs. Default settings have been determined through evaluation of common aircraft specifications in each class. They are included in the default values that are linked to the RESET INPUTS button and can be adjusted as needed by the user. Varying airfields will have unique geographic or environmental conditions and/or requirements that will give higher or lower values than the defaults. The user can adjust the values up or down and perform a sensitivity analysis to see the effects of varying the range of inputs for these two factors.

After making the fleet mix selections, the user should examine the **Runway Exit Availability OR Full Parallel Taxiway, and Runway Crossing Delay** input fields. The defaults for the **Runway Exit Availability** and **Full Parallel Taxiway** selections assume that the airfield will have adequate exit availability and a full parallel taxiway to avoid delays on the runway. **Runway crossings** are also assumed to be negligible or minimal, and therefore not causing any noticeable delays under the default conditions. Choosing alternative conditions, such as fewer exits or a partial parallel taxiway, will decrease the calculated airfield capacity by applying a proportionate factor to the original capacity. The applied factors range from 0.75 to 1.0.

IF the user inputs actual or real AROTs into the model, the **Runway Exit Availability** and selection should remain at the default setting and therefore no reduction in capacity would be included in the calculations. The exit reduction is intended for use with the other default inputs. When a true AROT is determined, exit availability has already been factored into the AROT as the actual time until the runway has been cleared.

Additionally, a full parallel taxiway is presumed to be the default case, and if a partial taxiway or no taxiway is selected, the runway occupancy times will therefore be greater and capacity will be diminished. A proportionate factor is applied to the original capacity in conjunction with other limiting factors. The factors range from 0.5 to 1.0.

| Aircraft Class Designations | | Sample Aircraft |
|---|---|---|
| **Category** | **Small-S** | BE36 - Beech Bonanza 36 |
| Description | Small - Single Engine | C172 - Cessna Skyhawk 172/Cutlass |
| Weight | < 12,500 lbs | C210 - Cessna 210 Centurion |
| | | PA28 - Piper Cherokee |
| | | PA38 - Piper Tomahawk PA38 |
| | | PA46 - Piper Malibu |
| | | PC12 - Pilatus PC-12 |
| | | TBM7 - Socata TBM-7 |
| | | SR20 - Cirrus SR-20 |
| **Category** | **Small-T** | BE19 - Beech 19 Sport |
| Description | Small - Twin Engine | BE20 - Beech 200 Super King |
| Weight | < 12,500 lbs | BE30 - Raytheon 300 Super King Air |
| | | BE55 - Beech Baron 55 |
| | | BE58 - Beech 58 |
| | | BE9L - Beech King Air 90 |
| | | C425 - Cessna 425 Corsair |
| | | C441 - Cessna Conquest |
| | | C500 - Cessna 500/Citation I |
| | | DHC6 - DeHavilland Twin Otter |
| | | PA44 - Piper Seminole |
| **Category** | **Small-+** | BE40 - Raytheon/Beech Beechjet 400/T-1 |
| Description | Small - Twin Engine | C25A - Cessna Citation CJ2 |
| Weight | 12,500 - 41,000 lbs | C560 - Cessna Citation V/Ultra/Encore |
| | | C750 - Cessna Citation X |
| | | CL30 - Bombardier (Canadair) Challenger 300 |
| | | EMB120-Brasilia |
| | | FA50 - Dassault Falcon/Mystère 50 |
| | | GALX - IAI 1126 Galaxy/Gulfstream G200 |
| | | LJ35 - Bombardier Learjet 35 |
| | | LJ55 - Bombardier Learjet 55 |
| | | SBR1 - North American Rockwell Sabre 40/60 |
| **Category** | **Large - TP** | ATR 42 |
| Description | Large - Turbo Prop | ATR 72 |
| Weight | 41,000 - 255,000 lbs | Dash 8 Q100/200 |
| | | Dash 8 Q300/400 |
| | | Saab 340 *RED denotes weight exception* |
| **Category** | **Large - Jet** | Airbus 318/319/320/321 |
| Description | Large - Jet | Boeing 737 Series |
| Weight | 41,000 - 255,000 lbs | DC-9 Series |
| | | MD 80/82/83/88/89 |
| | | Gulfstream III/IV/V |
| | | CRJ100/200 |
| | | CRJ700/900 |
| | | ERJ135/140/145 |
| | | EMB170/175/190/195 |
| | | CL60 - Bombardier Challenger 600/601/604 |
| **Category** | **Large - 757** | Boeing 757-200 |
| Description | Boeing 757 Series | Boeing 757-300 |
| Weight | 255,000 - 300,000 lbs | |
| **Category** | **Heavy** | Airbus 300/310 |
| Description | Heavy - Multi Engine | Airbus 330/340/350 |
| Weight | > 300,000 lbs | Airbus 380 |
| | | Boeing 747 Series |
| | | Boeing 767/777 |
| | | Boeing 787 |
| | | DC-10/MD-11 |

Source: Landrum & Brown.

***Exhibit 13. Aircraft classifications.***

The model makes some generalized assumptions as to the impact of not having enough properly spaced exits or not having a full parallel taxiway. The user is asked to make selections in only one of the two input cells for **Runway Exit Availability OR Full Parallel Taxiway.** The main assumption as stated previously is that the airfield will have a full parallel taxiway; **IF NOT,** the user should make a selection in that cell, OR the user can choose to select a runway exit scenario instead.

**DO NOT use both selections or the capacity value will be discounted twice by the applied factors.**

The final selection in this inputs section is to indicate "Yes" or "No" regarding the availability of an Airport Traffic Control Tower (ATCT). It is assumed in the default case that the airport has an ATCT. In the event that the user selects the "No" option, a 10% reduction to the existing calculated capacity is applied, and separation requirements are adjusted as needed in the case of IMC and dual parallel runways.

Depending on the fleet mix and input conditions, the hourly capacity output will show an operations mix that may already be somewhat balanced or nearly 50 percent arrivals and 50 percent departures. This is not always the case.

**If the user does not want to use any further advanced inputs, an assumption can be made that the average hourly capacity would be some proportional combination of the arrivals only capacity and the departures only capacity**.

For example: Assume the arrivals only capacity is 40 operations per hour and the departures only capacity is 60 operations per hour

- 36 minutes in arrivals only mode = 24 arrivals
- 24 minutes in departures only mode = 24 departures => **50% mix**

If the user wants to make adjustments to the default buffers and provide more gap spacing between arrivals and permit more departures in mixed operations, the user can click on the "SHOW Advanced Features" radio button (Exhibit 14).

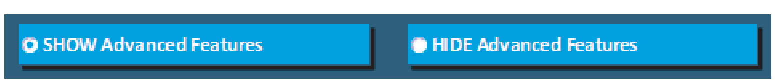


***Exhibit 14. SHOW Advanced Features button.***

The Advanced Inputs Section is displayed on clicking the SHOW Advanced Features button and is hidden again if the HIDE Advanced Features button is subsequently selected. The advanced input features are described and explained in the next section.

### Advanced Inputs, Section 1

The first section of Advanced Inputs allows the user to introduce a buffer to the average arrival to arrival separation and the average departure to departure separation (Exhibit 15). These buffers create more gap spacing, which in turn typically allows for more departures between arrival pairs in mixed operations. The buffer for arrivals can be applied in seconds or miles, depending on which approach is more common to local ATC or which data are available.

| | | | | | | |
|---|---|---|---|---|---|---|
| Arrival Gap Spacing Buffer | 0.0 | sec | <----OR----> | Arrival Gap Spacing Buffer | 0.0 | nmiles |
| Departure Hold Buffer | 10.0 | sec | | | | |

***Exhibit 15. Buffers.***

Method #1, as indicated in the model, is known as "gap spacing" and allows manual average increases to the minimum separation between arriving aircraft pairs to permit one or more departures to take off between the pair of arrivals.

The **Arrival Gap Spacing Buffer** should be increased incrementally and the output observed after each change. The user can increase the buffer until the desired level of additional departures is achieved or until the mix between arrivals and departures reaches a certain ratio. During the gap spacing adjustment process, the number of arrivals will decrease as more departures are added. The user should only increase the buffer if the change adds sufficient departures to compensate for fewer arrivals.

The **Departure Hold Buffer** is not meant to be used to try and increase overall capacity; rather it will actually decrease airfield capacity as a certain safety level may require more spacing before departure release based on specific operating conditions.

### Advanced Inputs, Section 2

The second section of Advanced Inputs deals with the arrival to arrival separation minima referenced previously and is based on default levels as outlined in FAA EM-78-8A, *Airport Capacity and Delay*. **For the common user, the separation minima default values can be used in most cases and no adjustments are necessary unless specific requirements exist.**

The **Arrival-Arrival Separation Requirements** are input in nautical miles and represent the minimum safe distance between the unique aircraft pairs listed in Exhibit 16. FAA report EM-78-8A, *Airport Capacity and Delay*, provides a set of guidelines for minimum separation distances. Each pair consists of a trailing and leading aircraft. Smaller aircraft are spaced farther behind larger aircraft due to the increased wake vortex from larger aircraft. Separation minima are higher during IMC weather conditions than during VMC weather conditions. Overall minimum spacing defaults are set to 1.9 nautical miles in VMC and 3.0 nautical miles in IMC.

*Note: These are minimum separation distances and the resulting capacity outputs represent an optimistic outcome.*

If observed average arrival runway occupancy times are less than 50 seconds, 2.5 nautical miles can be used as the alternate minimum separation gap. To use the **Alternative IMC Minimum** value, the user needs to select the "Yes" option to the right of the separation inputs. When the RESET INPUTS button is clicked, the separation defaults will reset to whichever minimum value has been selected.

| Arrival-Arrival Separation Requirements | | Distance in Nautical Miles (nm) | | | |
|---|---|---|---|---|---|
| Trailing Aircraft | Leading Aircraft | VMC | IMC | | |
| Small-S --- Heavy | Small-S, Small-T | 1.9 | 2.5 | 2.5 | **Alternate IMC Minimum** |
| Small-S --- Small+ | Small + | 1.9 | 2.5 | 2.5 | (if Observed AROT < 50 Seconds) |
| Large --- Heavy | Small + | 1.9 | 2.5 | 2.5 | **Use 2.5 nm in place of 3.0 nm?** |
| Small-S --- Small+ | Large-TP, Jet | 2.7 | 4.0 | | Yes |
| Large --- Heavy | Large-TP, Jet | 1.9 | 2.5 | 2.5 | |
| Small-S --- Small+ | Large-757 | 3.7 | 5.0 | | |
| Large --- Heavy | Large-757 | 2.7 | 4.0 | | |
| Small-S --- Small-T | Heavy | 4.6 | 6.0 | | |
| Small + --- 757 | Heavy | 3.6 | 5.0 | | |
| Heavy | Heavy | 2.7 | 4.0 | | |

***Exhibit 16. Single Model Advanced Inputs Section 2, showing Arrival-Arrival Separation Requirements and Alternate IMC Minimum.***

The user can make suitable adjustments as necessary to increase the arrival-arrival separation requirements to better represent conditional requirements at the airfield under consideration.

### Advanced Inputs Section 3

The final Advanced Inputs section is focused on the separation requirements for spacing between departures. The minimum levels used as defaults are also outlined in FAA's EM-78-8A, *Airport Capacity and Delay*. **For the common user the separation minima default values can be used in most cases and no adjustments are necessary unless specific requirements exist.**

The **Departure-Departure Separation Requirements** are input in seconds (as opposed to nautical miles for arrival-arrival separation) and range from 35 seconds in VMC for successive small aircraft to 120 seconds when a small aircraft follows a 757 jet or Heavy jet (see Exhibit 17). Again, this spacing is necessary to protect against the effects of the leading aircraft's wake vortex. Typically, 60 seconds is used as the minimum separation between departures allowing the leading aircraft sufficient time to take off and clear the end of runway while not allowing the following aircraft to enter the leading aircraft's wake vortex. These values are also minimum levels and can be increased if desired or required by local ATC.

| Departure - Departure Separation Requirements | | *Time in Seconds* | |
|---|---|---|---|
| Trailing Aircraft | Leading Aircraft | VMC | IMC |
| Small-S --- Small + | Small-S- Small + | 35 | 60 |
| Large -TP --- Large 757 | Small-S- Small + | 45 | 60 |
| Heavy | Small-S- Small + | 50 | 60 |
| Small-S --- Small+ | Large TP, Large Jet | 80 | 80 |
| Large --- Heavy | Large TP, Large Jet | 60 | 60 |
| Small-S --- Large Jet | Large 757, Heavy | 120 | 120 |
| Large 757, Heavy | Large 757, Heavy | 90 | 90 |

***Exhibit 17. Single Model Advanced Inputs Section 3, showing Departure-Departure Separation Requirements.***

All of the Advanced Inputs can be reset to the determined default values by clicking the RESET INPUTS button. RESET INPUTS

## Model Outputs

The model output results are the VMC and IMC hourly operations capacity levels that can be used as individual components or a total hourly mix in evaluating the airfield capacity of an airport. The outputs section as outlined in Exhibit 18 estimates the **Arrivals Only Capacity** with or without touch-and-go operations (labeled **Touch-N-Go** or **TNG**), the **Departures Only Capacity**, the **Mixed Ops-Departure Capacity**, and the **Total Mixed Operations Capacity**. As the user changes the inputs, these outputs change in value accordingly.

| OUTPUTS | | | |
|---|---|---|---|
| | VMC | IMC | Average |
| Arrivals Only Capacity | 40 | 34 | 39 |
| Arrivals Capacity (including TNG's) | 40 | 34 | 39 |
| Departures Only Capacity | 51 | 51 | 51 |
| Mixed Ops - Departure Capacity (including TNG's) | 0 | 0 | 0 |
| Total Mixed Operations Capacity | 40 | 34 | 39 |
| Arrivals Percentage | 100% | 100% | 100% |

***Exhibit 18. Single Model Outputs.***

The inclusion of TNG operations occurs when the user inputs a percentage up to 50% in cell D11. A **T-Factor** (touch-and-go factor) is estimated in the General Inputs, Section 1 to allow a maximum value of 1.4 when the maximum 50% input is used. The T-Factor is applied to the calculated arrivals to estimate a new total arrivals capacity. It is assumed that the majority of TNG operations involve flight training and are normally associated with small aircraft. Military aircraft may also perform significant flight training operations and would need to be uniquely accounted for in the fleet mix and airfield operating conditions. Specific focus on military aircraft is not discussed related to using this spreadsheet model.

TNG operations are calculated by the spreadsheet and added equally to both the **Arrivals Capacity (including TNGs)** output and the **Mixed Ops-Departure Capacity (including TNGs)** output, as included in the input by the user. The **Total Mixed Operations Capacity** output assumes arrival priority and includes all achievable departures between arrivals.

**Departures Only Capacity** only changes when adjustments to the departure-related inputs are increased or decreased. The **Arrivals Percentage** is arrivals hourly capacity divided by the total mixed hourly capacity and includes the TNG operations if they occur.

## Single Runway Model: Quick Reference Guide

**Step 1:** **Click** the RESET INPUTS button to restore all default inputs to base conditions.

**Step 2:** Determine and **Input** the %VMC if available. Otherwise, use the default. (Note: Exhibit 19 shows input locations for steps 1 through 7).
*VMC and IMC capacities are typically cited separately and the overall average may not be necessary, but for determination of the annual capacity or annual service volume (ASV) the split between VMC and IMC will be necessary.*

**Step 3:** **Input** the assumed percent of operations that occur as touch-and-goes.
*No adjustments need to be made to the departure-arrival separations, common approach, or standard deviations for a base capacity determination.*

**Step 4:** Determine or estimate, then **Input** the share allocations of the airfield's operational fleet mix.
*Remember, the total must add up to 100%, and only the selected aircraft classes will remain fully visible, as those inactive input cells will be shaded.*

**Step 5:** **Adjust** AROTs and Average Approach Speeds if supporting data or operational knowledge is available.
*Otherwise, use the default values which provide a usable base set of estimates.*

**Step 6:** **Make selections** with dropdown boxes as to the availability of runway exits, taxiways, and an Airport Traffic Control Tower.

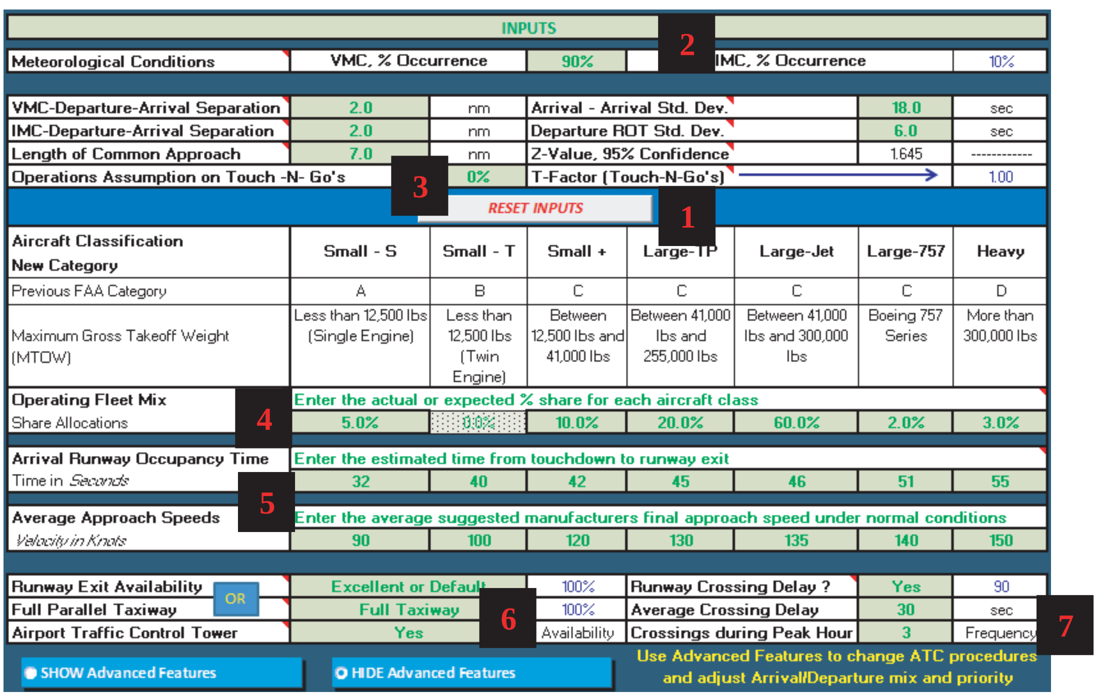


***Exhibit 19. Inputs, Single Runway Model.***

**Step 7: Make a selection** as to the existence of runway crossing requirements. **Input** assumptions as to the number of crossings that occur in an hour and how long the average delay is in seconds.
*No adjustments need to be made to the runway crossing delay if data is unavailable (i.e., keep the input set to "NO" and 0)*

**Step 8: Click** the SHOW Advanced Features button to unhide the remaining input cells for further adjustment of the average arrival to arrival separation times and average departure to departure separation times that determine the hourly capacity outputs, as needed (Exhibit 20).


***Exhibit 20. SHOW Advanced Features and HIDE Advanced Features buttons.***

**Step 9: Adjust** minimum arrival pair separation distances (nautical miles, abbreviated nm or nmiles in the spreadsheets) and minimum departure to departure times (seconds, abbreviated sec) if knowledge of air traffic control guidelines, local requirements and methodology is available and understood (Exhibit 21).
*Otherwise, use the default values which provide a usable base set of estimates.*

| Arrival-Arrival Separation Requirements | | *Distance in Nautical Miles (nm)* | | | |
|---|---|---|---|---|---|
| Trailing Aircraft | Leading Aircraft | VMC | IMC | | |
| Small-S --- Heavy | Small-S, Small-T | 1.9 | 2.5 | 2.5 | **Alternate IMC Minimum** |
| Small-S --- Small+ | Small + | 1.9 | 2.5 | 2.5 | (if Observed AROT < 50 Seconds) |
| Large --- Heavy | Small + | 1.9 | 2.5 | 2.5 | **Use 2.5 nm in place of 3.0 nm?** |
| Small-S --- Small+ | Large-TP, Jet | 2.7 | 4.0 | | **Yes** |
| Large --- Heavy | Large-TP, Jet | 1.9 | 2.5 | 2.5 | |
| Small-S --- Small+ | Large-757 | 3.7 | 5.0 | | |
| Large --- Heavy | Large-757 | 2.7 | 4.0 | | |
| Small-S --- Small-T | Heavy | 4.6 | 6.0 | | |
| Small + --- 757 | Heavy | 3.6 | 5.0 | | |
| Heavy | Heavy | 2.7 | 4.0 | | |

| Departure - Departure Separation Requirements | | *Time in Seconds* | |
|---|---|---|---|
| Trailing Aircraft | Leading Aircraft | VMC | IMC |
| Small-S --- Small + | Small-S- Small + | 35 | 60 |
| Large -TP --- Large 757 | Small-S- Small + | 45 | 60 |
| Heavy | Small-S- Small + | 50 | 60 |
| Small-S --- Small+ | Large TP, Large Jet | 80 | 80 |
| Large --- Heavy | Large TP, Large Jet | 60 | 60 |
| Small-S --- Large Jet | Large 757, Heavy | 120 | 120 |
| Large 757, Heavy | Large 757, Heavy | 90 | 90 |

***Exhibit 21. Inputting separation distances and minimum departure to departure times.***

At this point all of the major inputs have been made and the results in the outputs section should represent the baseline arrival priority mode capacity and the departure priority mode capacity. Depending on the set of inputs and selections that were used, the operations mix may or may not be balanced.

The model suggests two methods for arriving at a specific operations mix ratio or an optimum capacity level.

The first method is identified as the **Gap Spacing** or gap stretching method, and it increases the average separation gap between each arrival pair to allow for more departures between arrivals. Gap spacing allows the user to achieve a more balanced operational mix, essentially creating a "one in, one out" condition for 50% arrivals and 50% departures (Exhibit 22).

**Method #1 for adjusting Arrival/Departure Mix (Gap Spacing)**
Gap Spacing allows more time between arrival pairs to permit more than one departure between pairs.

***Exhibit 22. Method 1 (gap spacing).***

**Step 10 (Method #1, Gap Spacing): Adjust** the **Arrival Gap Spacing Buffer** by increasing either the *time buffer* (seconds) or the *distance buffer* (nautical miles) until the desired output is achieved (Exhibit 23). Use only one option.
*The Departure Hold Buffer provides safety assurance before a departure is cleared for take off,* ***but*** *is not used as a part of the arrival gap spacing method.*

| | | | | | | |
|---|---|---|---|---|---|---|
| Arrival Gap Spacing Buffer | 0.0 | sec | <----OR----> | Arrival Gap Spacing Buffer | 0.0 | nmiles |
| Departure Hold Buffer | 10.0 | sec | 10 | | | |

***Exhibit 23. Using Method #1 (Gap Spacing) to adjust the arrival gap spacing buffer.***

**Step 11 (Method #2):** If a specific arrival percentage is desired, the user can take an algebraic approach and proportionally assign time segments where different operating modes would be conducted.

**Adjust** the share allocations for **Mixed Operations, Arrivals Only,** or **Departures Only** capacities to achieve the desired operations mix (Exhibit 24). Make sure the total sum of the inputs equals 100%. If the total does not add up to 100%, a sum warning (*ADJUST ALLOCATIONS)* will appear in red lettering underneath the heading **VMC Allocations** to alert the user.

**Method #2 for adjusting Arrival/Departure Mix (Variable Airfield Operations)**
Variable operations permits operating with different capacties (e.g. Departure Priority, and Mixed) for portions of the design hour.

| Arrival Percentage Variance (Portion of Capacity Hour in Mixed/Arr. Priority/Dep. Priority) | | | | |
|---|---|---|---|---|
| VMC Allocations | 0% | Mixed Operations | 0.0 | min |
| 11 | 55% | Arrivals Only | 33.0 | min |
| | 45% | Departures Only | 27.0 | min |
| | 100% | Total | 60 | min |
| Calc. % Arr 32% | 0 | Arrivals (Mixed) | | *Average* |
| | 17 | Arrivals (Only) | 17 | Arrivals |
| | 0 | Departures (Mixed) | 35 | Departures |
| | 35 | Departures (Only) | 51 | Total |

***Exhibit 24. Using Method #2 to adjust the arrival gap spacing buffer.***