Airport Runway Location and Orientation

CEE 4674 Airport Planning and Design

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Runway Location Considerations

The following factors should be considered in locating and orienting a runway:

- Wind
- Airspace availability
- Environmental factors (noise, air and water quality)
- Obstructions to navigation
- Air traffic control visibility
- Wildlife hazards

Read Chapter 2 of FAA AC/150-5300-13 for more information about each topic
Runway Orientation and Wind

- The orientation of the runway is an important consideration in airport planning and design.
- The goal of this exercise is to define the runway orientation that maximizes the possible use of the runway throughout the year accounting for a wide variety of wind conditions.
- FAA and ICAO regulations establish rules about runway orientation and their expected coverage.
- Ideally, all aircraft operations on a runway should be conducted against the wind.
- Unfortunately, wind conditions vary from hour to hour thus requiring a careful examination of prevailing wind conditions at the airport site.
Cross Wind Operations

All aircraft have maximum demonstrated cross wind components (usually specified in the flight manual)

Wind vector

Crosswind Component

Aircraft Velocity Vector

Resulting Aircraft Ground Speed Vector

Runway

Wind vector
Demonstrated Wind Conditions

Each aircraft has a uniquely stated maximum crosswind component (derived from flight test experiments)

- A Boeing 727-200 (approach group C) has a maximum demonstrated wind component of 35 knots
- A Cessna 172 (a single engine aircraft falling in approach speed group A) has a maximum demonstrated crosswind component of 17 knots

The challenge for the designer is to accommodate all of the aircraft using the facility in a reliable and reasonable manner.
Reporting Wind Conditions

Wind is reported on an azimuthal basis as shown below:

\[ w = 15 \text{ knots} \]

Wind from 315° at 15 knots
Sample Crosswind Computation

Runway 27

$w_c = w \sin (\gamma)$

$w_h = w \cos (\gamma)$

NOTE: Winds are always reported with respect to the magnetic North (in ATC transmissions)
Crosswind Calculator (Appendix 1 of FAA AC 150/5300-13)

**Example:**
- Wind speed 20 knots. Angle between runway and direction of wind - 60°. Crosswind component - 17 knots.
- Headwind component - 10 knots.
Design Criteria (FAA and ICAO)

Read Chapter 2 of FAA AC 150/5300-13 or Aerodrome design manual (Volume 1 for ICAO standards)

Employ the most critical aircraft expected to operate in the airfield (in this context the most critical is the largest)

- Provide a runway (or runways) orientation that satisfies 95% coverage (i.e., crosswinds below a critical value) considering yearly wind conditions

- If one runway does not meet the 95% criteria design a second crosswind runway

The argument of using the most critical aircraft might sound counterintuitive (but it is necessary)
Recognizing that each aircraft has unique maximum demonstrated crosswind characteristics the FAA (and ICAO as well) set a low value for crosswind design criteria.

<table>
<thead>
<tr>
<th>Airport Reference Code</th>
<th>Design Crosswind Value (knots)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-I and B-I</td>
<td>10.5</td>
</tr>
<tr>
<td>A-II and B-II</td>
<td>13.0</td>
</tr>
<tr>
<td>A-III, B-III and C-I through D-III</td>
<td>16.0</td>
</tr>
<tr>
<td>A-IV through D-IV</td>
<td>20.0</td>
</tr>
</tbody>
</table>
ICAO Crosswind Design Criteria

Similar to the FAA criteria in many ways. However, ICAO has two aerodrome classifications.

<table>
<thead>
<tr>
<th>Aerodrome Runway Reference Code</th>
<th>Runway Reference Field Length (m.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>&lt; 800</td>
</tr>
<tr>
<td>B</td>
<td>800 - 1,200</td>
</tr>
<tr>
<td>C</td>
<td>1,200 - 1,800</td>
</tr>
<tr>
<td>D</td>
<td>&gt; 1,800</td>
</tr>
</tbody>
</table>
ICAO Crosswind Design Criteria

Similar to the FAA criteria in many ways but simpler (only three design values).

<table>
<thead>
<tr>
<th>Runway Length (m.)</th>
<th>Design Crosswind Value (knots)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1,200</td>
<td>10.0</td>
</tr>
<tr>
<td>1,200 - 1,500</td>
<td>13.0</td>
</tr>
<tr>
<td>&gt; 1,500</td>
<td>20.0</td>
</tr>
</tbody>
</table>
Data Sources

Collect wind data from a **reliable source:**

- National Oceanic and Atmospheric Administration (NOAA), Environmental Data Service (EDS)
- The EDS's National Climatic in Asheville, North Carolina
- The wind data is usually available for hundreds of stations across the U.S.
- Ironically, Blacksburg has a National Weather Service station but EDS does not have a record of us!
- Carefully use weather record from two or more nearby stations if wind data is not readily available at the proposed airport site (**be very careful of local weather effects**)
Data Sources

- For mountainous terrain with data without wind data, the use of nearby stations is of questionable value.
- Take one year of wind data if possible.
- Several automated reporting systems exist at airport that can be used for this purpose (EDS will not have data about these).
  
  AWOS - Automated Weather Observation System

- The data available from NOAA usually includes 10-15 years (daily observations).
- Use 5-10 years of data for airport planning purposes (except when you are collecting the data yourself).
# Sample Wind Data

## Wind Direction Versus Wind Speed

**Station:** Anywhere, USA  
**Hours:** 24 Observations/Day  
**Period of Record:** 1964-1973

<table>
<thead>
<tr>
<th>Direction</th>
<th>0-3</th>
<th>4-6</th>
<th>7-10</th>
<th>11-16</th>
<th>17-21</th>
<th>22-27</th>
<th>28-33</th>
<th>34-40</th>
<th>41 OVER</th>
<th>TOTAL</th>
<th>AVERAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>469</td>
<td>842</td>
<td>568</td>
<td>212</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2091</td>
<td>6.2</td>
</tr>
<tr>
<td>02</td>
<td>568</td>
<td>1263</td>
<td>820</td>
<td>169</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2820</td>
<td>6.9</td>
</tr>
<tr>
<td>03</td>
<td>294</td>
<td>775</td>
<td>519</td>
<td>73</td>
<td>9</td>
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<td>0</td>
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<td>04</td>
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<td>0</td>
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<td>0</td>
<td>1771</td>
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<tr>
<td>05</td>
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<td>0</td>
<td>0</td>
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<td>0</td>
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<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<td>7.6</td>
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<tr>
<td>08</td>
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<td>261</td>
<td>138</td>
<td>69</td>
<td>73</td>
<td>52</td>
<td>41</td>
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<td>09</td>
<td>167</td>
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<td>98</td>
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<tr>
<td>11</td>
<td>323</td>
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<td>268</td>
<td>312</td>
<td>111</td>
<td>23</td>
<td>28</td>
<td>0</td>
<td>0</td>
<td>1651</td>
<td>9.1</td>
</tr>
</tbody>
</table>
Wind Rose Analysis

• A clever way to portray all wind data in a graphical template and estimate the percent runway coverage
• The wind rose is just a graphical way to add decompose vectors
• The wind rose is populated with percentages derived from wind observations
• You can build a wind rose with a piece of cardboard and a transparent template
Wind Rose Template

Enter percentages in each cell

Each cell represents a wind direction and magnitude
Sample Wind Rose with Data

84.1% winds < 10 knots
Wind Rose and Template

Runway orientation shown is 105-285°

About 2.72% of time winds exceed 13 knots
Use of FAA Computer Program (AD42.exe)

The FAA computer program companion to the AC 5300-13 can be used to study runway orientation coverages.

It requires a text file in a very specific format that contains number of wind observations from various azimuths and winds speeds (similar to the wind rose template).
Sample Data for Computer Program

<table>
<thead>
<tr>
<th>STATION: ANYWHERE, USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUNWAY ORIENTATION: 105.00 195.00 DEGREE</td>
</tr>
<tr>
<td>CROSSWIND COMPONENT: 10.50 10.50 KNOTS</td>
</tr>
<tr>
<td>TAILWIND COMPONENT: 60.00 60.00 KNOTS</td>
</tr>
<tr>
<td>WIND COVERAGE: 98.84%</td>
</tr>
</tbody>
</table>

Wind Speeds

Azimuth (x 10)

<table>
<thead>
<tr>
<th>Hourly Observations of Wind Speed (kn)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3  4-6  7-10  11-16  17-21  22-27  28-33</td>
</tr>
<tr>
<td>DIRECTION</td>
</tr>
<tr>
<td>1</td>
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<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
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<tr>
<td>13</td>
</tr>
<tr>
<td>14</td>
</tr>
<tr>
<td>15</td>
</tr>
</tbody>
</table>

Used for 2 runway ends
Sample Output of AD42.exe Program

Sample result for 2 runways

Primary runway

Crosswind runway

WIND COVERAGE: 98.84 %
Sample Analysis for One Runway End (5-knot tailwind component allowed)

**WIND OBSERVATIONS**

- **STATION:** ANYWHERE, USA
- **RUNWAY ORIENTATION:** 105.00 DEGREE
- **CROSSWIND COMPONENT:** 13.00 KNOTS
- **TAILWIND COMPONENT:** 5.00 KNOTS
- **WIND COVERAGE:** 80.41 %

**HOURLY OBSERVATIONS OF WIND SPEED (KNOTS)**

<table>
<thead>
<tr>
<th></th>
<th>0-3</th>
<th>4-6</th>
<th>7-10</th>
<th>11-16</th>
<th>17-21</th>
<th>22-27</th>
<th>28-33</th>
<th>DIRECTION</th>
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<tbody>
<tr>
<td>1</td>
<td>469</td>
<td>842</td>
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<td>212</td>
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<td>0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>568</td>
<td>1263</td>
<td>820</td>
<td>169</td>
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<td>3</td>
<td>294</td>
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<td>73</td>
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</tr>
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<tr>
<td>7</td>
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<td>273</td>
<td>84</td>
<td>36</td>
<td>10</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
Single Runway End Analysis

Runway End 110° can be used 80.4% of time (allows 5-knot tailwind)
Runway Orientation: Extras

CEE 4674
Analysis of Air Transportation Systems

Dr. Antonio A. Trani
Professor
Explanations About Tailwind Allowances

- Aircraft are expected to land and takeoff against the wind.
- Under some conditions, pilots are allowed to operate with a small tailwind component.
- The amount of tailwind varies from airline to airline but is seldom more than 8 knots (relatively small winds).
- Implications of taking off with tailwinds:
  - Longer runway length.
- Implications of landing with tailwinds:
  - Faster approach speeds (i.e., ground speed).
  - Longer landing runway requirements.
Reasons for Tailwind Allowances

- Pilot prefers to use a higher precision approach by taking a small tailwind
- Busan (Korea) accident (http://aviation-safety.net/database/record.php?id=20020415-0)
- Kingston, Jamaica
- Terrain in one of the approach forces a pilot to take a small tailwind

For Design of Runway Orientation;
- Use 5 knots of tailwind to estimate the percent of time a runway end is used.
Example Problem

- Design the optimal runway orientation for an airport using FAA airport design code D-V
- Use the default data in FAA program AD42.exe downloaded from the web site

**Solution:**

- **Step 1:** determine the design crosswind component
  - D-V requires 20 knots of cross wind component
    (see FAA AC 150/5300-13)
Example Problem (cont.)

- **Step 2:**
  - Use the FAA AD42.exe program or use the Java tool available at the FAA GIS website.
  - This step requires that you estimate the percent coverage for each runway orientation.

- **Step 3:**
  - Find the new coverage for each new runway orientation (say every 5 degrees).
  - Create a plot with coverage vs runway orientation.

- **Step 4:**
  - Select the runway orientation that provides the highest coverage.
Example Problem (cont.)

Coverage (%)

Orientation (degrees)

Optimal Coverage
Example Problem (cont.)

• **Step 5:**

  • Check is the coverage meets the 95% criteria required by FAA and ICAO

  • If the 95% is met you are done

  • Otherwise add a second (crosswind) runway repeating steps 1-4 until the 95% criteria is achieved
When Do I use a 60 knot Tailwind in the FAA AD42.exe Program?

- When you want to know the percent of time a runway is used from both runway ends, use an artificially high value of tailwind.
- This tells you in one step the percent of time the runway is usable from both approaches.
Wind Rose Java Tool at FAA Website

- Available at: [https://airports-gis.faa.gov/airportsgis/publicToolbox/windroseForm.jsp](https://airports-gis.faa.gov/airportsgis/publicToolbox/windroseForm.jsp)

**ALL_WEATHER Wind Rose Form**

New All Weather Windrose | New IFR Windrose | New VFR Windrose | Open Windrose | Save Windrose

Upload Wind Data File | View Report | View Windrose | Download as DXF | Download as SVG | Help

Calculate

Title: myairport

Num Runways: 1

Runway 1

Runway Orientation: 20

Crosswind Component: 20

Tailwind Component: 5

Note: Use a 60 knot tailwind to indicate runway is bi-directional.

Wind Coverage:

**Hourly Observations of Wind Speed (knots)**

<table>
<thead>
<tr>
<th>Direction</th>
<th>0-3</th>
<th>4-6</th>
<th>7-10</th>
<th>11-16</th>
<th>17-21</th>
<th>22-27</th>
<th>28-33</th>
<th>34-40</th>
<th>&gt; 41</th>
<th>Total</th>
</tr>
</thead>
<tbody>
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<td>200</td>
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<td>0</td>
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</table>
Pusan, Korea