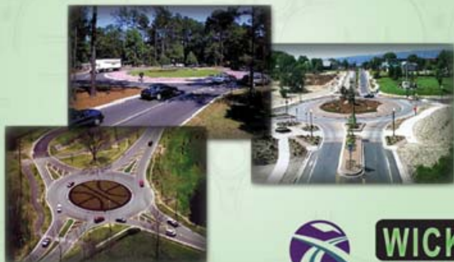
Introduction to Roundabouts: The In's & Out's



Design, Geometry & Capacity

Roundabout Design, Capacity & Geometry

- Roundabout Design Process
- Geometric Parameters
- Fast Path Speeds
- Speed Consistency
- Case Studies

Introduction to Roundabouts: The In's & Out's

Roundabout Design Process

Roundabout Design is Holistic

- The whole is more important than the parts
- How the parts interact is crucially important
- Individual geometrics are not as important

- Frankenstein was made of good parts!

Roundabout Design

- Roundabouts are not Homogenous
  - Different types of roundabouts
  - Applied differently in different situations
  - Different problems need different solutions
  - Major difference – Single Lane to Multi-Lane
  - Different principles can apply

Roundabout Design

- There are no 6 easy steps to roundabout design
- Much of the important information is counter-intuitive
- They range from very easy to very complex
- They are as far as you can get from "cookie-cutter" design

Two aspects of design

1. Solving the problem (holistic)
   - This can be very difficult
   - Guides can not help

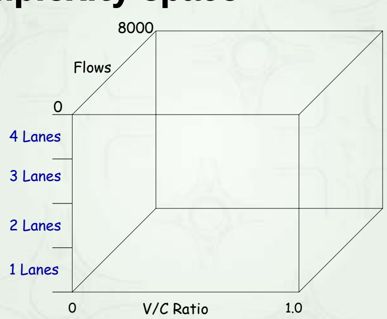
2. The Details (non-holistic)
   - Geometric refinement of the elements
   - Guides give very good advice and help

Painting a picture is analogous
-What makes a great picture?

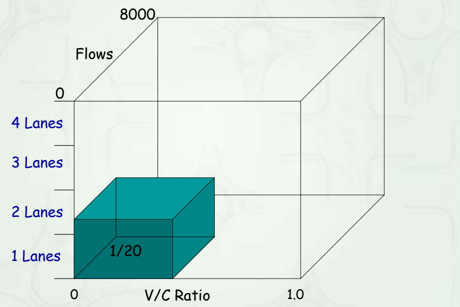
Simplicity and Complexity

- Major difference is single-lane vs. multi-lane
- Success with a SLR is no qualification
- Year 1 success no qualification – wait 20 years
- Experience is needed over the whole range

Complexity Space



Complexity Space



The Design Problem

Traffic Volumes

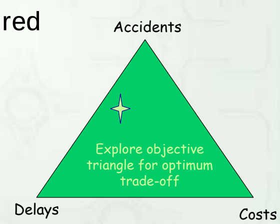
Geometric Layout } AT A COST

- Accidents
- Queues
- Delays

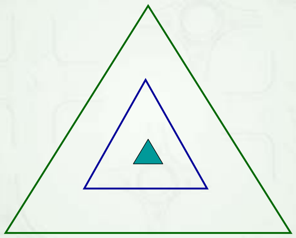
Conflict and Trade-Off

- Often the aims conflict
- A trade-off is needed
- Optimization required

NO FINISH LINE



Conflict and Trade-Off



Trade-Off

- Competing aims
- Trade-off is fundamental
- Rules cannot be traded
- Principles can be traded

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Balance

- BALANCE IS CRUCIAL
- Designer must balance between competing AIMS
- And balance within an AIM

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Three Sources of Knowledge

1. Design Guides
   - Principles to be traded
   - Very few rules (not for trading)
2. Computer Models
   - Theoretical Gap Models or Empirical Models
3. Expert heuristic knowledge of a designer
   - Experience of whole of the complexity space
   - Skill at using **<u>Guides and Models</u>**

Design Guides

- Roundabout Design is <u>HOLISTIC</u>
  - How the parts relate to each other is critical
- Design Guides are <u>NOT HOLISTIC</u>
  - They are about the PARTS not the whole
  - Guides can not help with this aspect of the design.

Design Guides

- All Guides have limitations – they can only go so far
- US Guide must be used as the authors <u>intended</u>
- Wrong to use as a rule book or standard
- **<u>The guide repudiates using it as a standard</u>**

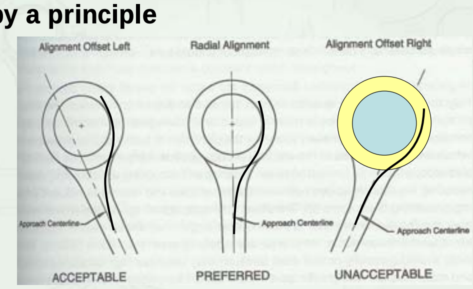
Introduction to the US Guide

- Since there is no absolutely optimum design… a guide was produced
- This guide is not intended as an inflexible rule book
- But rather attempts to explain:
  - Some principles of good design and
  - Indicate potential trade-offs
- In this respect, the design space consists of:
  - Performance evaluation models and
  - Design principles such as those provided in the guide
  - Combined with expert heuristic knowledge of a designer
- **Adherence to the principles does not ensure good design which remains the responsibility of the designer**

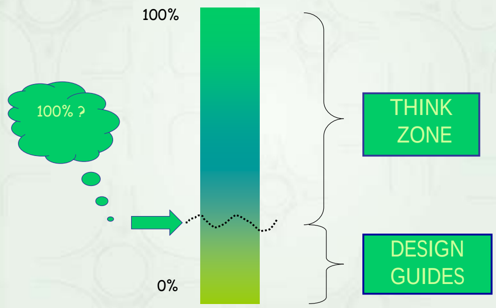
Enhancing the US Guide

- Replace rules with principles where possible
- Stronger discrimination between SLR & MLR
- Sight Distances ~ 3-4 sec. not 6.5 sec gap
- Multi-lane fastest path text and exhibit contradict

Example of a rule that should be replaced by a principle



Design Quality



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Computer Models

- Crucially Important!
- Validated directly against appropriate field data
- Sufficiently accurate for design processes
- Gap Models or Empirical Models
- THEY GIVE VERY DIFFERENT RESULTS
- ADOT's preference is RODEL (Empirical)

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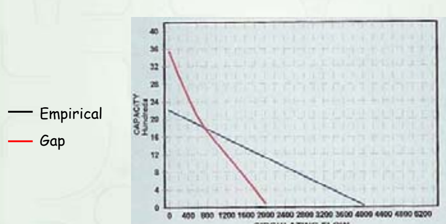
Gap vs. Empirical 7.3m Entry - 80m ICD



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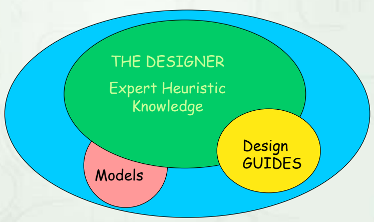
Expert Designers

- The most important (only intelligent part)
- Skill in using Models and Guides (tools)
- Skill in producing geometric layouts
- Designer is responsible for the design
- Not Model or Guide

Design Tools & Aides

- THE DESIGN SPACE



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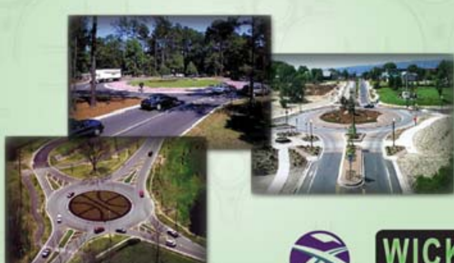


Geometry & Capacity

ADOT

WICK Engineers Inc.

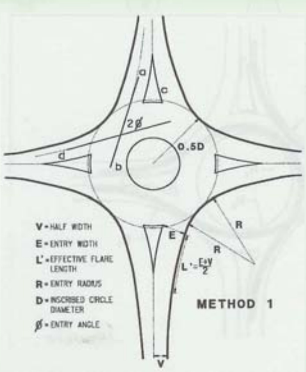
Geometry & Capacity

- Empirical Capacity is Sensitive to Geometry
  - It gives a designer an understanding of geometry
  - Powerfully affects design
  - Leads to subtle 'geometric' solutions
- Gap Theory has Weak Geometric Relationships
  - Does not give an understanding of geometry
  - Has little effectiveness
  - Does not find 'geometric' solutions

Geometric Parameters Affecting Capacity

- Half Width "V"
- Entry Width "E"
- Flare Length "L"
- Entry Radius "R"
- Entry Angle "Ø"
- Inscribed Circle Diameter "D"

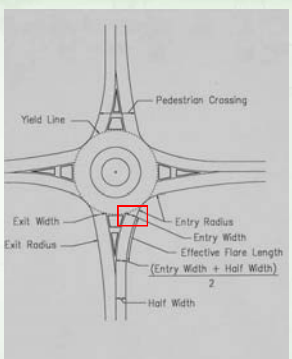
Geometric Parameters



Half Width "V"

- Measured curb face to curb face
- Capacity is very sensitive to "V"
  - Larger V = Larger Capacity
- V is accident neutral – does not increase accidents
- It is always known before a design begins

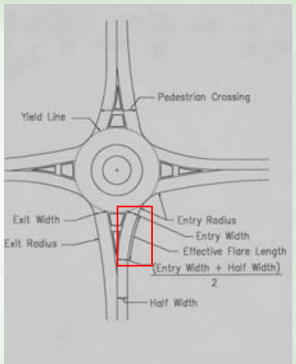
Geometric Parameters "E" Entry Width



Entry Width "E"

- Measured curb face to curb face
- Increasing E sharply increases capacity
- E is so powerful that it can "take over" the designer
- BUT increasing E increases crashes
  - Increase E cautiously
  - Use other geometrics to increase capacity
  - Get several smaller increase rather then one large
  - Small changes less disruptive to other geometry

Geometric Parameters “L” Flare Length



Effective Flare Length “L”

- Capacity is very sensitive to “L”
- Flare length is accident neutral
- L = 0 on parallel approaches
- L is usually between 18’ ~ 330’ (5m – 100m)
- 330’ flare gives a 95% of extra capacity
  - V=12’…..flared to ….E=24’ over 330’
  - Has the same capacity as V=24”, E=24’
- Even 18’ L gives good capacity increases
- “E” and “L” are related

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Flare Length and Safety

- Flaring is safer
  - Allows smaller entry lane widths
  - Allows smaller circulating widths
  - Allows smaller exits
  - Allows smaller geometry
- Results in slower entry speeds but higher capacity
- Provides “safe” capacity increases

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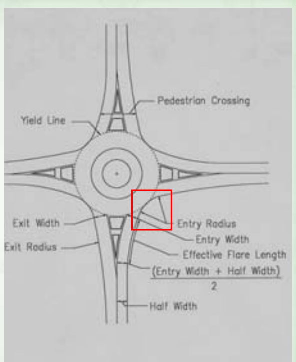
“E” & “L” are Powerfully Related

- E, L, V are related
- V is known and fixed
- E and L can be varied
- Long L greatly increases capacity
  - But not if E is almost equal to V
- If E is increased, capacity is greatly increased
  - But not if L is very small (L<7’)
- Powerful Capacity Effects
  - Counter-intuitive
  - Much weaker in theoretical models (SIDRA)

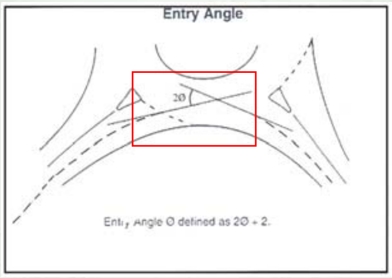
Geometric Parameters “R” Entry Radius



Entry Radius “R”

- Increasing “R” beyond 65’ (20m) = small capacity increase
- Reducing “R” below 50’ (15m)
  - Capacity drops severely,
  - Gap Theory Models do not include R – Blind to the effects
- A small “R” can reduce entry speeds
  - R is made very small
  - The disastrous capacity effects are not predicted in gap theory
  - Roundabout may fail before predicted design life
- Small R can cause crashes on MLRs
  - On MLRs R should not be less than 50’ (15m)
  - 65’ (20m) gives full capacity – slow entry speeds otherwise

Geometric Parameters “Ø” (Phi)



Entry Angle “Ø” (Phi)

- Entry Angle “Ø” (Mean angle between entry and circulating traffic)
- The smaller Phi, the smaller the capacity
- By Itself small Phi allows for fast entry speeds
  - However Phi can safely be made smaller, if other geometrics are used to control entry speeds
- Very small Phi not recommended if:
  - Severe neck turning is needed to see to the left at the yield line

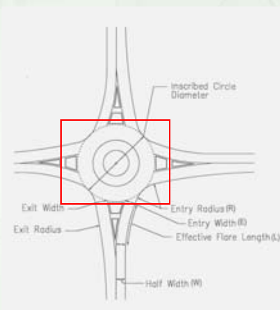
Entry Angle “Ø” (Phi)

- Gap Models do not include Phi – blind to its effects
  - Designs use very large Phi
  - Like R, the large loss in capacity is not predicted
  - Larger Phi increases crashes into the central island
- Large Phi is very bad on MLRs
  - Leads to entry path overlap
  - Uncomfortable for drivers – additional capacity reduction
- Phi best between 20° – 35° on MLRs

R and Phi are Related

- Small “R” and large “Ø” go together
- Combined effect is a net drop in capacity
- Countries with very low traffic densities use large Phi and small R to control speeds on SLRs
- Small R and large Phi can cause problems on MLRs

Geometric Parameters “D” Inscribed Circle Diameter



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Inscribed Circle Diameter “D”

- Effect on capacity is **usually** small
- Avoid very large D – fast circulating speeds
- Reduce D and increase E and L = more capacity
- Smaller D avoids reverse curves – entry to exit
- Minimum D set by a total of entry and exit widths
- Large D useful at high circulating flows
  - Increasing D increases capacity
  - Small Circulating flows – Capacity increase is small
  - Large circulating flows – Capacity increase is small
  - Has greatest effect when capacity is low

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Exit Geometry

- Has no effect on capacity IF ADQUATE
- Exits must relate to other geometry – Holistic
- Exits must be affective – Parked cars/ bus stops
- Parallel along the exit radius – than taper if required
- Taper lengths only need be 1:15 ~ 1:20
- Small exit radii large exit angles
  - OK on SLRs – Can reduce exit speeds - Low anyway
  - Bad on MLRs
  - Affects pedestrian safety

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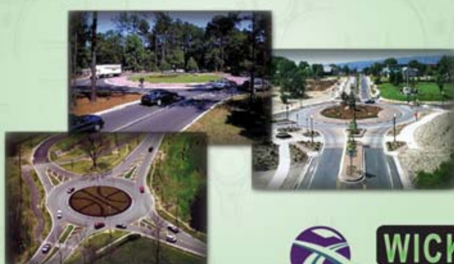

Fast Path & Speed Consistency

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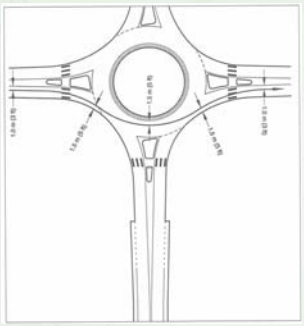
It's Safe to Cross Over to Wick

Fast Path Speeds

- Roundabout Speed is determined by the fastest path allowed by the geometry
- Through movements are usually the fastest path, although sometimes right turn paths are more critical.
- Recommended Design Speeds in the FHWA Guidelines (pg 133).



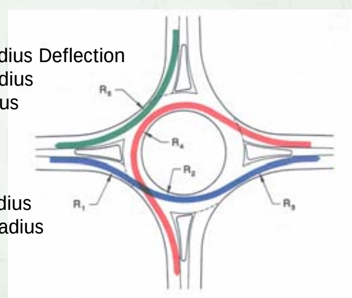
FHWA Exhibit 6-5

How to Measure the Fastest Path?

What Radii to Check?

R1: Entry Path Radius Deflection
R2: Circulating Radius
R3: Exit Path Radius

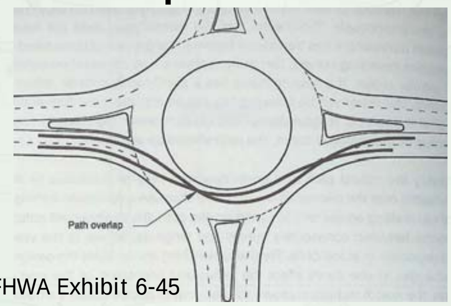
R4: Left Turn Radius
R5: Right Turn Radius



Speed Consistency

- Speed consistency helps reduce crash rates and severity between conflicting streams of traffic
- Also simplifies the task of merging into the conflicting traffic stream
- FHWA guidelines recommend no more than a 12 MPH difference between traffic movements

Path Overlap



FHWA Exhibit 6-45

Vehicle Path Overlap

- Large entry angles causes “vehicle path overlap”
- Small entry radius can cause “vehicle path overlap”
- Large exit angles causes “vehicle path overlap”
- Small exit radius can cause “vehicle path overlap”
- This dramatically reduces capacity.
- Causes accidents at the entry, circulating roadway and the exit.

Design Steps

- The following are only a guide and starting point for roundabout layouts.
- These steps only cover the basic geometric layout.

Design Steps

1. Foundation
   a) Check Traffic Data (Design Year AM & PM)
   b) Check Approach Volumes, Road Capacity
   c) Check Exit Volumes, Road Capacity
   d) Look for anomalies
   e) ? Any errors transcribing data ?
   f) Use diagrams for traffic volumes
   g) Look for large right and left turn volumes

Design Steps

2. Use a computer model
   1. Will tell you how many lanes
   2. If you need a by-pass or double lefts
   3. Check queues, delays and LOS
   4. Indicates what you should draw, diagrammatic sketch
3. Assume an approx. ICD from site constraints (SLR – 115 ft. , 2-Lane 150 ft.)

Design Steps

4. Run Model
   a) Revise geometry if needed to obtain delay and queue lengths desired
      i. Single lane w/ trucks E<= 5.5m
      ii. Maximize L, Keep E to a minimum
   b) Test By-pass (+300 right turns) Instead of 2-lane entry
   c) Use model as exploratory tool not a black box
   d) Get the strategy right

Design Steps

5. Start Rough Drawing (Use tracing paper!)
   a) Find intersection of road centerlines (make it the center of ICD)
   b) Draw ICD
   c) Draw central island (Offset circulating roads)
   d) Shift roundabout (tracing paper) as needed to get proper offsets
   e) Check circulating road width against entry lanes
   f) Pedestrians need a 2m (6') splitter island, offset 3' on either side of the centerline
   g) Draw arcs from splitter to central island
   h) Join entry and exit arcs (finish off splitter island)

Design Steps

6. Finish Rough Drawing (Using tracing paper!)
   a) Layout flare and entry widths for approaches
   b) Sketch in entry radius
   c) Shift roundabout as needed to get desired parameter
   d) Revise layout/ position to get it to fit the intersection and parameters better
   e) Change geometric parameters as needed
   f) Do the dynamic design (iterate!)

We're almost there!

Design Steps

7. Check Vehicle Overlap
8. Check Fastest Path
   a) Sketch in the line to start with (on CAD use a spline function, not arcs and tangents)
   b) Best fit a radius to the spline
9. Update Computer Model
10. Iterate as needed
11. Lastly draw accurately

References

- Roundabouts an Information Guide, FHWA
- Roundabouts: An Arizona Case Study and Design Guidelines, ADOT
- The Design of Roundabouts, Transportation Research Laboratory, Department of Transport, Mike Brown
- Designing and Implementing Roundabouts –Univ. of Wisconsin Course 2/9-11/2004
- Designing and Implementing Roundabouts –Scott Ritchie & Barry Crown Course 4/04

Questions????