Airport Geometric Design Standards

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Virginia Tech
Organization of this Presentation

• Review of geometric design standards
• Runway-runway separation standards
• Runway-taxiway separations
• Taxiway and taxilanes
• Runway exit types and kinematic model application
• Runway exit locations
Taxiway and Runway Design Distances

- Source: FAA AC 5300-13A (Chapters 2, 3 and 4)
- Dictated by safety analyses
- Provide sufficient space for expansion and good movement of aircraft
- For regular aircraft (those than can be classified according to the FAA design standard) use Tables
- Study carefully Appendix 1 in FAA AC 5300-13 to understand the general geometric design rationale of the methods explained in Chapter 2
Where do I find the Runway and Taxiway Geometric Design Standards?

- Runway design standards - see paragraphs 301 to 324
  - Runway design concepts (paragraph 302)
  - Runway geometry (paragraph 304)
- Taxiway and taxilane design standards - 401 to 422
  - Taxiway width (paragraph 403)
  - Taxiway clearance requirements (paragraph 404)
  - Parallel taxiways (paragraph 305) etc.
- Appendix 7 or use interactive form in Table 3-8 (runway design standards matrix)
Runway Geometric Design Standards

source: FAA AC 150/5300-13 (Fig. 3-26)
Geometric Design Challenges

- **Size of Aircraft Design Group VI (Airbus A380 types)**

- ADG VI aircraft have total lengths ranging from 76 to 82 meters representing a modest increment from current Boeing 747-400 transports
Large Aircraft Wingspan Challenge

- ADG VI aircraft have total lengths of 230 feet today.
- ADG VI aircraft have wingspans around 15% larger than current transports (262 feet for Airbus A380).
- Structural weight penalties of folding wings are unacceptable to most airlines.
Impacts on Taxiway Design Standards

- Taxiway dimensional standards for aircraft design group VI have increased to avoid possible foreign object damage.
- 200 foot wide runways and 100 foot wide taxiways.

ADG VI Runway
(200 feet wide – 61 meters)

ADG VI Taxiway
(100 feet wide – 31 meters)
Sample Airport to Learn Design Standards

Nomenclature

- B = Runway width
- C = Runway safety area width
- D = Runway to parallel taxiway distance
- E = Taxiway safety area width
- G = Runway centerline to aircraft parking area
- J = Taxiway to parallel taxiway/taxilane distance
- K = Taxiway to fixed/movable object
- P = Runway safety area length beyond runway end
- Q = Runway object free area width
- R = Runway object free area length beyond runway end
- W = Taxiway width
- Z = Taxilane to fixed/movable object
Sample Runway Design Standards Form

Table 3-8. Runway design standards matrix

<table>
<thead>
<tr>
<th>Aircraft Approach Category (AAC) and Airplane Design Group (ADG): (select from pull-down menu at right)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITEM</td>
</tr>
<tr>
<td>Runway Design</td>
</tr>
<tr>
<td>Runway Length</td>
</tr>
<tr>
<td>Runway Width</td>
</tr>
<tr>
<td>Shoulder Width</td>
</tr>
<tr>
<td>Blast Pad Width</td>
</tr>
<tr>
<td>Blast Pad Length</td>
</tr>
<tr>
<td>Crosswind Component</td>
</tr>
<tr>
<td>Runway Protection</td>
</tr>
<tr>
<td>Runway Safety Area (RSA)</td>
</tr>
<tr>
<td>Length beyond departure end 10, 11</td>
</tr>
<tr>
<td>Length prior to threshold Width</td>
</tr>
<tr>
<td>Runway Object Free Area (ROFA)</td>
</tr>
<tr>
<td>Length beyond runway end</td>
</tr>
<tr>
<td>Length prior to threshold Width</td>
</tr>
<tr>
<td>Runway Obstacle Free Zone (ROFZ)</td>
</tr>
<tr>
<td>Length</td>
</tr>
<tr>
<td>Width</td>
</tr>
<tr>
<td>Precision Obstacle Free Zone (POFZ)</td>
</tr>
<tr>
<td>Length</td>
</tr>
<tr>
<td>Width</td>
</tr>
</tbody>
</table>

Select ADG/AAC

Refer to paragraphs 302 and 304

Refer to paragraph 308

Refer to paragraph 308
### Sample Runway Design Standards Form

#### Table 3-8. Runway design standards matrix

**Aircraft Approach Category (AAC) and Airplane Design Group (ADG):**
(select from pull-down menu at right)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DIM&lt;sup&gt;1&lt;/sup&gt;</th>
<th>B – II</th>
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<tbody>
<tr>
<td></td>
<td>Visual</td>
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<td>Runway Obstacle Free Zone (ROFZ)</td>
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<td></td>
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<td>Length</td>
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<td>N/A</td>
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<tr>
<td>Width</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Precision Obstacle Free Zone (POFZ)</td>
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<td></td>
</tr>
<tr>
<td>Length</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Width</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Approach Runway Protection Zone (RPZ)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>L</td>
<td>1000 ft</td>
</tr>
<tr>
<td>Inner Width</td>
<td>U</td>
<td>500 ft</td>
</tr>
<tr>
<td>Outer Width</td>
<td>V</td>
<td>700 ft</td>
</tr>
<tr>
<td>Acres</td>
<td></td>
<td>13.770</td>
</tr>
<tr>
<td>Departure Runway Protection Zone (RPZ)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>L</td>
<td>1000 ft</td>
</tr>
<tr>
<td>Inner Width</td>
<td>U</td>
<td>500 ft</td>
</tr>
<tr>
<td>Outer Width</td>
<td>V</td>
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</tr>
<tr>
<td>Acres</td>
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<td>13.770</td>
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<td>Runway Separation</td>
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<td></td>
</tr>
<tr>
<td>Runway centerline to:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parallel runway centerline</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Holding position</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parallel Taxiway/Taxilane centerline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aircraft parking area</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>Helicopter touchdown pad</td>
<td>G</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Notes:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Appendix 7 contains non-interactive tables for all RDCs.
- Values in the table are rounded to the nearest foot. 1 foot = 0.305 meters.
Airport has both new and legacy parallel taxiway standards
B-II standard near runway end 30
New taxiway has been re-aligned
## Runway Design Standards (D-IV)

### Table 3-8. Runway design standards matrix

<table>
<thead>
<tr>
<th>Aircraft Approach Category (AAC) and Airplane Design Group (ADG): (select from pull-down menu at right)</th>
<th>VISIBILITY MINIMUMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITEM</td>
<td>DIM&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Runway Design</td>
<td>VISIBILITY MINIMUMS</td>
</tr>
<tr>
<td>Runway Length</td>
<td>A</td>
</tr>
<tr>
<td>Runway Width</td>
<td>B</td>
</tr>
<tr>
<td>Shoulder Width</td>
<td></td>
</tr>
<tr>
<td>Blast Pad Width</td>
<td></td>
</tr>
<tr>
<td>Blast Pad Length</td>
<td></td>
</tr>
<tr>
<td>Crosswind Component</td>
<td></td>
</tr>
<tr>
<td>Runway Protection</td>
<td>R</td>
</tr>
<tr>
<td>Runway Safety Area (RSA)</td>
<td>P</td>
</tr>
<tr>
<td>Length beyond departure end&lt;sup&gt;10,11&lt;/sup&gt;</td>
<td>C</td>
</tr>
<tr>
<td>Width</td>
<td></td>
</tr>
<tr>
<td>Runway Object Free Area (ROFA)</td>
<td>R</td>
</tr>
<tr>
<td>Length beyond runway end</td>
<td>P</td>
</tr>
<tr>
<td>Length prior to threshold&lt;sup&gt;12&lt;/sup&gt;</td>
<td>Q</td>
</tr>
<tr>
<td>Width</td>
<td></td>
</tr>
<tr>
<td>Runway Obstacle Free Zone (ROFZ)</td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td></td>
</tr>
<tr>
<td>Width</td>
<td></td>
</tr>
</tbody>
</table>

Refer to paragraphs 302 and 304

Refer to paragraph 308

Refer to paragraph 308
## Runway Design Standards (D-IV)

### Table 3-8. Runway design standards matrix

**Aircraft Approach Category (AAC) and Airplane Design Group (ADG):**  
(select from pull-down menu at right)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DIM¹</th>
<th>Visual</th>
<th>Not Lower than 1 mile</th>
<th>Not Lower than 3/4 mile</th>
<th>Lower than 3/4 mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precision Obstacle Free Zone (POFZ)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>L</td>
<td>1700 ft</td>
<td>1700 ft</td>
<td>1700 ft</td>
<td>2500 ft</td>
</tr>
<tr>
<td>Width</td>
<td>U</td>
<td>500 ft</td>
<td>500 ft</td>
<td>1000 ft</td>
<td>1000 ft</td>
</tr>
<tr>
<td>Inner Width</td>
<td>V</td>
<td>1010 ft</td>
<td>1010 ft</td>
<td>1510 ft</td>
<td>1750 ft</td>
</tr>
<tr>
<td>Outer Width</td>
<td></td>
<td>29.465</td>
<td>29.465</td>
<td>48.978</td>
<td>78.914</td>
</tr>
<tr>
<td>Departure Runway Protection Zone (RPZ)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>L</td>
<td>1700 ft</td>
<td>1700 ft</td>
<td>1700 ft</td>
<td>1700 ft</td>
</tr>
<tr>
<td>Inner Width</td>
<td>U</td>
<td>500 ft</td>
<td>500 ft</td>
<td>500 ft</td>
<td>500 ft</td>
</tr>
<tr>
<td>Outer Width</td>
<td>V</td>
<td>1010 ft</td>
<td>1010 ft</td>
<td>1010 ft</td>
<td>1010 ft</td>
</tr>
<tr>
<td>Acres</td>
<td></td>
<td>29.465</td>
<td>29.465</td>
<td>29.465</td>
<td>29.465</td>
</tr>
</tbody>
</table>

**Runway Separation**  
*Runway centerline to:*  
Parallel runway centerline  
Holding position  
Parallel Taxiway/Taxilane centerline  
Aircraft parking area  
Helicopter touchdown pad

- **Refer to paragraph 316**
  - H: 250 ft  
  - D: 400 ft  
  - G: 500 ft  

- **Refer to AC 150/5390-2**
Footnotes:

1. Letters correspond to the dimensions in Figure 3-26.
2. The runway to taxiway/taxilane centerline separation standards are for sea level. At higher elevations, an increase to these separation distances may be required to keep taxiing and holding aircraft clear of the inner-transitional OFZ (refer to paragraph 308.c). Using this standard to justify a decrease in runway to taxiway/taxilane separation is not permitted.
3. For ADG-V, the standard runway centerline to parallel taxiway centerline separation distance is 400 feet for airports at or below an elevation of 1,345 feet; 450 feet for airports between elevations of 1,345 feet and 6,560 feet; and 500 feet for airports above an elevation of 6,560 feet.
4. For aircraft approach categories A/B, approaches with visibility less than ½-statute miles, runway centerline to taxiway/taxilane centerline separation increases to 400 feet.
5. For ADG-V, approaches with visibility less than ½-statute mile, the separation distance increases to 500 feet. See footnote 7.
6. For ADG-VI, approaches with visibility less than 3/4 statute mile, the separation distance increases to 500 feet plus elevation adjustment. For approaches with visibility less than ½-statute mile, the separation distance increases to 550 feet. See footnote 7.
7. For ADG-III, this distance is increased 1 foot for each 100 feet above 5,100 feet above sea level.
8. For ADG-IV, V, and VI, this distance is increased 1 foot for each 100 feet above sea level.
9. For all ADGs that are aircraft approach categories D and E, this distance is increased 1 foot for each 100 feet above sea level.
10. The RSA length beyond the runway end begins at the runway end when a stopway is not provided. When a stopway is provided, the length begins at the stopway end.
11. The RSA length beyond the runway end may be reduced to that required to install an Engineered Materials Arresting System (EMAS) (the designed set-back of the EMAS included) designed to stop the design aircraft exiting the runway end at 70 knots.
12. This value only applies if that runway end is equipped with electronic or visual vertical guidance. If visual guidance is not provided, use the value for “length beyond departure end.”
13. For Airplane Design Group III airplanes with maximum certificated takeoff weight of 150,000 lbs or less and approach visibility minimums of not less than 3/4 mile, the standard runway width is 100 feet, the shoulder width is 20 feet, and the runway blast pad width is 140 feet.
14. For RDC C-I and C-II, a RSA width of 400 feet is permissible.
15. The holding position dimension standards pertain to facilities for small airplanes exclusively, including airplane design groups I and II.
Taxiway Design Group

- Taxiway design group needs to be established before any taxiway design is carried out
- Main gear width and cockpit to main gear dimensions control the TDG

Figure 4-1. Taxiway Design Groups (TDGs)
Taxiway Dimensions

Notes:
1. For dimension M and dimension W values, see Table 4-2.
2. See Appendix 1 for CMG and MGW data.

source: FAA AC 150/5300-13 (Fig. 4-7)
Parallel Taxiway Dimensions

source: FAA AC 150/5300-13 (Fig. 4-8)
# Taxiway Design Standards (Based on ADG Groups)

**Source:** FAA AC 150/5300-13 (Table 4-1)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DIM (See Figure 3-26)</th>
<th>ADG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>I</td>
</tr>
<tr>
<td><strong>TAXIWAY PROTECTION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSA</td>
<td>E</td>
<td>49 ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(15 m)</td>
</tr>
<tr>
<td>Taxiway OFA</td>
<td></td>
<td>89 ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(27 m)</td>
</tr>
<tr>
<td>Taxilane OFA</td>
<td></td>
<td>79 ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(24 m)</td>
</tr>
<tr>
<td><strong>TAXIWAY SEPARATION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxiway Centerline to Parallel</td>
<td>J</td>
<td>70 ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(21 m)</td>
</tr>
<tr>
<td>Taxiway/Taxilane Centerline 1</td>
<td>K</td>
<td>44.5 ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(13.5 m)</td>
</tr>
<tr>
<td>Taxiway Centerline to Fixed or Movable Object</td>
<td>K</td>
<td>64 ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(19.5 m)</td>
</tr>
<tr>
<td>Taxilane Centerline to Parallel</td>
<td></td>
<td>39.5 ft</td>
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<tr>
<td></td>
<td></td>
<td>(12 m)</td>
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<td>Taxilane Centerline to Fixed or Movable Object</td>
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<td>20 ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(6 m)</td>
</tr>
<tr>
<td><strong>WINGTIP CLEARANCE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxiway Wingtip Clearance</td>
<td></td>
<td>15 ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4.5 m)</td>
</tr>
<tr>
<td>Taxilane Wingtip Clearance</td>
<td></td>
<td>20 ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(6 m)</td>
</tr>
</tbody>
</table>

**Note:** 1. These values are based on wingtip clearances. If 180 degree turns between parallel taxiways are needed, use this dimension or the dimension specified in Table 4-2, whichever is larger.
## Taxiway Design Standards (Based on TDG Groups)

Source: FAA AC 150/5300-13 (Table 4-2)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DIM (See Figure 4-7)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxiway Width</td>
<td>W</td>
<td>25 ft (7.5 m)</td>
<td>35 ft (10.5 m)</td>
<td>50 ft (15 m)</td>
<td>50 ft (15 m)</td>
<td>75 ft (23 m)</td>
<td>75 ft (23 m)</td>
</tr>
<tr>
<td>Taxiway Edge Safety Margin</td>
<td>M</td>
<td>5 ft (1.5 m)</td>
<td>7.5 ft (2 m)</td>
<td>10 ft (3 m)</td>
<td>10 ft (3 m)</td>
<td>15 ft (5 m)</td>
<td>15 ft (5 m)</td>
</tr>
<tr>
<td>Taxiway Shoulder Width</td>
<td></td>
<td>10 ft (3 m)</td>
<td>10 ft (3 m)</td>
<td>20 ft (6 m)</td>
<td>20 ft (6 m)</td>
<td>25 ft (7.5 m)</td>
<td>35 ft (10.5 m)</td>
</tr>
<tr>
<td>Taxiway/Taxilane Centerline to Parallel Taxiway/Taxilane Centerline</td>
<td>J</td>
<td>70 ft (21 m)</td>
<td>70 ft (21 m)</td>
<td>160 ft (49 m)</td>
<td>160 ft (49 m)</td>
<td>240 ft (73 m)</td>
<td>350 ft (107 m)</td>
</tr>
</tbody>
</table>

**TAXIWAY FILLET DIMENSIONS**

See Table 4-3, Table 4-4, Table 4-5, Table 4-6, Table 4-7 and Table 4-8.

Note: 1. Use this dimension or the dimension specified in Table 4-1, whichever is larger, when 180 degree turns between parallel taxiways are required.
Definition of Taxiway OFA and Separation from Fixed or Movable Objects

source: FAA AC 150/5300-13 (Figure 4-9)
Separation from Fixed or Movable Objects from Taxilane (Apron Taxiway)

source: FAA AC 150/5300-13 (Figure 4-11)
Example (IAD Airport)

- 325 feet (Taxiway to parallel taxiway distance) meets minimum standard for ADG VI
- 700 feet (Runway to Taxiway distance) above the minimum standard for ADG VI
- 303 feet (Taxiway to parallel taxilane distance) meets minimum standard for ADG VI

Image Source: U.S. Geological Survey
Rules Used in Derivation of Taxiway/Taxilane Separation Standards

- Taxiway centerline to parallel taxiway/taxilane centerline require **1.2 times airplane wingspan** plus 10 feet (3 m);
- Taxiway centerline to fixed or movable object require **0.7 times airplane wingspan** plus 10 feet (3 m);
- Taxilane centerline to parallel taxilane centerline required plus **1.1 times airplane wingspan** plus 10 feet (3 m.);
- Taxilane centerline to fixed or movable object require **0.6 times airplane wingspan** plus 10 feet (3 m.) and
Aircraft Rights-of-Way Near Gate Areas

- Dual taxilanes
- **2.3 times airplane wingspan** plus 30 feet (10 m)
- Aircraft parked at gates require wingtip to wingtip separations at gates or tie-down areas for safety:
  - 10 ft. (3 m.) for aircraft in groups I and II
  - 15 ft. (5 m.) for group III
  - 20 ft. (6 m.) for group IV
  - 25 ft. (8 m.) for group V
  - 30 ft. (10 m.) for group VI

Source: FAA AC 150/5300-13
Example: Dual Taxilane Between Two Terminal Buildings (Concourses)

Application of Dimensional Standards

- Double Service Road
- Dual Taxilane: 1080' to 1150'
- 2.3 (WS) + 30
Example: Dual Taxilane Between Two Terminal Buildings (Concourses)
Example Dual Taxilane (IAD)

2.3 * (critical wingspan) + 30 feet

Taxilane to taxilane distance

Taxilane to fixed/movable object

Image Source: Commonwealth of Virginia
Runway Design Standards (D-VI)

Table 3-8. Runway design standards matrix

<table>
<thead>
<tr>
<th>Aircraft Approach Category (AAC) and Airplane Design Group (ADG): (select from pull-down menu at right)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ITEM</strong></td>
</tr>
<tr>
<td><img src="image" alt="Design standards used for an airport if an A380 is the critical design aircraft" /></td>
</tr>
</tbody>
</table>

### Runway Design

<table>
<thead>
<tr>
<th>ITEM</th>
<th>CATEGORY</th>
<th>VISIBILITY MINIMUMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runway Length</td>
<td></td>
<td>Not Lower than 1 mile</td>
</tr>
<tr>
<td>Runway Width</td>
<td></td>
<td>200 ft</td>
</tr>
<tr>
<td>Shoulder Width</td>
<td></td>
<td>40 ft</td>
</tr>
<tr>
<td>Blast Pad Width</td>
<td></td>
<td>280 ft</td>
</tr>
<tr>
<td>Blast Pad Length</td>
<td></td>
<td>400 ft</td>
</tr>
<tr>
<td>Crosswind Component</td>
<td></td>
<td>20 knots</td>
</tr>
</tbody>
</table>

### Runway Protection

<table>
<thead>
<tr>
<th>ITEM</th>
<th>CATEGORY</th>
<th>VISIBILITY MINIMUMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Runway Safety Area (RSA)</td>
<td></td>
<td>1000 ft</td>
</tr>
<tr>
<td>Runway Object Free Area (ROFA)</td>
<td></td>
<td>600 ft</td>
</tr>
<tr>
<td>Runway Obstacle Free Zone (ROFZ)</td>
<td></td>
<td>500 ft</td>
</tr>
<tr>
<td>Precision Obstacle Free Zone (POFZ)</td>
<td></td>
<td>1000 ft</td>
</tr>
<tr>
<td>Approach Runway Protection Zone (RPZ)</td>
<td></td>
<td>600 ft</td>
</tr>
<tr>
<td>Departure Runway Protection Zone (RPZ)</td>
<td></td>
<td>500 ft</td>
</tr>
<tr>
<td><img src="image" alt="Refer to paragraph 308" /></td>
<td></td>
<td><img src="image" alt="Refer to paragraph 308" /></td>
</tr>
<tr>
<td><img src="image" alt="Refer to paragraph 308" /></td>
<td></td>
<td><img src="image" alt="Refer to paragraph 308" /></td>
</tr>
<tr>
<td><img src="image" alt="Refer to paragraph 308" /></td>
<td></td>
<td><img src="image" alt="Refer to paragraph 308" /></td>
</tr>
</tbody>
</table>

- Design standards used for an airport if an A380 is the critical design aircraft
Detailed Geometric Design of Taxiway Turns

- Aircraft can have long distances between cockpit and main gear
- Main landing gear tracks inside the centerline followed by the nose gear
- Taxiway fillets are needed to provide safety margins in turns

source: Airbus and the author
### Table 4-6. Standard intersection details for TDG 5

<table>
<thead>
<tr>
<th>Dimension (See Figure 4-13, Figure 4-14, Figure 4-15, and Figure 4-16)</th>
<th>30</th>
<th>45</th>
<th>60</th>
<th>90</th>
<th>120</th>
<th>135</th>
<th>150</th>
<th>180²</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta$ (degrees)</td>
<td>37.5</td>
<td>37.5</td>
<td>37.5</td>
<td>37.5</td>
<td>37.5</td>
<td>37.5</td>
<td>37.5</td>
<td>37.5</td>
</tr>
<tr>
<td>W-0 (ft)</td>
<td>40</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>50</td>
<td>50</td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>W-1 (ft)</td>
<td>52</td>
<td>60</td>
<td>65</td>
<td>65</td>
<td>72</td>
<td>73</td>
<td>73</td>
<td>88</td>
</tr>
<tr>
<td>W-2 (ft)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>150</td>
</tr>
<tr>
<td>L-1 (ft)</td>
<td>100</td>
<td>165</td>
<td>180</td>
<td>180</td>
<td>210</td>
<td>215</td>
<td>180</td>
<td>185</td>
</tr>
<tr>
<td>L-2 (ft)</td>
<td>120</td>
<td>90</td>
<td>95</td>
<td>90</td>
<td>70</td>
<td>70</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td>L-3 (ft)</td>
<td>14</td>
<td>25</td>
<td>37</td>
<td>103</td>
<td>191</td>
<td>276</td>
<td>440</td>
<td>96</td>
</tr>
<tr>
<td>R-Fillet (ft)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>35</td>
</tr>
<tr>
<td>R-CL (ft)</td>
<td>110</td>
<td>110</td>
<td>110</td>
<td>95</td>
<td>115</td>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>R-Outer (ft)</td>
<td>350</td>
<td>250</td>
<td>200</td>
<td>164</td>
<td>160</td>
<td>160</td>
<td>160</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Note: Values in the table are rounded to the nearest foot. 1 foot = 0.305 meters.

source: FAA AC 150/5300-13 (Table 4-6 and Figure 4-13)
<table>
<thead>
<tr>
<th>Dimension (See Figure 4-13, Figure 4-14, Figure 4-15, and Figure 4-16)</th>
<th>30</th>
<th>45</th>
<th>60</th>
<th>90</th>
<th>120</th>
<th>135</th>
<th>150</th>
<th>180</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta$ (degrees)</td>
<td>30</td>
<td>45</td>
<td>60</td>
<td>90</td>
<td>120</td>
<td>135</td>
<td>150</td>
<td>180</td>
</tr>
<tr>
<td>W-0 (ft)</td>
<td>41</td>
<td>41</td>
<td>41</td>
<td>41</td>
<td>41</td>
<td>41</td>
<td>41</td>
<td>41</td>
</tr>
<tr>
<td>W-1 (ft)</td>
<td>50</td>
<td>50</td>
<td>55</td>
<td>56</td>
<td>60</td>
<td>57</td>
<td>55</td>
<td>60</td>
</tr>
<tr>
<td>W-2 (ft)</td>
<td>65</td>
<td>75</td>
<td>85</td>
<td>85</td>
<td>95</td>
<td>102</td>
<td>107</td>
<td>105</td>
</tr>
<tr>
<td>W-3 (ft)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>184</td>
</tr>
<tr>
<td>L-1 (ft)</td>
<td>360</td>
<td>355</td>
<td>390</td>
<td>440</td>
<td>450</td>
<td>489</td>
<td>410</td>
<td>450</td>
</tr>
<tr>
<td>L-2 (ft)</td>
<td>110</td>
<td>155</td>
<td>135</td>
<td>125</td>
<td>110</td>
<td>145</td>
<td>165</td>
<td>120</td>
</tr>
<tr>
<td>L-3 (ft)</td>
<td>17</td>
<td>31</td>
<td>49</td>
<td>129</td>
<td>246</td>
<td>363</td>
<td>594</td>
<td>141</td>
</tr>
<tr>
<td>R-Fillet (ft)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>75</td>
</tr>
<tr>
<td>R-CL (ft)</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>130</td>
<td>155</td>
<td>165</td>
<td>170</td>
<td>175</td>
</tr>
<tr>
<td>R-Outer (ft)</td>
<td>400</td>
<td>300</td>
<td>270</td>
<td>205</td>
<td>210</td>
<td>215</td>
<td>215</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Note: Values in the table are rounded to the nearest foot. 1 foot = 0.305 meters.
Example #1 Taxiway-Taxiway Junction for Aircraft Design Group VI

A380-800 at LAX (A.A. Trani)
Example # 1 Design for Airbus A380

• Design a taxiway-taxiway junction for an Airbus A380 class vehicle using FAA design criteria

• Draw the solution to scale and specify the dimensions of the taxiway-taxiway junction

• Compare the solution with the recommendations by Airbus
Example # 1 Design for Airbus A380

Obtain the critical dimensions for geometric design standards

Consult with the aircraft manufacturer data
Figure 4-1 in AC 5300-13
Taxiway Design Group for A380

CMG = 104.6 feet and MG width = 47 feet
Taxiway-Taxiway Junctions

- Sample solution shown for TDG 7

Table 4-8. Standard intersection details for TDG 7

| Dimension (See Figure 4-13, Figure 4-14, Figure 4-15, and Figure 4-16) | TDG 7 |
|---|---|---|---|---|---|---|---|---|---|
| Δ (degrees) | 30 | 45 | 60 | 90 | 120 | 135 | 150 | 180 3 |
| W-0 (ft) | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 41 |
| W-1 (ft) | 50 | 50 | 55 | 56 | 60 | 57 | 55 | 60 |
| W-2 (ft) | 65 | 75 | 85 | 85 | 95 | 102 | 107 | 105 |
| W-3 (ft) | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 184 |
| L-1 (ft) | 360 | 355 | 390 | 440 | 450 | 489 | 410 | 450 |
| L-2 (ft) | 110 | 155 | 135 | 125 | 110 | 145 | 165 | 120 |
| L-3 (ft) | 17 | 31 | 49 | 129 | 246 | 363 | 594 | 141 |
| R-Fillet (ft) | 0 | 0 | 0 | 60 | 60 | 60 | 60 | 75 |
| R-CL (ft) | 150 | 150 | 150 | 150 | 155 | 165 | 170 | 175 |
| R-Outer (ft) | 400 | 300 | 270 | 205 | 210 | 215 | 215 | N/A |

Note: Values in the table are rounded to the nearest foot. 1 foot = 0.3048 meters

source: FAA AC 150/5300-13A
Taxiway-Taxiway Implementation

\[
\begin{align*}
W_0 &= 41 \text{ ft} \\
W_1 &= 56 \text{ ft} \\
W_2 &= 85 \text{ ft} \\
W_3 &= 130 \text{ ft} \\
R_{\text{fillet}} &= 60 \text{ ft} \\
R_{\text{outer}} &= 130 \text{ ft} \\
L_1 &= 440 \text{ ft} \\
L_2 &= 125 \text{ ft}
\end{align*}
\]

### Source
FAA AC 150/5300-13A

<table>
<thead>
<tr>
<th>( \Delta ) (degrees)</th>
<th>30</th>
<th>45</th>
<th>60</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>( W_0 ) (ft)</td>
<td>41</td>
<td>41</td>
<td>41</td>
<td>41</td>
</tr>
<tr>
<td>( W_1 ) (ft)</td>
<td>50</td>
<td>50</td>
<td>55</td>
<td>56</td>
</tr>
<tr>
<td>( W_2 ) (ft)</td>
<td>65</td>
<td>75</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>( W_3 ) (ft)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>( L_1 ) (ft)</td>
<td>360</td>
<td>355</td>
<td>390</td>
<td>440</td>
</tr>
<tr>
<td>( L_2 ) (ft)</td>
<td>110</td>
<td>155</td>
<td>135</td>
<td>125</td>
</tr>
<tr>
<td>( L_3 ) (ft)</td>
<td>17</td>
<td>31</td>
<td>49</td>
<td>129</td>
</tr>
<tr>
<td>( R_{\text{fillet}} ) (ft)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>60</td>
</tr>
<tr>
<td>( R_{\text{CL}} ) (ft)</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>130</td>
</tr>
<tr>
<td>( R_{\text{outer}} ) (ft)</td>
<td>400</td>
<td>300</td>
<td>270</td>
<td>205</td>
</tr>
</tbody>
</table>

Airbus A380-800
Check with Aircraft Manufacturer Data

- FAA recommends 130 feet Centerline radius
- Airbus suggests 167.3 feet

- FAA recommends 60 feet (fillet radius)
- Airbus suggests a minimum of 83.7 feet
Important Source to Help Your do Airport Geometric Design

- Consult aircraft manufacturer documents for airport planning
- These documents contain example taxiway-taxiway and runway-taxiway designs to help you compare your analysis
- See Chapter 4 (Section 4) on both Airbus and Boeing documents

Airbus A380 Turning Maneuvers
Airbus A380-800 Negotiating a Tight Turn

- The aircraft comes close to the taxiway edge
- FAA taxiway safety margin is 15 feet for ADG VI
Sample Old Taxiway Fillet Design

250 feet Lead-in to Fillet Old Design

Taxiway at ATL Airport (A. Trani)
Use of Specialized Software

• Several computer design software have been developed to facilitate geometric design of airports.

• AviPLAN Turn and AviPlan Turn Pro are a family of products designed to help designers simulate and verify airport designs.

• Software are add-ons to AutoCad.

• Designers select a path to be tested and the software performs a kinematic simulation to verify the design.
Gate Parking Maneuver Simulated in AviPLAN Turn Pro

source: Transoft Solutions
3D Visualization in AviPLAN Turn Pro

source: Transoft Solutions

Aircraft Maneuvering Envelopes
Other Important Sources to Help Your do Airport Geometric Design

- Consult aircraft manufacturer web sites to obtain 3D drawings of aircraft
- Airbus aircraft (http://www.airbus.com/support/maintenance-engineering/technical-data/autocad-3-view-drawings-of-airbus-aircraft/)
- Boeing aircraft (http://www.boeing.com/commercial/airports/3_view.page)

Boeing 787-8
source: Boeing
Legacy Airports
Modification of Standards
Legacy Design Standards and Old Airports

- Many airports in the U.S. were designed and constructed before the current design standards were developed

- Consequently many times we find that current geometric design standards are not met

- These airports require Modification of Standards (MOS)

- MOS are approved by FAA on a one-to-one basis

- For example, the Airbus A380 requires a 200 foot wide runway (see ADG VI standards)

- The FAA and ICAO have provided an MOS procedure whereby the A380 can operate from 150 foot runways with 50 foot stabilized shoulders
Example of a Legacy Airport
The Following Example Applies to LGA

- Delta Airlines operates Boeing 767-300 into LGA
- The critical aircraft wingspan is 156.08 feet (ADG IV)
Current Situation (LGA)

- Critical aircraft = Boeing 767-200 (ADS IV)
- Runway to taxiway distance: 350 feet
- Taxiway to taxiway distance: ~200 feet
### Runway Design Standards (Boeing 767 D-IV)

<table>
<thead>
<tr>
<th>Aircraft Approach Category (AAC) and Airplane Design Group (ADG):</th>
<th>C/D/E - IV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ITEM</strong></td>
<td>VISIBILITY MINIMUMS</td>
</tr>
<tr>
<td></td>
<td>Visual</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>RUNWAY SEPARATION</strong></td>
<td></td>
</tr>
<tr>
<td>Runway centerline to:</td>
<td></td>
</tr>
<tr>
<td>Parallel runway centerline</td>
<td>H</td>
</tr>
<tr>
<td>Holding Position (^8,9)</td>
<td></td>
</tr>
<tr>
<td>Parallel taxiway/taxilane centerline (^2)</td>
<td>D</td>
</tr>
<tr>
<td>Aircraft parking area</td>
<td>G</td>
</tr>
<tr>
<td>Helicopter touchdown pad</td>
<td></td>
</tr>
</tbody>
</table>

Required runway to taxiway = 400 feet
Available runway to taxiway = 350 feet
A Modification of Standard is needed from the FAA
Sample Modification of Standards (MOS)

- Taxiway centerline to parallel taxiway/taxilane centerline require **1.2 times airplane wingspan** plus 10 feet (3 m)
- Required for limiting ADG IV aircraft (171 foot wingspan) = 215 feet
- Rule for Modification of Standards (MOS) = 1.2 * critical wingspan + 10 feet
- Distance = 2 (156.08) + 10 feet = 197 feet
- Airport has 200 feet between parallel taxiways
- Boeing 767-300 operates from LGA
### Taxiway Design Standards for ADG IV

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DIM (See Figure 3-26)</th>
<th>ADG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>I</td>
</tr>
<tr>
<td><strong>TAXIWAY PROTECTION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSA</td>
<td>E</td>
<td>49 ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(15 m)</td>
</tr>
<tr>
<td>Taxiway OFA</td>
<td></td>
<td>89 ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(27 m)</td>
</tr>
<tr>
<td>Taxilane OFA</td>
<td></td>
<td>79 ft</td>
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<td></td>
<td></td>
<td>(24 m)</td>
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<td><strong>TAXIWAY SEPARATION</strong></td>
<td>J</td>
<td>70 ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(21 m)</td>
</tr>
<tr>
<td>Taxiway Centerline to Parallel</td>
<td>K</td>
<td>44.5 ft</td>
</tr>
<tr>
<td>Taxiway/Taxilane Centerline 1</td>
<td></td>
<td>(13.5 m)</td>
</tr>
<tr>
<td>Taxiway Centerline to Fixed or</td>
<td></td>
<td>64 ft</td>
</tr>
<tr>
<td>Movable Object</td>
<td></td>
<td>(19.5 m)</td>
</tr>
<tr>
<td>Taxilane Centerline to Parallel</td>
<td></td>
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<td>Taxilane Centerline 1</td>
<td></td>
<td>(12 m)</td>
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<tr>
<td>Taxiilane Centerline to Fixed or</td>
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<td></td>
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<tr>
<td>Movable Object</td>
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<td></td>
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<tr>
<td><strong>WINGTIP CLEARANCE</strong></td>
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<td></td>
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<tr>
<td>Taxiway Wingtip Clearance</td>
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<td>20 ft</td>
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<tr>
<td></td>
<td></td>
<td>(6 m)</td>
</tr>
<tr>
<td>Taxilane Wingtip Clearance</td>
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<td>15 ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4.5 m)</td>
</tr>
</tbody>
</table>

**Note:** 1. These values are based on wingtip clearances. If 180 degree turns between parallel taxiways are needed, use this dimension or the dimension specified in Table 4-2, whichever is larger.
Rules Used in Derivation of Taxiway/Taxilane Separation Standards (FAA)

- Taxiway centerline to parallel taxiway/taxilane centerline require **1.2 times airplane wingspan** plus 10 feet (3 m);
- Taxiway centerline to fixed or movable object require **0.7 times airplane wingspan** plus 10 feet (3 m);
- Taxilane centerline to parallel taxilane centerline required plus **1.1 times airplane wingspan** plus 10 feet (3 m.);
- Taxilane centerline to fixed or movable object require **0.6 times airplane wingspan** plus 10 feet (3 m.)
ICAO Geometric Standards

- ICAO standards for runways and taxiways are contained in Aerodrome Design Manual volumes 1 and 2
- The guidelines used by ICAO and FAA are very similar
- After all the groupings used in ICAO design standards, fall in line with the Aircraft Design Groups (ADG) employed by the FAA
### ICAO Geometric Standards (Taxiways)

<table>
<thead>
<tr>
<th>Code letter</th>
<th>Instrument runways</th>
<th>Non-instrument runways</th>
<th>Taxiway centre line to taxiway centre line (metres)</th>
<th>Taxiway, other than aircraft stand</th>
<th>Aircraft stand taxilane centre line to object (metres)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Code number</td>
<td>Code number</td>
<td></td>
<td>centre line to object (metres)</td>
<td>centre line to object (metres)</td>
</tr>
<tr>
<td>(1)</td>
<td>1 2 3 4</td>
<td>1 2 3 4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>82.5 82.5</td>
<td>37.5 47.5</td>
<td>23.75 16.25</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>87 87</td>
<td>42 52</td>
<td>33.5 21.5</td>
<td>16.5</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>- 168</td>
<td>- 93</td>
<td>44 26</td>
<td>24.5</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>- 176 176</td>
<td>- 101 101</td>
<td>66.5 40.5</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>- 182.5</td>
<td>- 107.5</td>
<td>80 47.5</td>
<td>42.5</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>- 190</td>
<td>- 115</td>
<td>97.5 57.5</td>
<td>50.5</td>
<td></td>
</tr>
</tbody>
</table>

**Note 1.** The separation distances shown in columns (2) to (9) represent ordinary combinations of runways and taxiways. The basis for development of these distances is given in the Aerodrome Design Manual, Part 2.

**Note 2.** The distances in columns (2) to (9) do not guarantee sufficient clearance behind a holding aeroplane to permit the passing of another aeroplane on a parallel taxiway. See the Aerodrome Design Manual, Part 2.
### ICAO Geometric Standards (Taxiways)

<table>
<thead>
<tr>
<th>ICAO Group</th>
<th>Taxiway Width (m)</th>
<th>Taxiway Clearance (m)</th>
<th>Taxiway + Shoulder Width (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>7.5</td>
<td>1.50</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>10.0</td>
<td>2.25</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>15.0/18.0&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>3.00/4.50&lt;sup&gt;(3)&lt;/sup&gt;</td>
<td>25.0</td>
</tr>
<tr>
<td>D</td>
<td>18.0/23.0&lt;sup&gt;(2)&lt;/sup&gt;</td>
<td>4.50</td>
<td>38.0</td>
</tr>
<tr>
<td>E</td>
<td>23.0</td>
<td>4.50</td>
<td>44.0</td>
</tr>
<tr>
<td>F</td>
<td>25.0</td>
<td>4.50</td>
<td>60.0</td>
</tr>
</tbody>
</table>

<sup>(1)</sup> 18 meters if wheelbase is equal or greater than 18 meters  
<sup>(2)</sup> 23 meters if wheelbase is equal or greater than 23 meters  
<sup>(3)</sup> 4.5 meters if wheelbase is equal or greater than 18 meters
Runway Surface Gradient Design Standards

Gulfstream III Landing at BCB (A. Trani)

Longitudinal Grade
Runway and Surface Gradients

• Located in FAA AC 150/5300-13A, Chapter 3 (paragraph 313)

• Includes vertical profile limits for runways and taxiways

• Important to maintain line-of-sight in the operations

• Pilot to pilot

• ATC controller to aircraft
313. Surface gradient.

a. Aircraft approach categories A and B. The longitudinal gradient standards for the centerline of runways and stopways are as follows and as illustrated in Figure 3-21. Keep longitudinal grades and grade changes to a minimum.

1. The maximum longitudinal grade is ±2.0 percent.
2. The maximum allowable grade change is ±2.0 percent.
3. Vertical curves for longitudinal grade changes are parabolic. The length of the vertical curve is a minimum of 300 feet (91 m) for each 1.0 percent of change. A vertical curve is not necessary when the grade change is less than 0.40 percent.
Longitudinal Runway Grades

- 1.5 % maximum for runways serving transport aircraft.
- Up to 2% for general utility runways (Groups A and B)
- 1.5 % transverse from crest (groups C, D, and E)
- **Maximum gradient change 1.5 % for groups C, D, and E. Use 2% for groups A and B**
- **Vertical curve length (1000 x grade change in feet for groups C, D, and E). Use 300 x grade change for groups A and B.**
- **Minimum distance between points of intersection (1000 ft. for each 1% grade change for groups C, D, and E)**
Longitudinal Grades
Approach Speed Groups A and B

Source: FAA AC 5300-13 – Figure 3-21

NOTES:
1. LENGTH OF VERTICAL CURVES WILL NOT BE LESS THAN 300 FT [91 M] FOR EACH 1% GRADE CHANGE, EXCEPT THAT NO VERTICAL CURVE WILL BE REQUIRED WHEN GRADE CHANGE IS LESS THAN 0.4%.
2. MAXIMUM GRADE CHANGE AT VERTICAL CURVES SHOULD NOT EXCEED 2.00 %.
3. MINIMUM DISTANCE BETWEEN POINTS OF VERTICAL INTERSECTION SHOULD BE 250 FT [76 M] X SUM OF ABSOLUTE GRADE CHANGES.
Longitudinal Grades
Approach Speed Groups C and D

Source: FAA AC 5300-13 – Figure 3-22

NOTES:
1. MINIMUM LENGTH OF VERTICAL CURVES = 1,000 FT [305 M] x GRADE CHANGE (IN %).
2. THE MINIMUM VERTICAL CURVE LENGTH IS EQUAL TO 1,000 FT [305 M] x GRADE CHANGE.
3. THE MINIMUM DISTANCE BETWEEN POINTS OF VERTICAL INTERSECTION MUST BE 1,000 FT [305 M] x SUM OF THE ABSOLUTE GRADE CHANGES.
Transverse Grades for Approach Speed Groups A/B and C/D/E

Source: FAA AC 5300-13 – Figure 3-23
Longitudinal and Transverse Grades of Runway Safety Areas

Source: FAA AC 5300-13 – Figure 3-24

NOTE: TRANSITIONS BETWEEN DIFFERENT GRADIENTS SHOULD BE WARPED SMOOTHLY.
Example Problem

• You are conducting a study for an existing airport. The airport wants to handle air carrier operations with airlines flying the Canadair CRJ-700 aircraft (regional jet).

• Determine the suitability of the runway to conduct air carrier operations. If the runway is not suitable for carrier operations suggest modifications to do it.

![Diagram of airport runway with elevation changes and station points.]
Example Problem: Solution (1)

- The Bombardier CRJ-700 is an interesting aircraft because it is a boundary case between Approach speeds B and C. The aircraft has the following geometric characteristics:

- Table 1. Bombardier CRJ-700 Information (source: Bombardier Aircraft).

<table>
<thead>
<tr>
<th>External:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Length overall</td>
<td>106 ft 8 in</td>
<td>32.51 m</td>
</tr>
<tr>
<td>Wingspan</td>
<td>76 ft 3 in</td>
<td>23.24 m</td>
</tr>
<tr>
<td>Wing area (net)</td>
<td>760 ft²</td>
<td>70.61 m²</td>
</tr>
</tbody>
</table>
• The maximum grade allowed is 1.5%. The runway satisfies this criteria.

• The maximum grade change is 1.5%. This criterion is violated at point A.

• The required 0.8% grade for the first $\frac{1}{4}$ of the runway is not met by the runway.

• The transitional curve lengths are 1,985 feet for point A and 1,400 for point B
Example Problem

- Design the two transition curves at points A and B in the vertical profile shown in the figure. Find the curve length and the elevation of the points on the transition curve at points A and B.
Sample Matlab Code

- The equation of a symmetric parabola used as transition curve is given by the following Matlab equations:

  ```matlab
  % G1 = grade of first tangent (%)
  % G2 = grade of second tangent (%)
  % L = length of transition curve (feet)
  % x = station along the horizontal axis defining the transition curve
  ```
Vertical Curve Solution for Point A

- The transition curve with point of intersection at A (1950 feet long) is shown below.
- The Point of Intersection (PI) (point A is located 2207 feet from the runway threshold).
- This is obtained as 970 meters (3182 feet) minus half of the curve length (1950 feet).
- The elevation of the curve is 2050 feet minus the drop in runway elevation between the runway threshold and the point of the curve (0.85/100 * 2207 feet).
- The elevation of the Point of the Vertical Curve is 2031.2 feet.
Vertical Curve Solution

Distance (ft.)

Elevation (ft.)

2022 2400 2600 2800 3000 3200 3400 3600 3800 4000 4200

2024 2026 2028 2030 2032 2034
Line of Sight Standards
(Paragraph 418 in FAA AC 150/5300-13)

- Along runways
  - Two points 5 feet above the runway should be mutually visible for the entire runway

- Between intersecting runways
  - Two points 5 feet above the runway should be mutually visible inside the runway visibility zone (polygon)
  - Three distance rules are used in the creation of the visibility zone: 1) < 750 feet, 2) 750-1500 feet and 3) >1500 feet
  - See diagram (next slide taken from FAA AC 5300-13)
Runway Visibility Requirements

source: FAA AC 150/5300-13 (Figure 3-7)
Runway Visibility Polygon (LGA)
Runway Exit Design
Geometric Design Standards for Runway Exits

- Sources:
  - FAA AC 5300-13 (Chapter 3)
  - ICAO Aerodrome Manual Volumes 1 and 2

- Design principle:
  - Provide ample space for aircraft to maneuver out of the runway
What is the Issue with Runway Exits?

- Runway exits are responsible for making operations more efficient on the ground
- Poorly designed runway exits add valuable service time (i.e., runway occupancy time)
- Poorly placed runway exits can contribute to go-arounds and runway incursions
- Runway occupancy time and its standard deviation are critical parameters for runway capacity estimation
Definitions

• Runway Occupancy Time (ROT)
  —The time elapsed between an aircraft crossing the runway threshold and the time when the same aircraft crosses the imaginary plane of a runway exit paved area

• Issues about ROT
  —The definition of ROT has been used inconsistently throughout the years
  —Many early ROT studies failed to recognize that when an aircraft starts turning towards the runway exit, the aircraft is still using the runway until its wingtip clears the runway edge plane
Factors Affecting ROT

• Aircraft mix
  — Percent of aircraft in various runway performance groups

• Runway geometric design factors
  — Runway width
  — Pavement condition (wet, dry, contaminated)

• Taxiway geometry design factors
  — Number of runway exits within the aircraft mix acceptability requirements
  — Taxiway type
  — Taxiway network interaction

• Pilot technique
  — Traffic pressure (i.e., having another aircraft on short final behind)
  — Gate location
Aircraft Landing Behavior Affects ROT Time Performance
Typical Aircraft Landing Roll Profile to Measure ROT

- Sample data collected at Charlotte-Douglas International Airport (CLT) Runway 05-23 (Trani et al., 1996)
Observed Variability in Landing Roll Performance Profiles

- Sample data collected at Charlotte-Douglas International Airport (CLT) Runway 05-23 (Trani et al. 1996)
Variability Across Many Aircraft (CLT Runway 05-23 Data)
Probability Density Function of ROT (Two Airports)

- The standard deviation of ROT is an important parameter affecting runway capacity

Data collected in 1994 (Trani et al.)

DCA mean ROT = 47.3 s
DCA ROT standard dev. = 9.8 s

ATL mean ROT = 50.8 s
ATL ROT standard dev. = 7.1 s
Inter-Arrival Time Distribution
(Atlanta Hartsfield Airport)

Closing cases

Opening cases

Observed Frequency vs. Inter-Arrival Time (s)

[Graph showing frequency distribution with bars for closing and opening cases]
Interaction Between ROT and Inter-Arrival Time (IAT)

- Data collected in Atlanta shows the interaction between ROT and IAT

- Atlanta mean ROT = 50.8 s
- Atlanta ROT standard dev. = 7.1 s
- Atlanta mean IAT = 92.1 s
- Atlanta IAT standard dev. = 32.2 s

Data collected in 1994 (Trani et al.)

VMC conditions

Graph showing the zone of ROT and IAT interaction with observed frequency.
Implications of Interaction Between ROT and IAT

• An advanced Air Traffic Management system (such as the one expected to be available with NextGen) coupled with more precise navigation in the terminal area will reduce IAT and its standard deviation.

• As IAT is reduced more overlap (i.e., interactions) between ROT and IAT would occur.

• This would make reductions in ROT necessary so that runways are never “chocked” by the ROT parameter.

• ROT can be reduced by:
  — More precise landing roll management (piloting technique and advanced guidance with aircraft energy management)
Effects of ROT on Runway Capacity

- Modest gains in runway saturation capacity are possible with reductions in ROT because in today’s environment, inter-arrival separations dominate over runway capacity

- ROT nevertheless is important in runways used with mixed operations (i.e., arrivals and departures) in both IMC and VMC conditions
  - Reduced weighted average ROT values reduce the gap needed to launch departures between successive arrivals
  - The same effect is true if reductions in the standard deviation of ROT are possible

- ROT is more important under VMC operations because inter-arrival times (IAT) are smaller compared to those observed during IMC conditions

- Standard deviation of ROT is very important

- Some small gains under IMC conditions (mixed operations in a single runway)
Runway Exits

• The purpose of runway exits is to improve service
• times of airport runways
• The number of runway exists varies from airport to
• airport and within runways at the same airport
Operational Values of Runway Exit Speeds

- Operational values measured by Virginia Tech research in 1992-1996 time period (Trani et al., 1996)
  - 90 degree angle ~ 8 m/s (15 knots)
  - 45 degree angle ~ 15 m/s (29 knots)
  - 30 degree angle ~ 21 m/s (41 knots)
- Technically, design speeds for these exits
# Types of Runway Exits

<table>
<thead>
<tr>
<th>Runway Exit Type</th>
<th>Characteristics and Use</th>
<th>Remarks and Exit Speeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right-angle (90 degree)</td>
<td>Low volume of traffic</td>
<td>Low speed (5-8 m/s)</td>
</tr>
<tr>
<td></td>
<td>Ends of a runway</td>
<td></td>
</tr>
<tr>
<td>45 degree General Aviation</td>
<td>Old design (not recommended)</td>
<td>Medium speeds (8-15 m/s)</td>
</tr>
<tr>
<td>30-degree Constant Radius Design</td>
<td>Older design</td>
<td>Older design</td>
</tr>
<tr>
<td></td>
<td>Use when &gt; 30 operations/hr</td>
<td>15-21 m/s</td>
</tr>
<tr>
<td>30-degree Spiral Design</td>
<td>Adopted in the mid 80s</td>
<td>Transition spiral</td>
</tr>
<tr>
<td></td>
<td>Use when &gt; 30 operations/hr</td>
<td>15-23 m/s</td>
</tr>
</tbody>
</table>
Right-Angle Exits

• Baseline centerline radius is 250 feet

• Pavement edge radius varies according to runway width
Sample Implementation (ATL)

- Runway (150 feet wide)
- F = 175 feet
- R = 250 feet
- 90 degree Runway Exit
- Parallel Taxiway

Source: Google Earth
45 Degree Angle Runway Exit

- Nominal 800 feet centerline radius
- 600 feet pavement edge radius
- Old design – FAA has dropped the design from AC 5300-13
Issues with 45 Degree Runway Exits

- Narrow width at tangency point (only 40 feet)
- Only useful for busy general aviation airports
- Since the FAA has dropped discussion of this design in the latest releases of the AC 5300-13 the geometry should be avoided
- The 30 degree-standard design seems to be favored in case peak operations exceed 25-30 per hour
Acute Angle or High-Speed Runway Exit
30 Degree - Constant Radius (Old Standard)
Acute Angle or High-Speed Runway Exit
30 Degree - Spiral Design
(2nd Old Design)

- Nominal 1400 feet centerline spiral
- Can use the FAA computer program AD42.exe application for design (companion computer program to AC 5300-13)
Acute Angle or High-Speed Runway Exit
30 Degree for ADG V, TDG 3 and 4
(current design)

source: FAA AC 150/5300-13 (Figure 4-23)
Acute Angle or High-Speed Runway Exit
30 Degree for ADG V, TDG 6
(current design)

source: FAA AC 150/5300-13 (Figure 4-23)
Acute Angle or High-Speed Runway Exit
30 Degree for ADG V, TDG 7
(current design)

source: FAA AC 150/5300-13 (Figure 4-23)
Comparison Between HS Exit Designs

• The old 30-degree acute angle exit standard was originally proposed by Horonjeff et al. with a constant centerline radius of 1800 feet

• In the early 1990s, a 1400 foot spiral transition was added to the 30 degree design

• In 2013, the FAA went back to a constant radius design (1500 feet at centerline)

• Note that in the current designs suggested by FAA, the transition centerline radii dimensions change at the junction with the parallel taxiway for various TDG groups
Design Considerations

- Virginia Tech observations suggest that most HS exits are used 15-20 knots below their design speed (60 knots).
- Perhaps this could be one reason for the FAA to change course.
- However, Virginia Tech research suggest that pilots do not like abrupt transitions from a 150 foot runway width to a narrow 75 foot HS runway exit (as is the case for the current FAA design).
- Always be generous with the transition form a wide runway to a narrow runway exit.
- HS runway exits are more effective when the separation between the runway and the parallel taxiway is at least 600 feet.
Example of a HS Runway Exit with 400 feet Separation (not recommended)

- Little tangent section on the HS exit for deceleration
- Taxiway is too close to the runway (pilots will exit at lower speeds)

Source: Google Earth
Example of a HS Runway Exit with 600 feet Separation (good practice)

- A generous tangent section on the HS exit for deceleration
- Pilots will exit at higher speeds in such design

Source: Google Earth
Specification of a High-Speed Runway Exit

Blue Line = loci of left offsets
Green Line = loci of right offsets
Red line = centerline (x and y coordinates)
Specification of High-Speed Runway Exit

Stations (along path)

Left offset

Right offset

25'R (7.5M)
Example Implementation (ATL)
30 Degree Angle Runway Exit

800 feet radius
250 feet radius
reverse geometry
1400 foot spiral

Runway (150 feet wide)
Parallel Taxiway

Source: Google Earth
High-Speed Speed Exits (IAD)
(Standard 30 degree angle)

No longer recommended
Same location can confuse pilots
Issues with 30 Degree Runway Exits

• The FAA recommends a minimum runway-taxiway separation of 600 feet for High-Speed runway exits

• Some airport have used 30 degree runway exits with only 400 feet between runway and taxiway centerlines (avoid - this is bad practice)
  • The result is low exits speeds and possible issues with busting hold lines

• Be careful and try to provide the minimum 600 foot recommended distance

• Consider limited pilot visibility while crossing active runways
Airbus A340-600 Visibility from Cockpit

Source: Airbus
Sample Limited Visibility due to High-Speed Runway Exits (LAX Airport)

Final turning angle at hold line = 30 degrees
Example of Limited Visibility due to Short Runway-Taxiway Distance

- Holding Line (281 feet)
- 400 feet

Airbus A340-600 visibility limit

Airbus 340-600 turns 39 degrees at hold line

Runway Centerline

Center Taxiway
Example of Limited Visibility from Aircraft Cockpit Driven by Hold Line Location

• Before the aircraft nose reaches the hold line, the aircraft wingtip violates the hold line distance
Procedures to Located Runway Exits

• Factors that affect the runway exit locations:
  — Fleet mix
  — Operations/hr
  — Environmental conditions (wet vs. dry pavement)
  — Terminal or gate locations
  — Type and number of runway exits

• Manual tables developed by ICAO and FAA

• Use computer models like REDIM - Runway Exit Design Interactive Model (Developed at Virginia Tech for the FAA and NASA)
Example Problem

Where to locate runway exits?
Three-Segment Method to Estimate Runway Exit Locations

Flare segment

Free roll segment

Braking segment
Flare Segment

• Aircraft cross the runway threshold at approach speed (1.3 $V_{\text{stall}}$) (called $V_{\text{app}}$)

• Refer to approach speeds in FAA AC 5300-13 Appendix 13

• The touchdown speed is empirically known to be around $V_{\text{app}} \times 0.95$ (95% of the approach speed)

• Touchdown point location varies from 1500 feet for aircraft in approach speed groups C and D to 850 feet for aircraft in groups A and B

• Calculate distance $S_1$ using known touchdown distance
Free Roll or Transition Segment

- Touchdown speed at 0.95 * Vapp
- Aircraft rolls freely after touchdown for 1-2 seconds before brakes are applied
- In modern aircraft spoilers deploy automatically as soon as the main landing gear “squat” switch detects strut deflection
- Aircraft decelerates at ~0.03*g (0.3 m/s-s) in the free roll segment
- Calculate the final speed using a simple constant deceleration profile (a = 0.03 * g)
- Calculate distance S2 using the known initial speed and free roll time
Braking Segment

• Aircraft starts braking at the end of the free roll or transition phase

• Average deceleration rates measures in the field vary from 1.3 to 2.0 m/s-s (use average 1.7 m/s-s)

• Aircraft decelerates until reaching a comfortable exit speed ($V_{exit}$)

• Use the exit speeds defined for typical runway exit types defined in slide “Operational Values of Runway Exit Speeds”

• Calculate distance $S_3$ using initial speed, final speed and deceleration rate
Applicable Formulas
(Uniformly Decelerated Motion)

\[
a = \frac{v_f - v_0}{t}
\]

\[
v_f = v_o + at
\]

\[
s = \frac{1}{2} (v_0 + v_f)t
\]

\[
v_f^2 = v_o^2 + 2as
\]

- \(a\) = Deceleration (m/s-s)
- \(v_f\) = Final speed (m/s)
- \(s\) = Distance (m)
- \(v_0\) = Initial speed (m/s)
- \(t\) = Time (s)
Matlab Code to Calculate Runway Exit Locations

% Simple Matlab code to estimate runway exit location

% using the three point method

% A. Trani (2009)

% Define parameters

Vapp = 125;                 % approach speed (knots)
tfr1 = 2;                        % free roll time (seconds)
Stouchdown = 350;      % meters
a_brake = -1.5;           % average braking rate (m/s-s)
a_fr1 = 0.3;                  % average free roll deceleration (m/s-s)
Vexit = 15;                   % exit speed (knots)
Vapp = Vapp / 1.94;     % convert to meters/second
Vexit = Vexit / 1.94;     % in m/s
% Flare segment
Vtouchdown = 0.95 * Vapp;                  % touchdown speed (m/s)

tflare = 2 * Stouchdown / (Vapp - Vtouchdown); % tie in flare maneuver

S1 = Stouchdown;                          % distance in flare segment

% Transition segment
Vo_transition = Vtouchdown;

Vf_transition = Vo_transition + a_fr1 * tfr1; % final speed in transition segment

S2 = (Vf_transition + Vo_transition) / 2 * tfr1; % distance in transition segment

% Braking segment

t_brake = (Vexit - Vf_transition)/a_brake; % time in braking segment (s)

S3 = 1/2 * (Vf_transition - Vexit) * t_brake; % distance in braking phase (m)

% Add all segments
stotal = S1 + S2 + S3;

disp(['Flare distance =   ', num2str(S1), '  meters'])
disp(['Transition distance =   ', num2str(S2), '  meters'])
disp(['Braking distance =   ', num2str(S3), '  meters'])
Example Calculation (Example # 2)

- Estimate the practical runway exit location for an Embraer 170 aircraft with the following parameters:
Calculations Using Matlab Code
(Validate using your calculator)

- Flare distance = 400 meters
- Transition distance = 121 meters
- Braking distance = 975 meters
- Total Distance to Runway Exit = 1495 meters (4,905 ft)
Runway Exit Location Example # 3

• A new airport with a 9,100 foot runway requires runway exits

• The airport authority wants to locate two high-speed exits for the runway. The runway should also have two right angle exits (at either end of the runway).

• Task: Find three right angle runway exit locations (one for each aircraft group) using the three point method. Consider that the runway is used from both directions. Add a fourth runway exit at the end of each runway end.
### Runway Exit Location Example # 3

#### Table 3 Aircraft Parameters

<table>
<thead>
<tr>
<th>Aircraft Group</th>
<th>Parameters</th>
<th>Representative Aircraft (REDIM Name)</th>
</tr>
</thead>
</table>
| Small single-engine GA aircraft       | Approach speed = 105 knots  
Touchdown location = 280 meters  
Average deceleration = -1.60 m/ s-s  
Free roll time = 2.0 seconds          | Cessna 208, Piper Saratoga                                                      |
| Business jets                         | Approach speed = 125 knots  
Touchdown location = 350 meters  
Average deceleration = -1.75 m/ s-s  
Free roll time = 2.0 seconds          | Cessna 550 (CE-550), Learjet 31 (Learjet 31),                  |
| Medium-size transport aircraft        | Approach speed = 143 knots  
Touchdown location = 450 meters  
Average deceleration = -1.50 m/ s-s  
Free roll time = 2.0 seconds          | Boeing 737-400 (B-737-400), Airbus A320 (A-320-200)             |
Runway Exit Location Example # 3

- Analysis using Matlab code for Three-segment method.

For GA aircraft:
  Flare distance = 280 meters
  Transition distance = 103.4 meters
  Braking distance = 612.8 meters
  Total Distance to Runway Exit = 996.2 meters

For Business jet aircraft:
  Flare distance = 350 meters
  Transition distance = 123.0 meters
  Braking distance = 835.61 meters
  Total Distance to Runway Exit = 1308.6 meters

For medium-size transport aircraft:
  Flare distance = 450 meters
  Transition distance = 140.6 meters
  Braking distance = 1318.5 meters
Runway Exit Location Example # 3

- Analysis using Matlab code for Three-segment method.

For GA aircraft:
- Flare distance = 280 meters
- Transition distance = 103.4 meters
- Braking distance = 612.8 meters
- Total Distance to Runway Exit = 996.2 meters

For Business jet aircraft:
- Flare distance = 350 meters
- Transition distance = 123.0 meters
- Braking distance = 835.61 meters
- Total Distance to Runway Exit = 1308.6 meters

For medium-size transport aircraft:
- Flare distance = 450 meters
- Transition distance = 140.6 meters
### Runway Exit Location Example # 3

<table>
<thead>
<tr>
<th>Runway Exit</th>
<th>Location (m)</th>
<th>Type / Exit Speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1000</td>
<td>90-deg / 8 m/s</td>
</tr>
<tr>
<td>2</td>
<td>1300</td>
<td>90-deg / 8 m/s</td>
</tr>
<tr>
<td>3</td>
<td>1910</td>
<td>90-deg / 8 m/s</td>
</tr>
<tr>
<td>4 (last exit on runway)</td>
<td>2774</td>
<td>90-deg / 8 m/s</td>
</tr>
</tbody>
</table>

Landing from left to right
Runway Exit Location Example # 3

- Possible compromise to establish four 90-deg. exits available per landing direction
- Recall: the values calculated with the three segment are only approximations
The World is Random

• The previous example assumes that all variables in the landing process are deterministic (i.e., single values)

• The real world is more complex than that

• Pilots seldom touchdown at the same point even in hundreds of landings

• Similarly, we observe variations in deceleration rates

• The previous model can be easily converted to a stochastic model (a model that uses random variables)
Sample Matlab Code to Convert Problem to include Stochastic Variables

```matlab
VappMean = 138; % approach speed (knots)
Vapp_std = 2.5; % approach speed std deviation (knots)
tfr1 = 2; % free roll time (seconds)
StouchdownMean = 350; % touchdown distance (meters)
Stouchdown_std = 60; % touchdown distance (meters) std deviation
a_brakeMean = -1.8; % average braking rate (m/s-sec)
a_brake_std = 0.20; % average braking rate (m/s-sec) std deviation
a_fr1 = 0.3; % average free roll or transition deceleration (m/s-sec)
Vexit = 15; % exit speed (knots)

noSimulations = 1000;

% Convert units to meters
VappMean = VappMean / 1.94; % convert to meters
Vapp_std = Vapp_std / 1.94; % in m/s
Vexit = Vexit / 1.94;

% Create random variables
Vapp = VappMean + randn(1,noSimulations) * Vapp_std; % in meters per second
Stouchdown = StouchdownMean + randn(1,noSimulations) * Stouchdown_std;
a_brake = a_brakeMean + randn(1,noSimulations) * a_brake_std;
```

Additional Variables
(standard deviations)
Sample Matlab Code to Convert Problem to include Stochastic Variables (Part 2)

```matlab
disp( ' ')
disp(['Mean touchdown (or flare) distance = ', num2str(mean(Stouchdown)), ' meters'])
disp(['Mean deceleration rate = ', num2str(mean(a_brake)), ' meters/second-second'])
disp(['Mean braking distance = ', num2str(mean(S3)), ' meters'])
disp(' ')

% Make a histogram of the total distance to the exit location
figure
hist(stotal,40)
xlabel('Total Distance to Exit Location (m)')
ylabel('Frequency')
grid

% Make a cumulative density plot of the total distance to the exit point
figure
cdfplot(stotal)
xlabel('Total Distance to Exit Location (m)')
ylabel('Cumulative Density Function')
```

Display mean values in the Command Window

Make a histogram of distance to exit location
Sample Results for a Medium Size Transport Aircraft

Aircraft showed a large amount of variability to reach the exit point (central tendency is around 1500 meters)
A good design point for this aircraft would be to select the exit point to accommodate 80% of the landings.
Why Not Using 100% of the Population?

- Selecting the 80th percentile point allow most aircraft (80% of them) to use the selected exit
- The remaining 20% of the aircraft will be forced to use a further downrange exit
- This balances the runway occupancy time for all aircraft landing at the facility
## FAA Guidance on Runway Exit Locations

<table>
<thead>
<tr>
<th>DISTANCE THRESHOLD</th>
<th>WET RUNWAYS</th>
<th>DRY RUNWAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TO EXIT</td>
<td>RIGHT &amp; ACUTE ANGLED EXITS</td>
<td>RIGHT ANGLED EXITS</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>T</td>
</tr>
<tr>
<td>0 ft (0 m)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>500 ft (152 m)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1000 ft (305 m)</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>1500 ft (457 m)</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>2000 ft (610 m)</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>2500 ft (762 m)</td>
<td>84</td>
<td>1</td>
</tr>
<tr>
<td>3000 ft (914 m)</td>
<td>96</td>
<td>10</td>
</tr>
<tr>
<td>3500 ft (1067 m)</td>
<td>99</td>
<td>41</td>
</tr>
<tr>
<td>4000 ft (1219 m)</td>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td>4500 ft (1372 m)</td>
<td>100</td>
<td>97</td>
</tr>
<tr>
<td>5000 ft (1524 m)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>5500 ft (1676 m)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>6000 ft (1829 m)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>6500 ft (1981 m)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>7000 ft (2134 m)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>7500 ft (2286 m)</td>
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<td>100</td>
</tr>
<tr>
<td>8000 ft (2438 m)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>8500 ft (2591 m)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>9000 ft (2743 m)</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

**Notes:**
- S - Small, single engine
- T - Small, twin engine
- L - Large
- H - Heavy
- 12,500 lbs (5670 kg) or less
- 12,500 lbs (5670 kg) or less
- 12,500 lbs (5670 kg) to 300,000 lbs (13608 kg)
- 300,000 lbs

**Table 4-9 in AC 150/5300-13A**
Things to Avoid (1)

(a) Taxiway crossing high-speed exit and Wide throated runway entrance

(b) Extra-wide throated taxiway without "No Taxi" islands leading from the apron directly to parallel taxiways and runways
Things to Avoid (2)

(c) Taxiway intersection exceeds "3-node" concept

(d) Taxiway intersecting two or more runways
(e) Aligned taxiway between two closely spaced runway ends
(f) Two or more taxiway entrances lacking "No Taxi" islands

(g) "Y" Shaped taxiway crossing a runway
Things to Avoid (5)

1. Taxiway intersection exceeds “3-node” concept
2. Taxiway intersecting a high-speed exit from runway.
Common Design Practices (1)
Common Design Practices (2)

Figure 4-6. Bypass taxiway & Entrance Taxiway
Common Design Practice (3)

Dual parallel taxiway entrance