سعة التقاطعات الدوارة

Roundabout Capacity

التحليل العملياتي

- السعة
- معايير الأداء
- التقييم الحقلي للدوارات

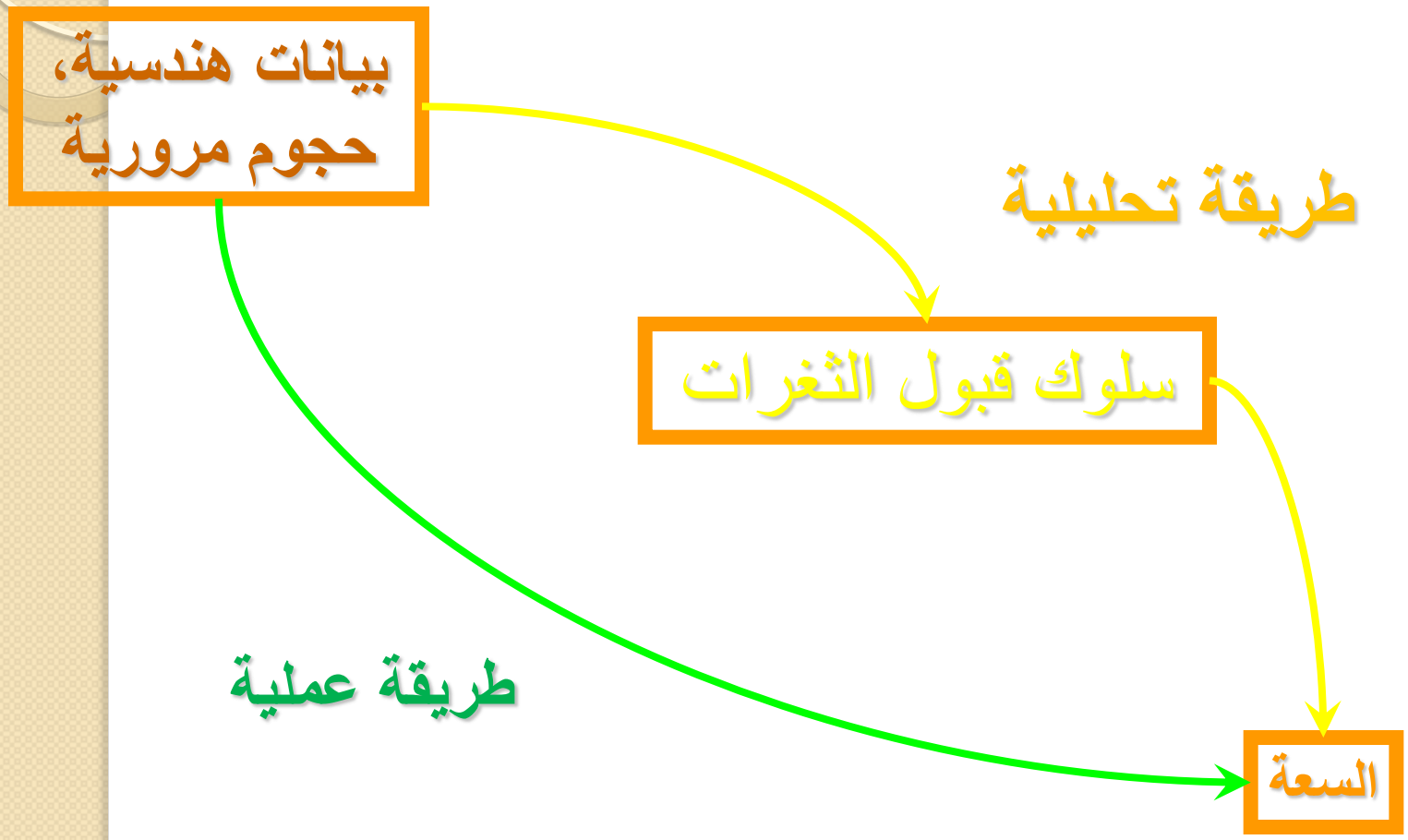
What Affects Capacity?
ماذا يؤثر على السعة

- تتأثر سعة الدوار بسعة كل ذراع من أذرع الوصول (الدخول) إلى الدوار
- ترتبط سعة أذرع الدخول إلى الدوار بـ:
  - العناصر الهندسية للدوار
  - الغزارات المتصادمة على الشريط الدائري
  - خصائص قبول الثغرات
- كل ما يتعلق بالثغرة الحرجة

How Can Capacity Be Evaluated? تقييم السعة

- طريقتان أساسيتان :
  - طريقة تحليلية Analytical method
  - طريقة تجريبية (عملية) Empirical method
- يمكن استخدام المحاكاة Also can use simulation

الطريقة التحليلية والعملية



الطريقة التحليلية Analytical Method

- تتعلق السعة بخصائص الجريان المروري،

Capacity is a function of, among others, the characteristics of the traffic stream

- تحسب السعة وفقاً لنظرية قبول الثغرات Based on gap acceptance theory
- تشابه منهجية HCM للتقاطعات بدون إشارات ضوئية Similar to methodology in HCM for TWSC
- Method is generally more portable to other countries
- Gap acceptance logic used in simulation

الطريقة التحليلية الأسترالية
Australian Analytical Method

- تتعلق السعة بالمعايير التالية: Capacity is a function of the following parameters:
  - **الثغرة الحرجة** **Critical gap:** Minimum gap in major traffic stream that a minor vehicle will accept
  - **زمن التتابع** **Follow-up time:** Additional time it takes a second minor vehicle to accept the same gap
  - **درجة وجود أرتال العربات (مجموعات العربات)** **Proportion of bunched vehicles:** The degree to which approaching vehicles are platooned

Empirical Method الطريقة التجريبية

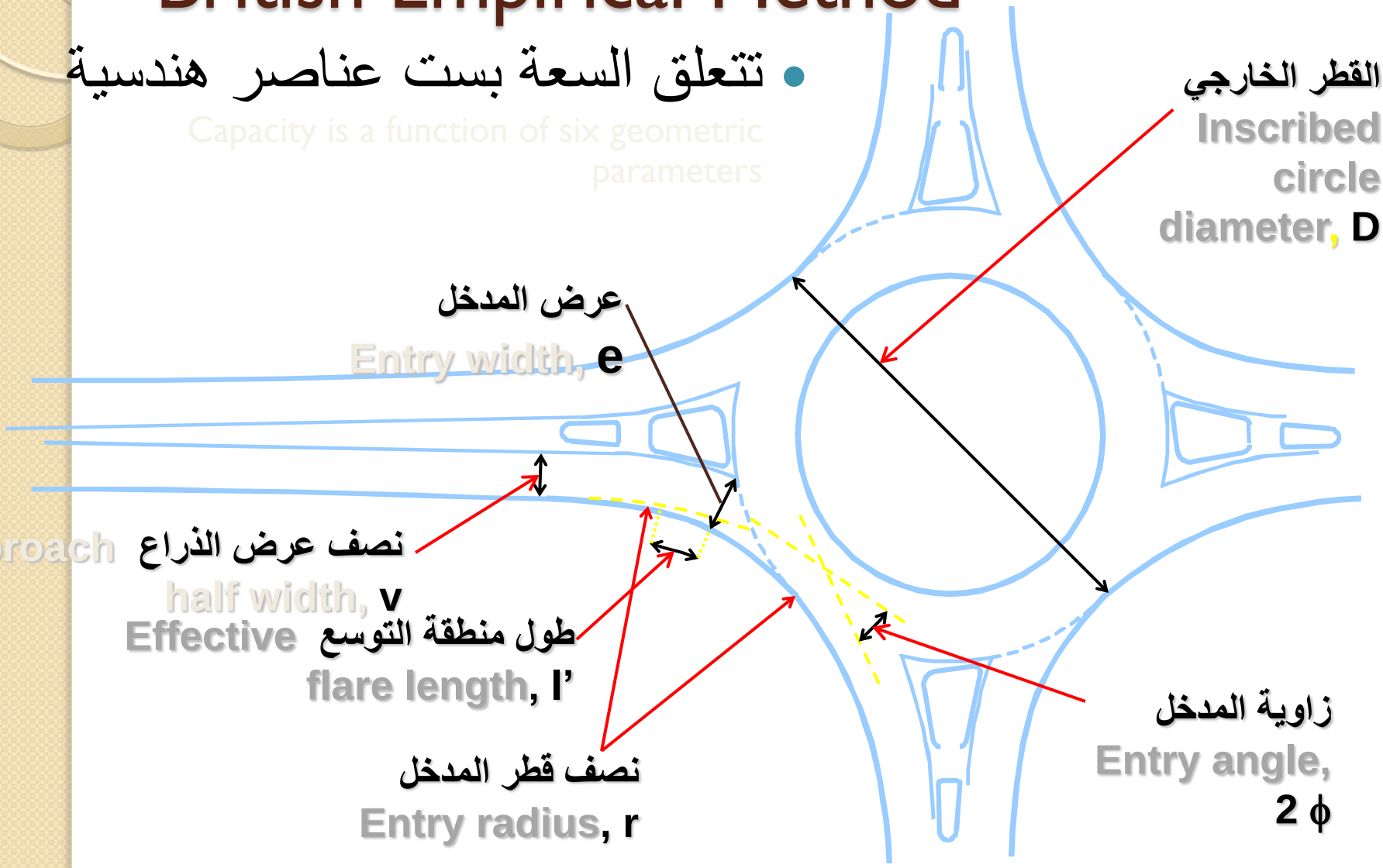
- تتعلق السعة بالعناصر الهندسية Capacity is a function of geometric features
- الإرجاع الخطي لقاعدة بيانات ضخمة Linear regression of huge database
- يتم قياس السعة مباشرة في الحقل Capacity directly measured in field
- معادلات خاصة بكل بلد Equations unique to each country
- تتطلب المعايرة:Calibration requires
  - التشغيل في ظروف السعة operating at capacity
  - التغييرات الهندسية geometric variation

الطريقة التجريبية البريطانية

British Empirical Method

- تتعلق السعة بست عناصر هندسية

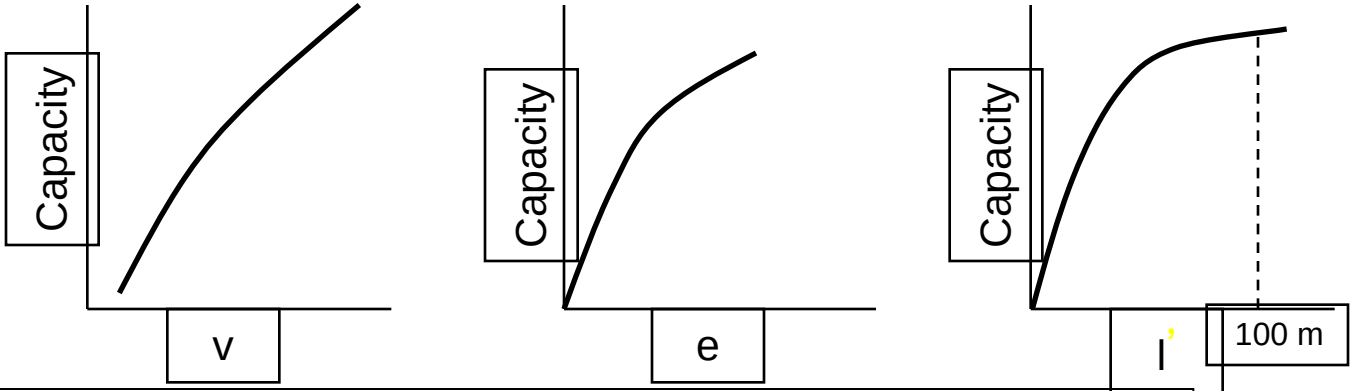
Capacity is a function of six geometric parameters



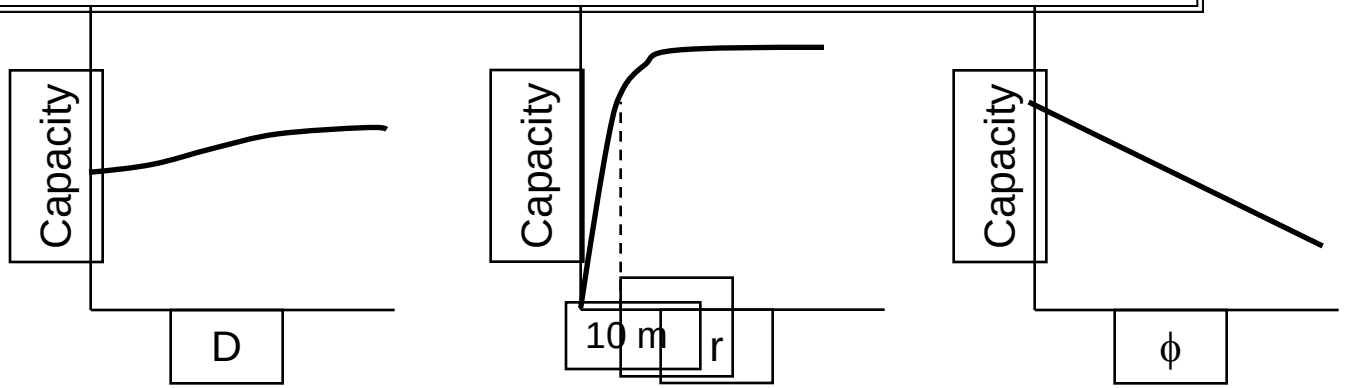
الطريقة البريطانية (الحساسية الهندسية)

Geometric Sensitivity

Major effects: v, e, l’ التأثيرات الرئيسة



Minor effects: D, r, ϕ التأثيرات الثانوية

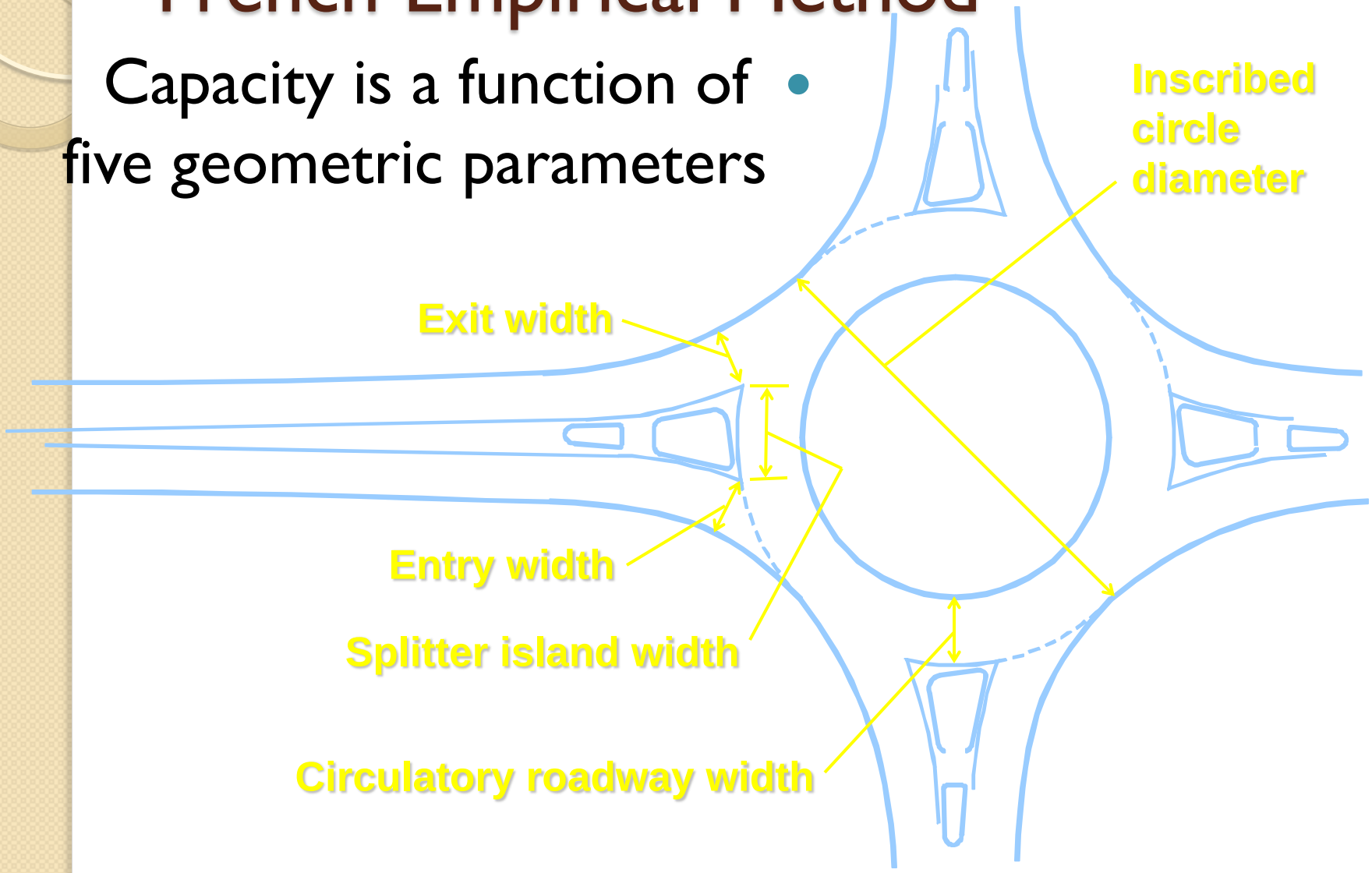


Source: Barry Crown

الطريقة الفرنسية التجريبية

French Empirical Method

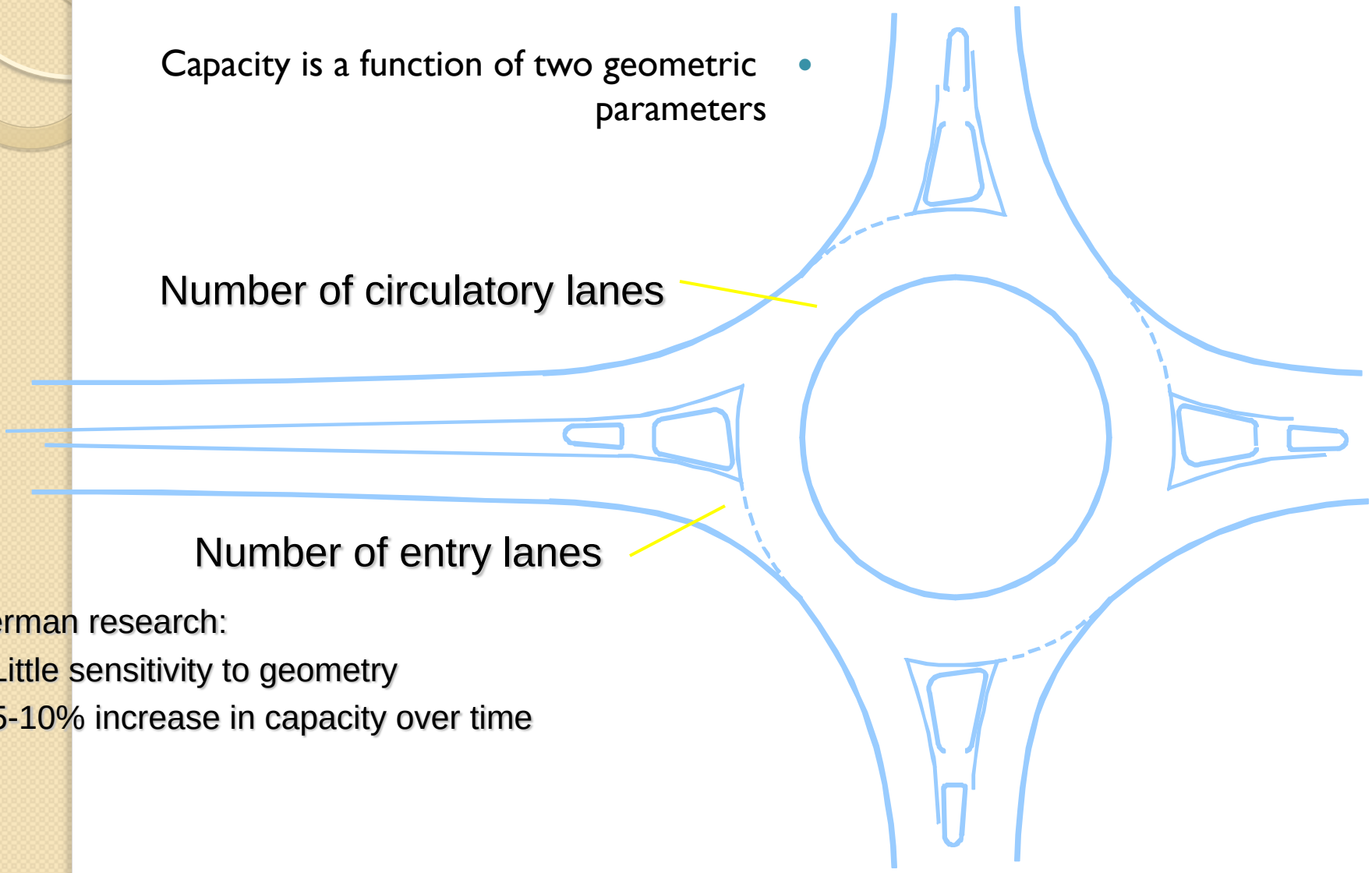
- Capacity is a function of five geometric parameters



الطريقة الألمانية التجريبية

German Empirical Method

- Capacity is a function of two geometric parameters



German research:

- Little sensitivity to geometry
- 5-10% increase in capacity over time

Summary of Analysis Methodologies

- Variety of model forms
- Each has been custom-tailored to the design philosophies and driver behavior of each country
- FHWA guide matches models to design philosophy for each roundabout category
- As more research is done in the U.S., expect to see U.S.-specific methodology

How Do I Determine the Capacity for Each Category of Roundabout?

- Determine base capacity for the appropriate category:
  - Single-lane roundabouts
  - Double-lane roundabouts
- Adjust the capacity for other factors

الدوارات بحارة واحدة Single-Lane Roundabouts

- **الدوارات المدينية الصغيرة** Urban compact roundabouts
  - التصميم على أساس النموذج الألماني **Design based on German-style design**
  - معادلات السعة من أجل بيانات ألمانية **Capacity equation based on German data**

- **دوارات بحارة واحدة** **Single-lane roundabouts**
  - التصميم من أجل النماذج البريطانية، الفرنسية الأسترالية **Design based on British-, French-, and Australian-style design**
  - المعادلات على أساس البيانات البريطانية **Equation based on British data**

دوارات بحارة واحدة

Single-Lane Roundabouts

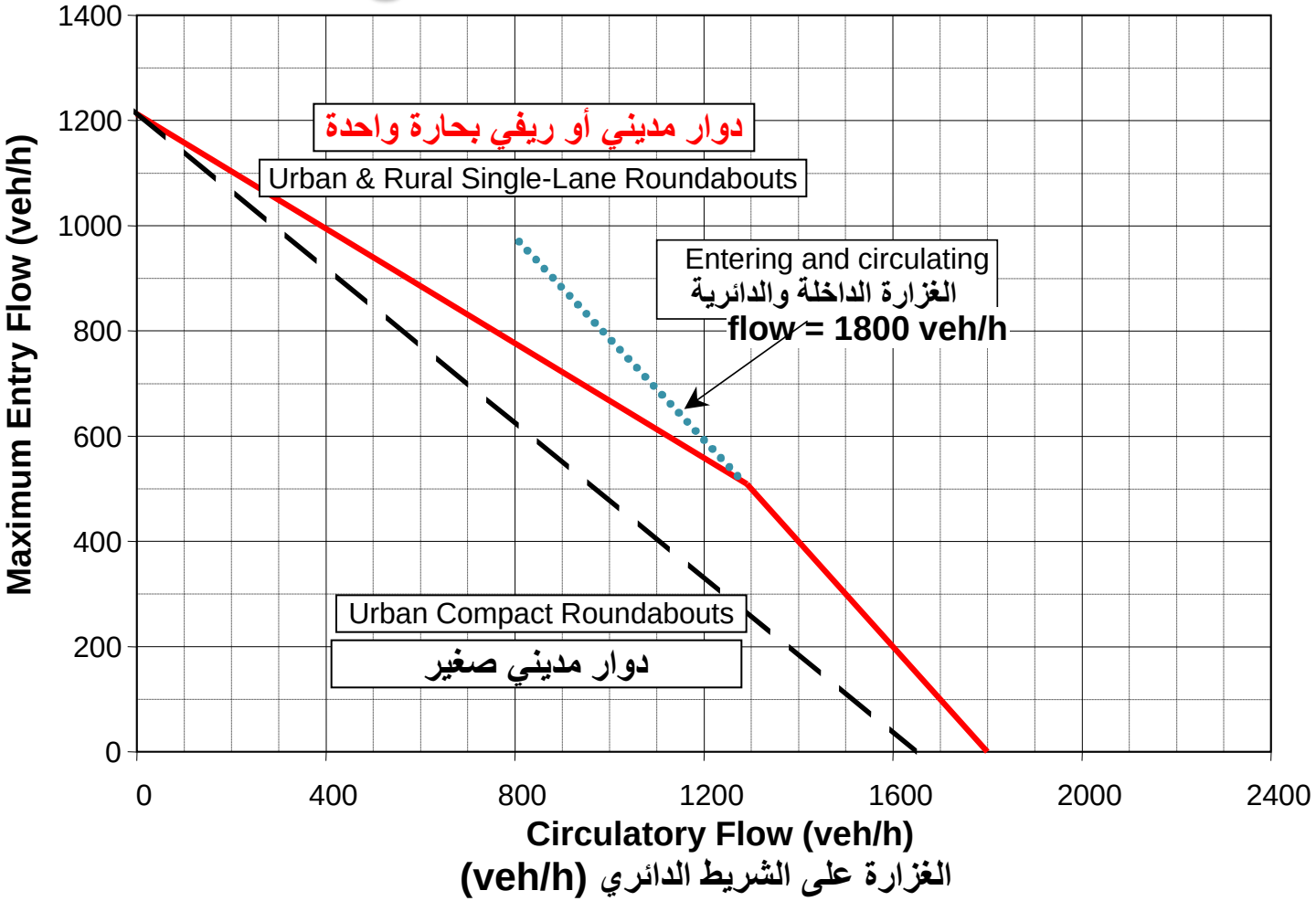


Exhibit 4-3, p. 87

الدوارات بحارتين Double-Lane Roundabouts

- التصميم الأساسي وفق النموذج البريطاني
  Design based primarily on British-style design
- المعادلات حسب البيانات البريطانية Equation based on British data

Double-Lane Roundabouts الدوارات بحارتين

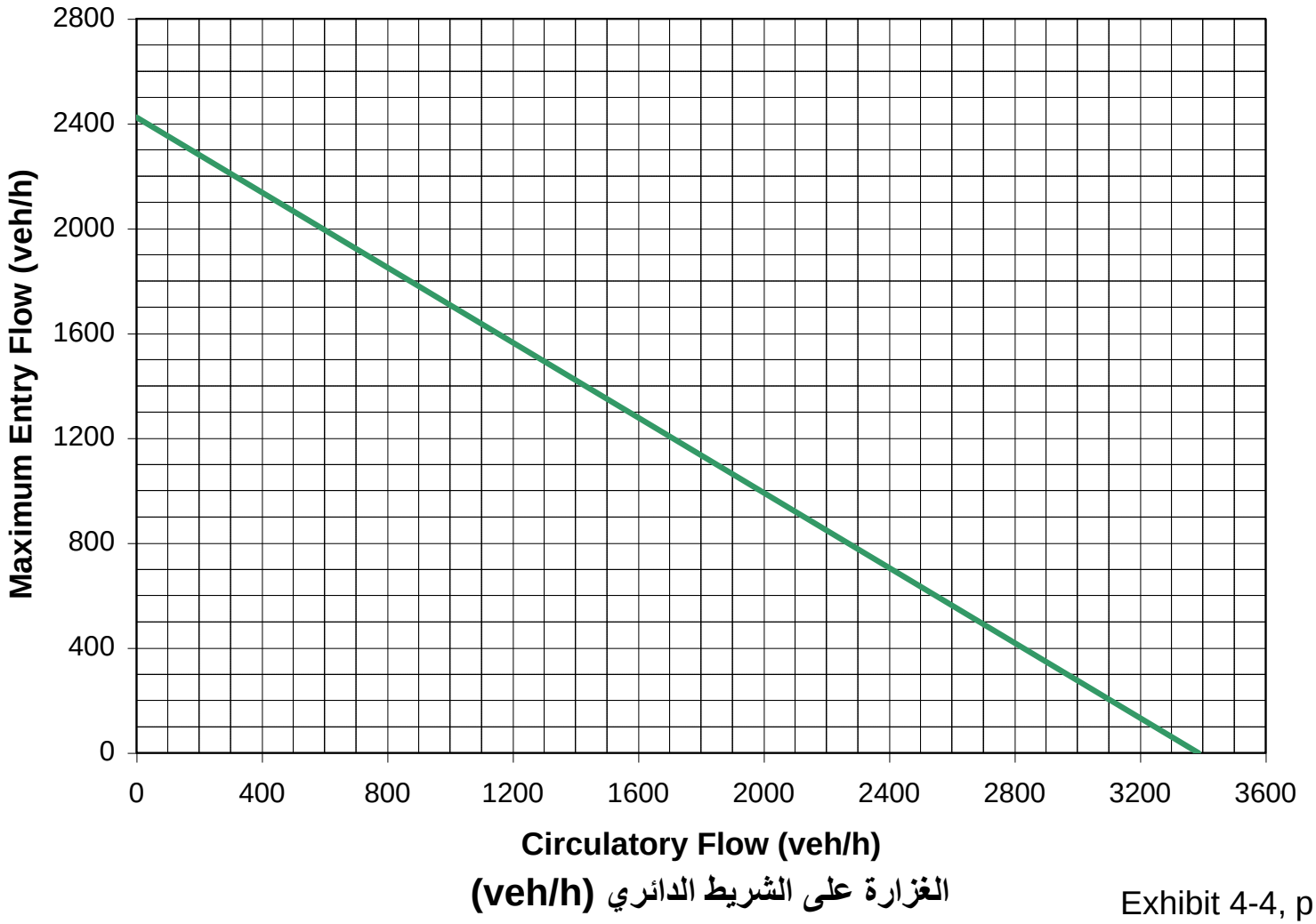


Exhibit 4-4, p. 87

تعديلات السعة Capacity Adjustments

- الحارات القصيرة (الأذرع المتسعة) Short lanes (flared approaches)
- المشاة Pedestrians

Capacity adjustments: Short lanes تصحيح السعة : الحارات القصيرة

- **الحارات القصيرة هي حارات إضافية جزئية تضاف عند التوسع من حارة واحدة إلى حارتين**

Short lanes are the additional partial lanes added when flaring a roundabout from one to two lanes

No. of vehicle spaces in short lane	Capacity factor (applied to double-lane approach capacity)
0 (single-lane approach)	0.500
1	0.707
2	0.794
4	0.871
6	0.906
8	0.926
10	0.939

Exhibit 4-5, p. 89

Capacity Comparison مقارنة السعة

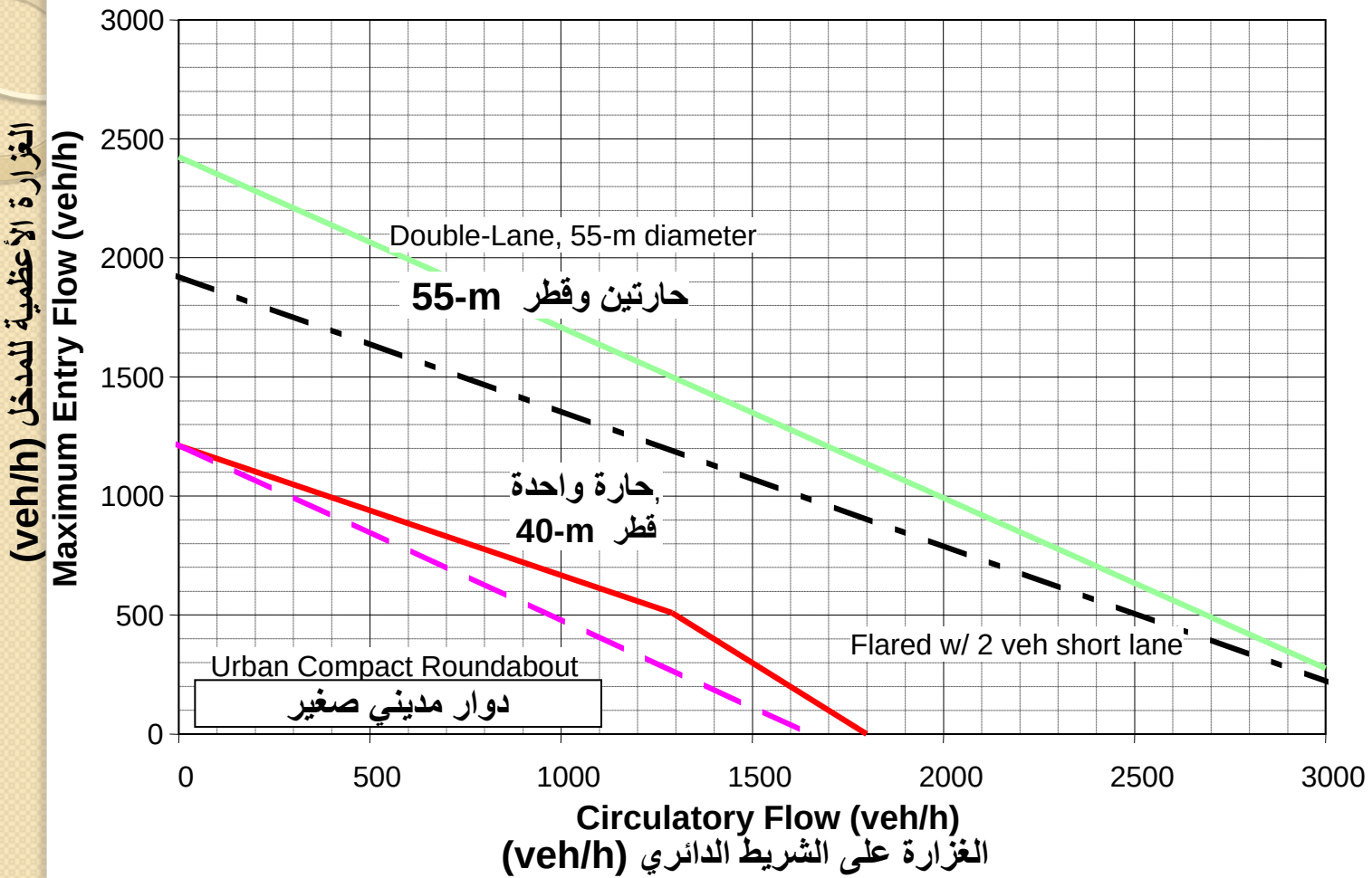


Exhibit 4-6, p. 89

معامل تصحيح السعة للمشاة للدوارات بحارة واحدة

Capacity adjustment: Pedestrians at single-lane roundabout

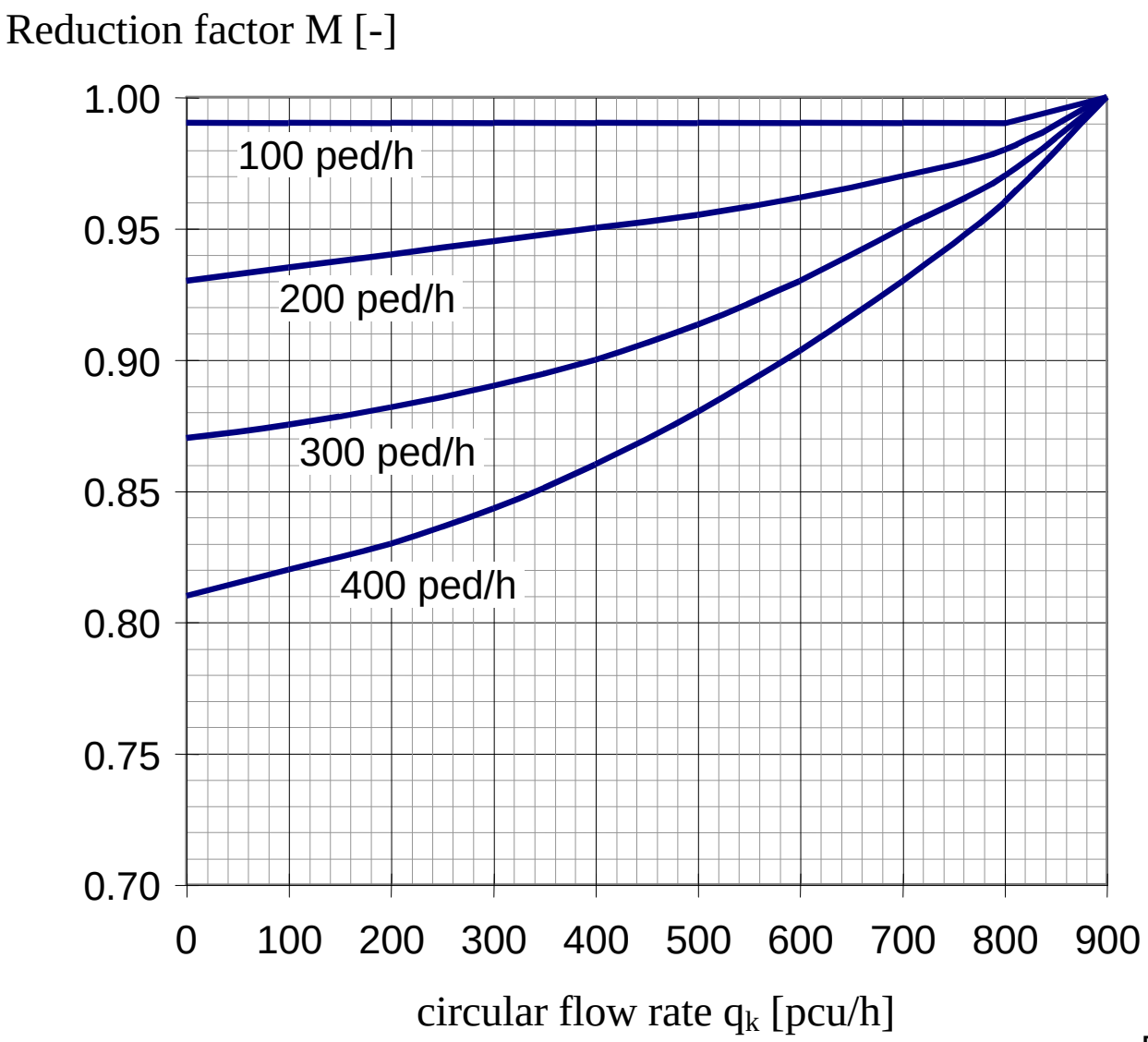


Exhibit 4-7, p. 90

معامل تصحيح السعة للمشاة للدوارات بحارتين

Capacity adjustment: Pedestrians at double-lane roundabout

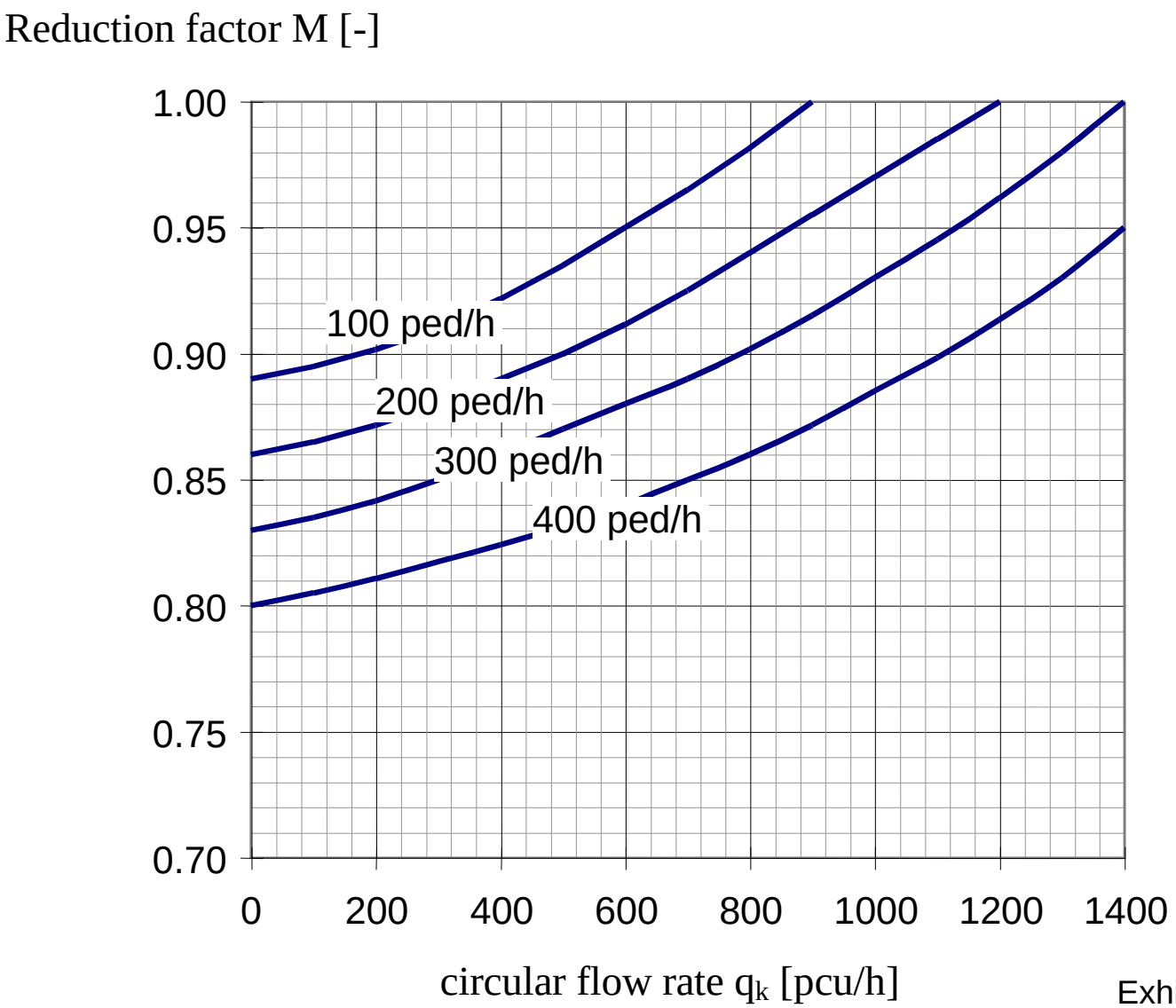


Exhibit 4-8, p. 91

Other Situations حالات أخرى

- What about larger roundabouts (three- and four-lane entries مداخل بثلاث وأربع حارات)?
  - Have been used in U.S. (Colorado, California)
  - FHWA document does not provide specific guidance
  - Requires use of other methodologies, primarily UK
- Requires careful design to ensure adequate operational and safety performance

Exit Capacity سعة المخرج

- Single-lane exits preferred
  - Shorter pedestrian crossings
  - Better speed control on exit
- **Capacity**
  - 1,400 veh/h with tangential alignment, no peds or bikes
  - 1,200-1,300 veh/h for normal urban conditions
- Rule of thumb:

  >1,200 veh/h → double lane exit

Degree of Saturation درجة الإشباع

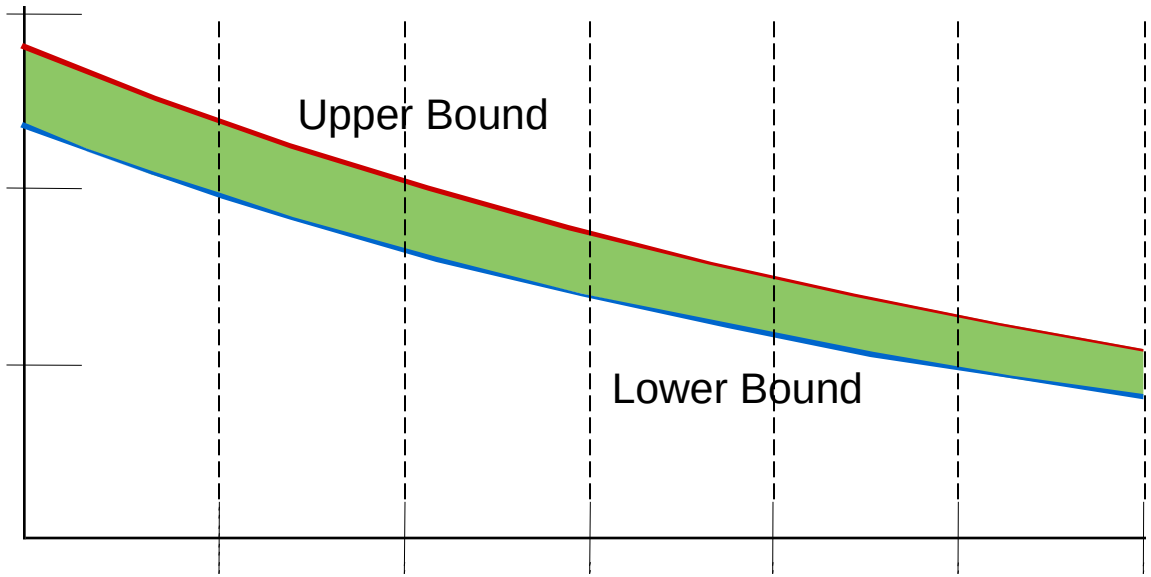
- For each approach, determine entry volume and entry capacity
- **Degree of saturation = volume / capacity**
- Critical approach: approach with highest degree of saturation
- **Typical desirable maximum = 0.85**
- Higher degrees of saturation lead to more unstable operation, increased delay and queuing

What about the HCM?

- Roundabouts introduced in 1997 HCM
- Method unchanged in HCM 2000
- Uses analytical method
- Only estimates capacity; no guidance on delay or level of service

HCM 2000 Method

- Applies only to single-lane roundabouts
- Only estimates capacity; no delay or LOS



How do I use the data? كيف يتم استعمال البيانات

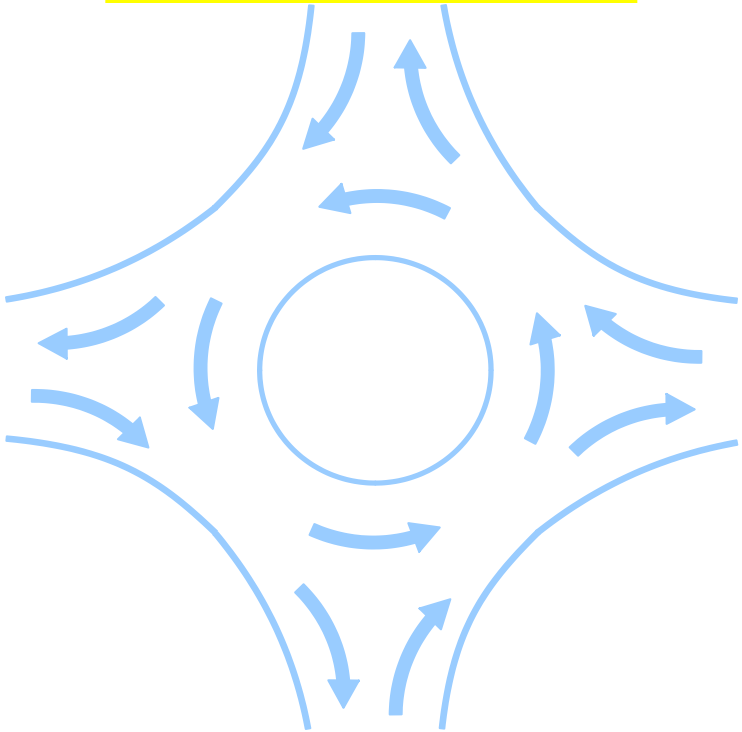
Turning movements

حركات الانعطاف

Roundabout volumes

حجوم المرور





Step 1: Convert to passenger car equivalents تحويل الغزارات إلى عربات حسابية

- Convert trucks and other vehicle types to passenger car equivalents (pce)

نوع العربة Vehicle Type	العربة المكافئة Passenger Car Equivalent (pce)
Car عربة حسابية	1.0
Single-unit truck or bus شاحنة مفردة أو باص	1.5
Truck with trailer شاحنة مع مقطورة	2.0
Bicycle or motorcycle دراجة عادية أو نارية	0.5

Exhibit 4-1, p. 84

Step 2: Apply Peak Hour Factor (PHF) تطبيق معامل ساعة الذروة

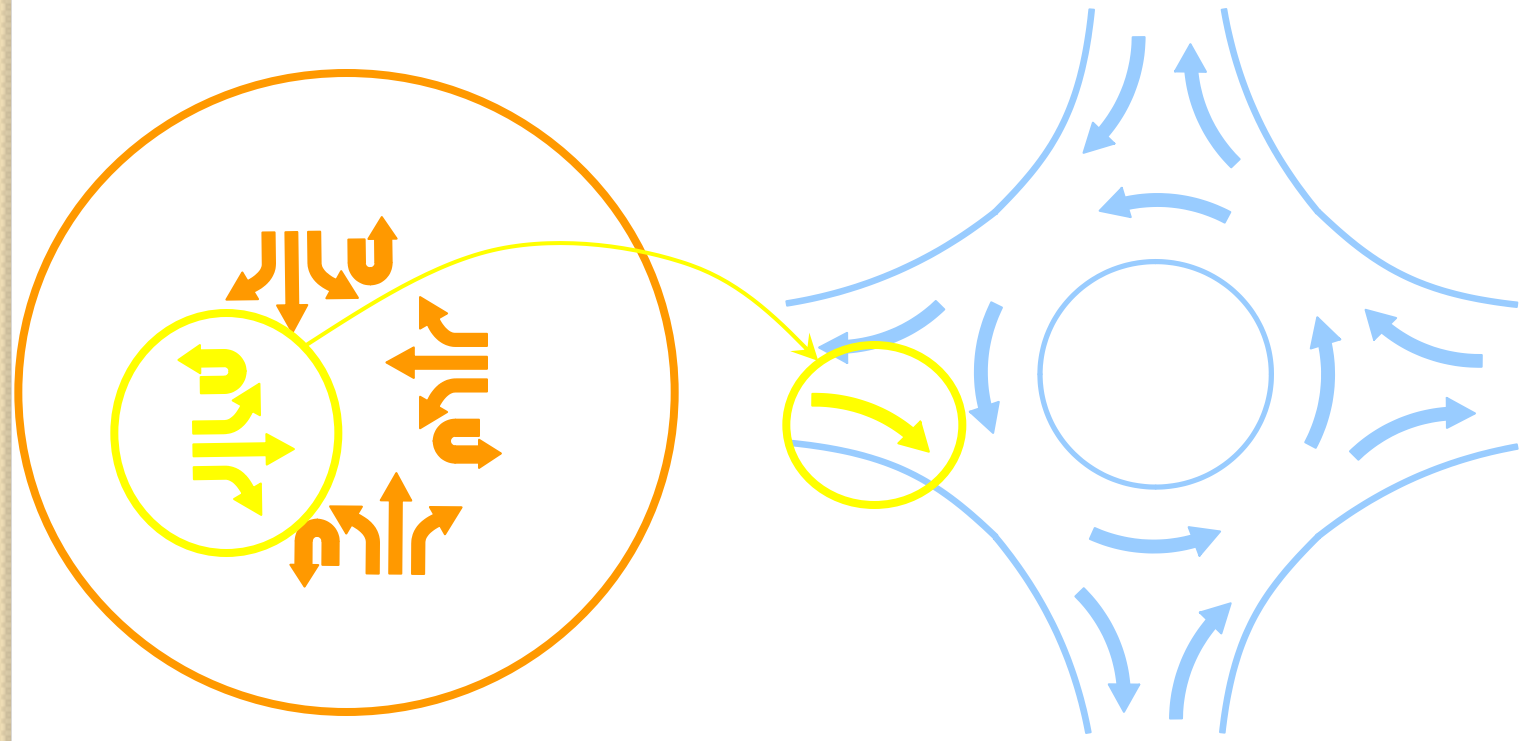
- Peak Hour Factor is the ratio of the hourly volume to the peak 15-minute flow rate
- Use of PHF is consistent with HCM

Formula (HCM):

Peak 15-min flow rate (veh/h) = Volume (veh/h) / PHF

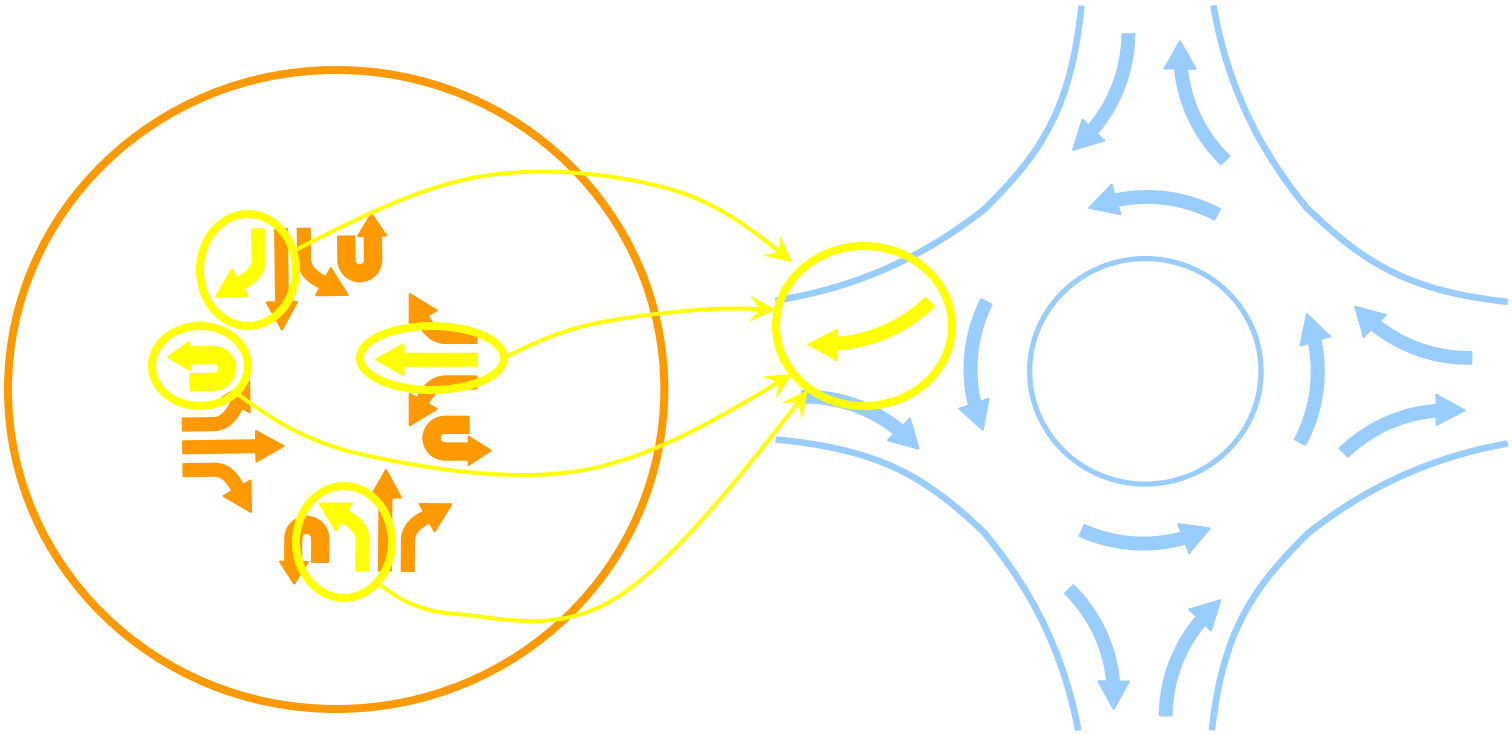
Step 3: Calculate Entry Volume حجوم المرور للمدخل

- Entry volume = sum of entering turning movements



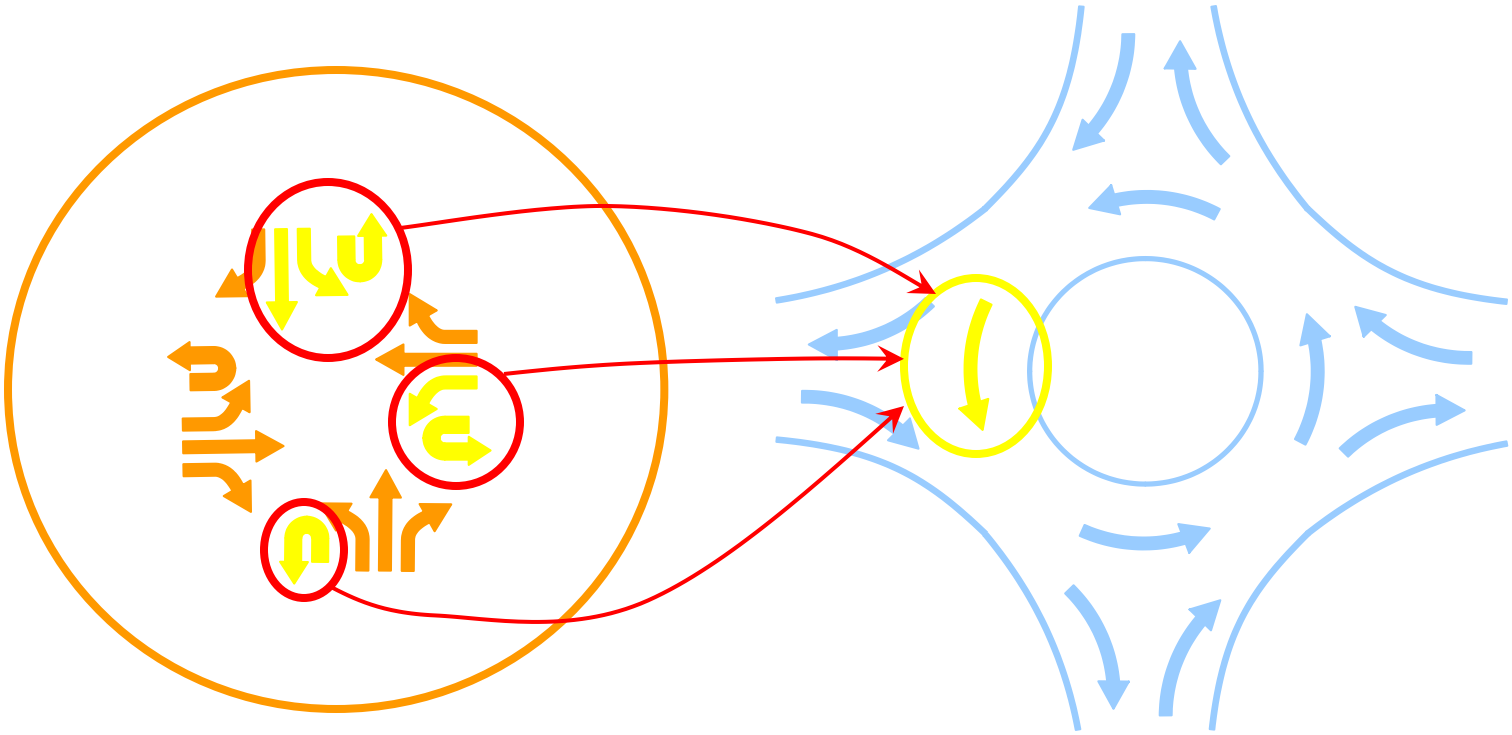
Step 4: Calculate Exit Volume حجوم المرور للمخرج

- Exit volume = sum of turning movements as shown



Step 5: Calculate Circulatory Volume حجوم المرور على الشريط الدائري

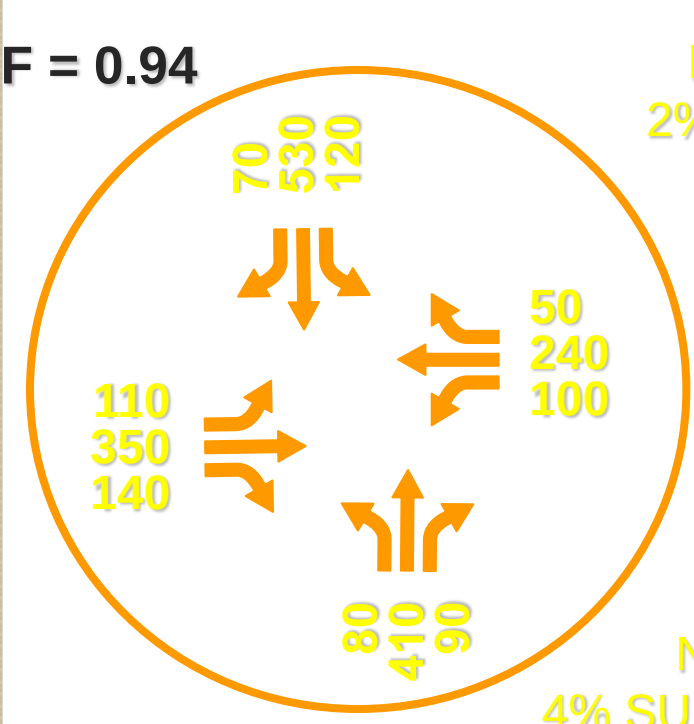
- Circulatory volume = sum of turning movements as shown



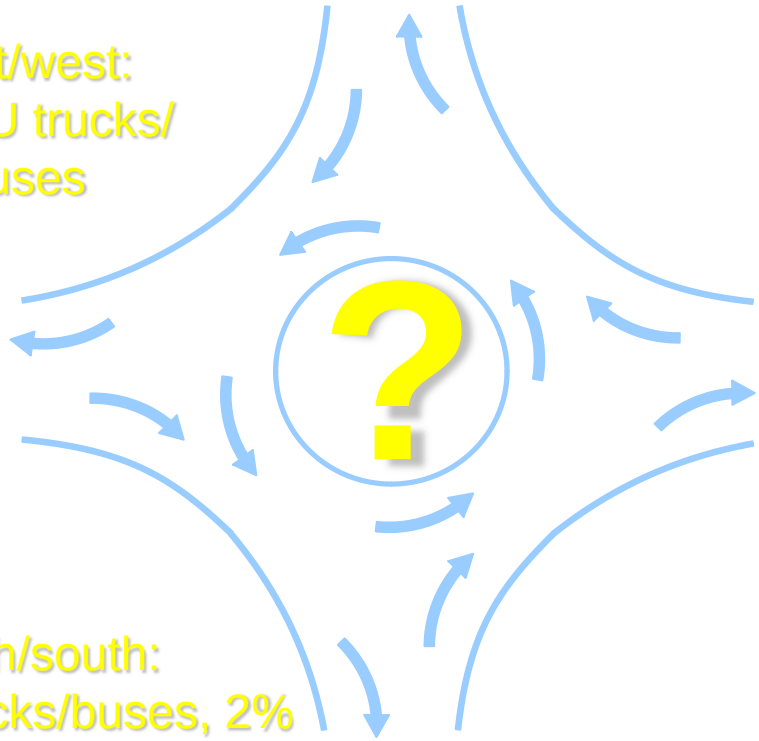
مثال : تحويل الحجوم Example:Volume Conversion

حركات الانعطاف Turning movements	→	الحجوم للدوار Roundabout volumes

PHF = 0.94



East/west:
2% SU trucks/
buses



North/south:
4% SU trucks/buses, 2%
combo trucks

Example Step 1: PCE Calculation

- SB TH: 530 veh (4% SU/bus, 2% combo)

0.94 = % cars (0.94) × 1.0 pce/veh

0.06 = % SU/bus (0.04) × 1.5 pce/veh

0.04 = % combo (0.02) × 2.0 pce/veh

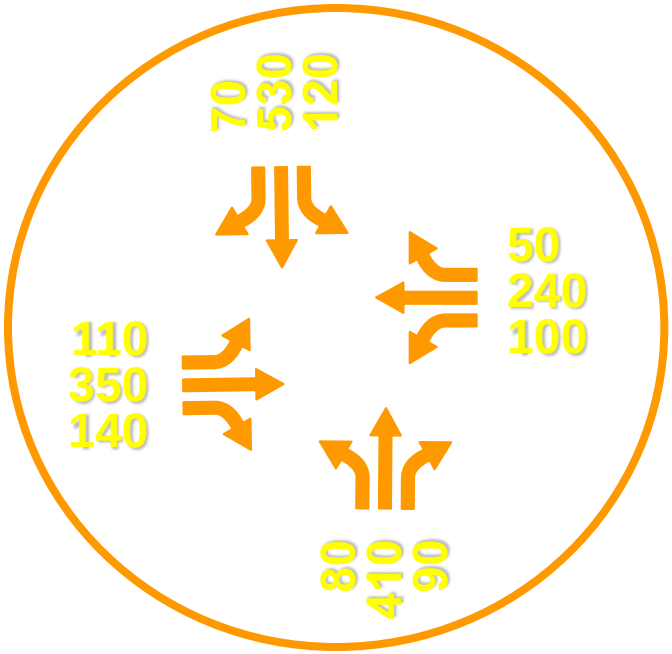
Vehicle Type	Passenger Car Equivalent (pce)
Car	1.0
Single-unit truck or bus	1.5
Truck with trailer	2.0
Bicycle or motorcycle	0.5

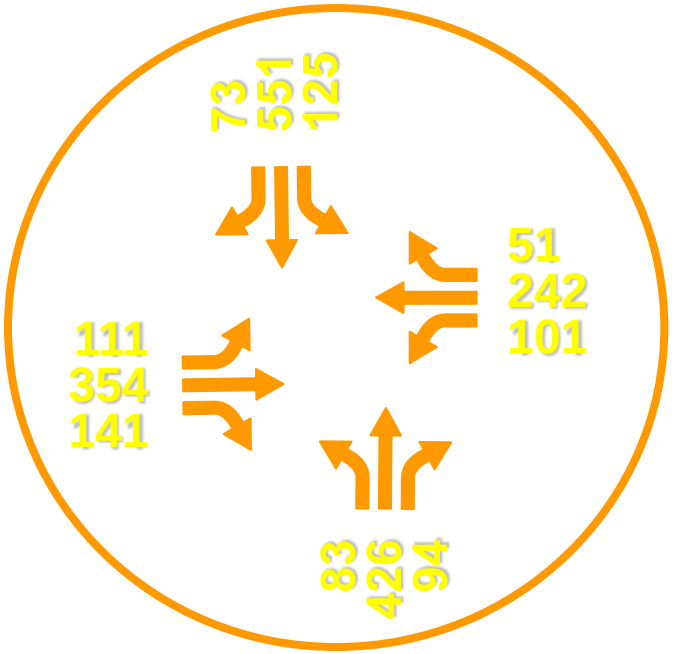
× 530 veh

551 pce

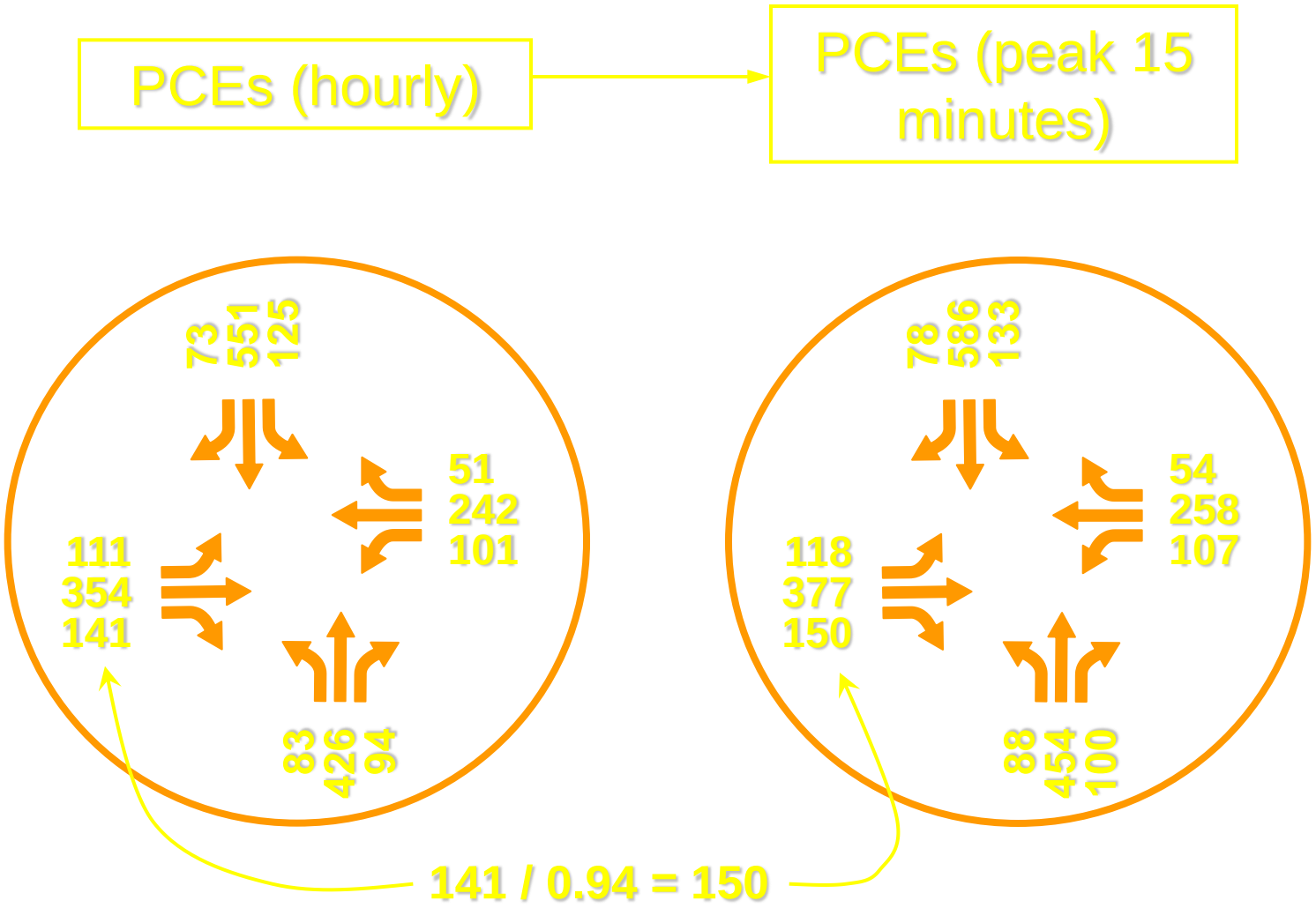
Example Step 1: Completed PCE Calculation

Raw Counts → PCEs



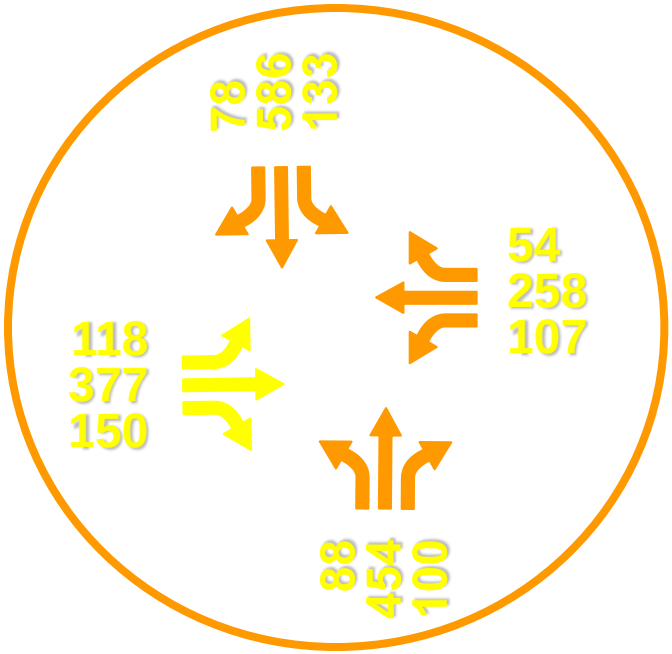


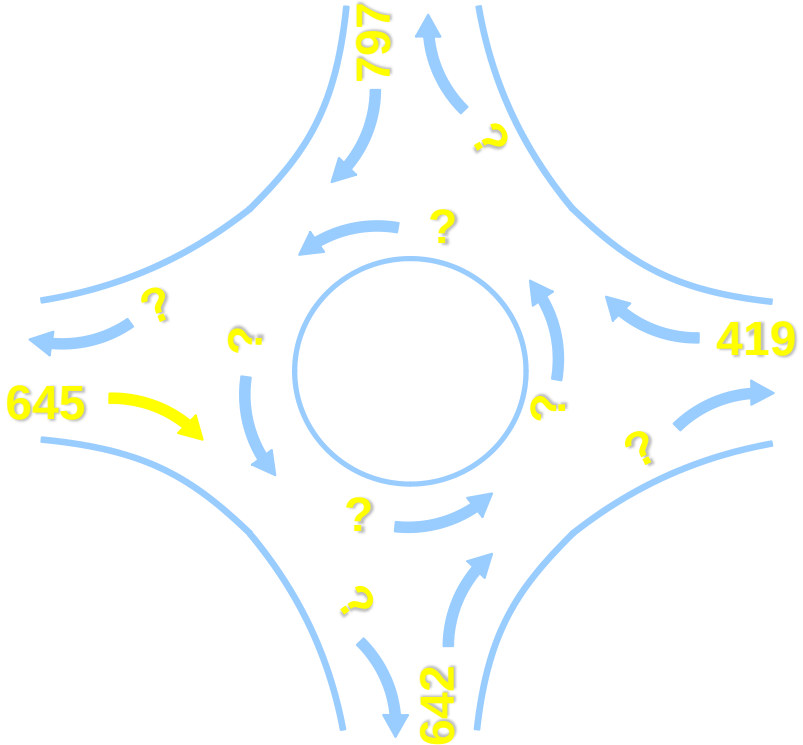
Example Step 2: PHF Factor



Example Step 3: Calculate Entry Volume

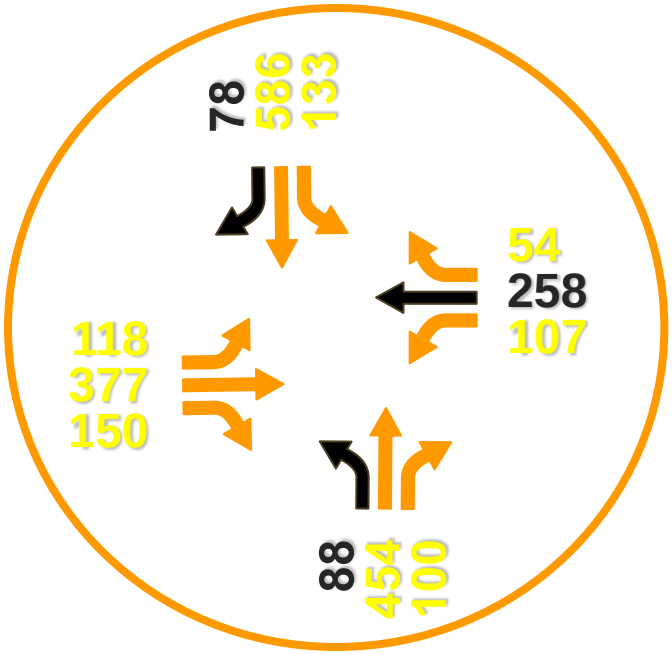
- Entry volume = sum of entering turning movements

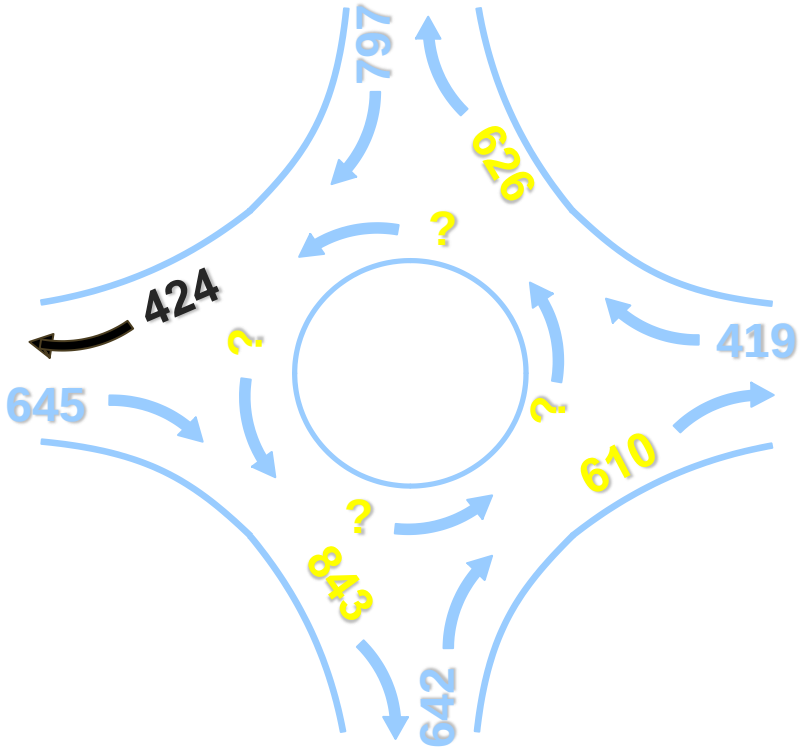




Example Step 4: Calculate Exit Volume

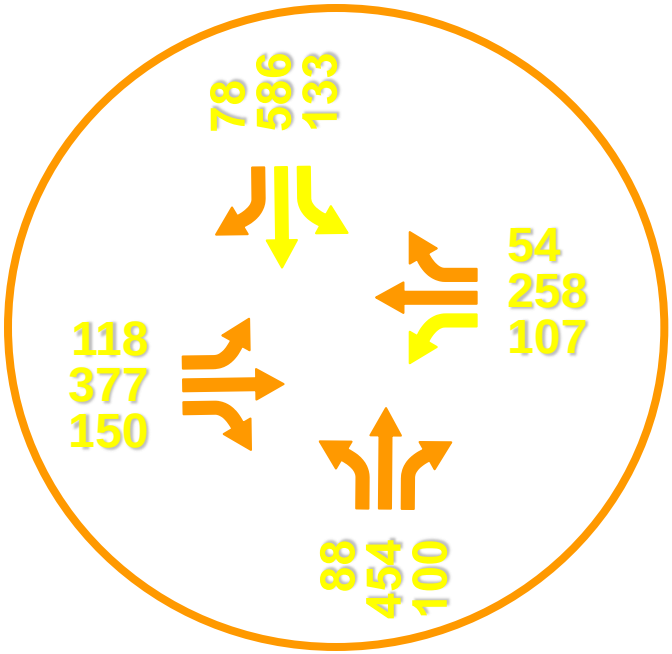
- Exit volume = sum of turning movements as shown

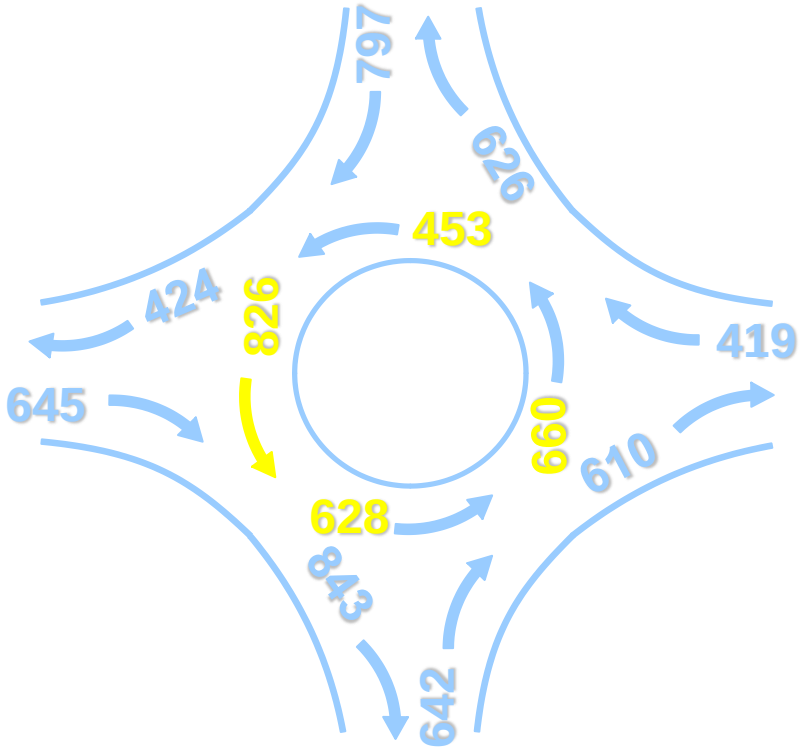




Example Step 5: Calculate Circulatory Volume

- Circulatory volume = sum of turning movements as shown

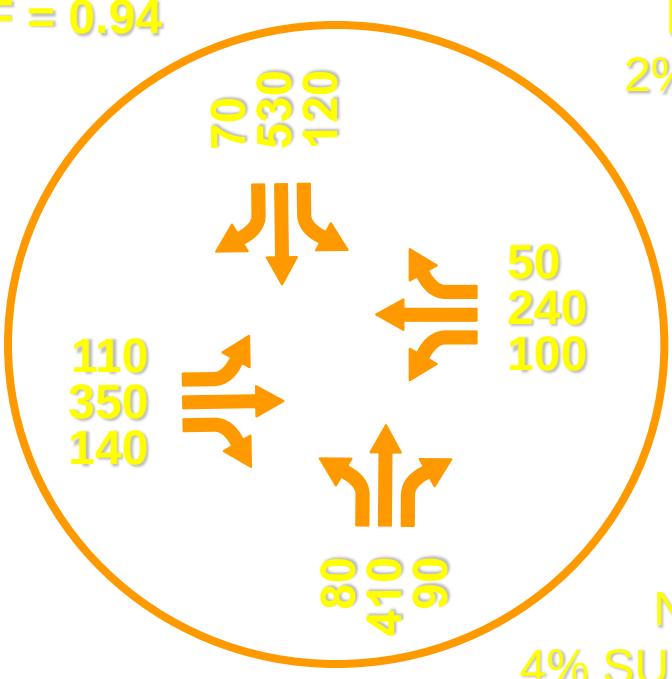




Example: Solution

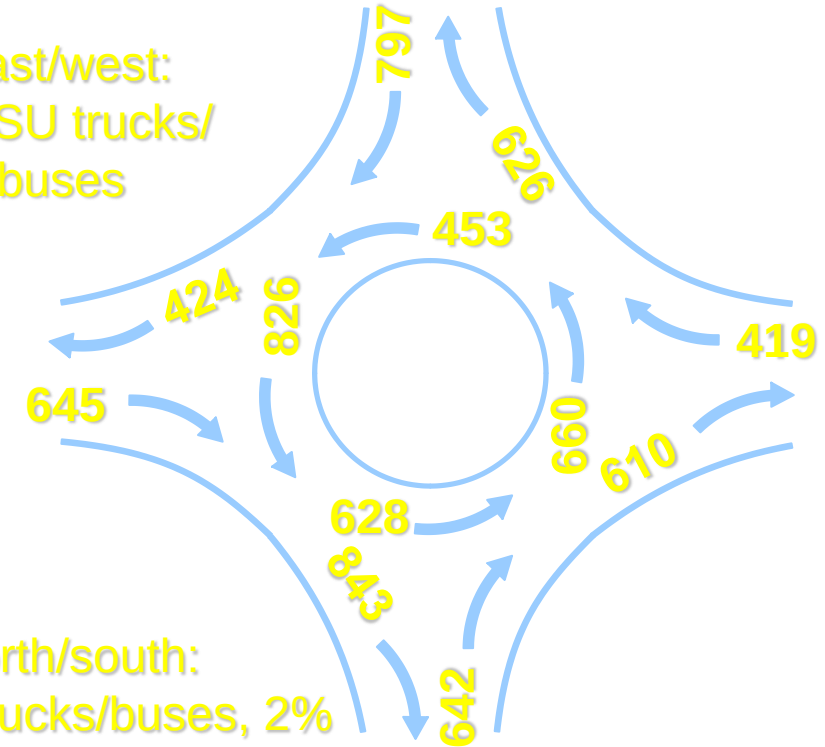
Turning movements → Roundabout volumes

PHF = 0.94



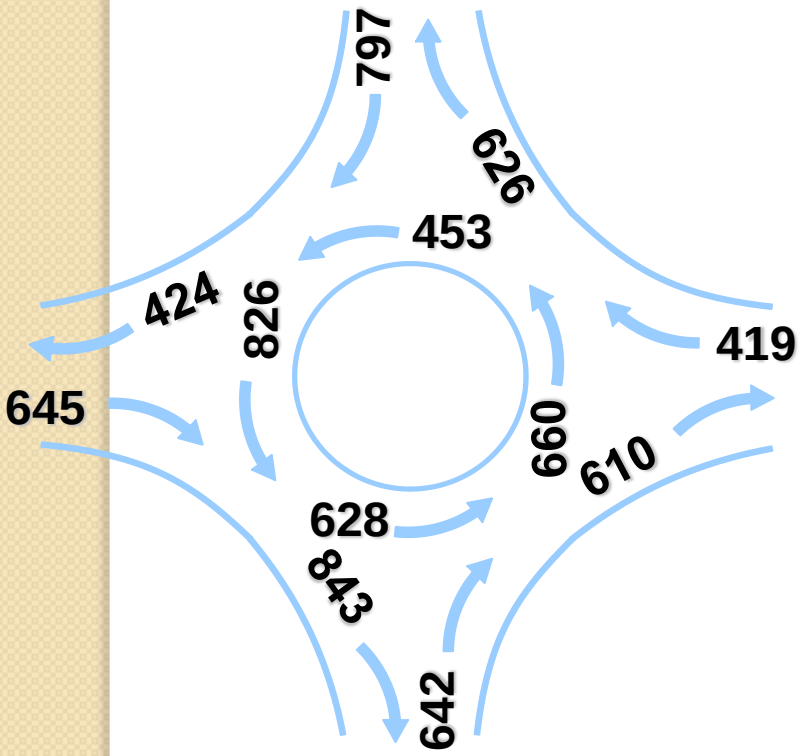
East/west:
2% SU trucks/
buses

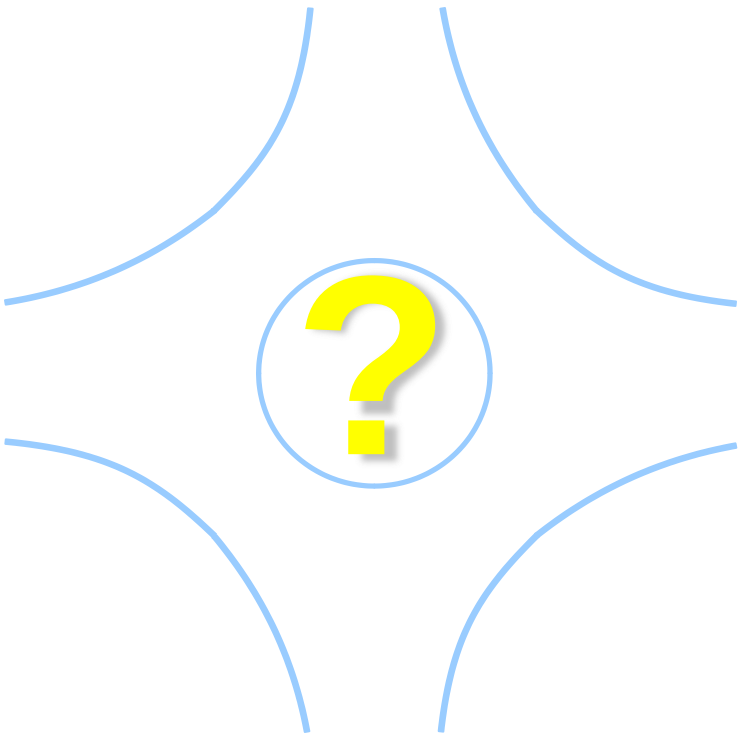
North/south:
4% SU trucks/buses, 2%
combo trucks



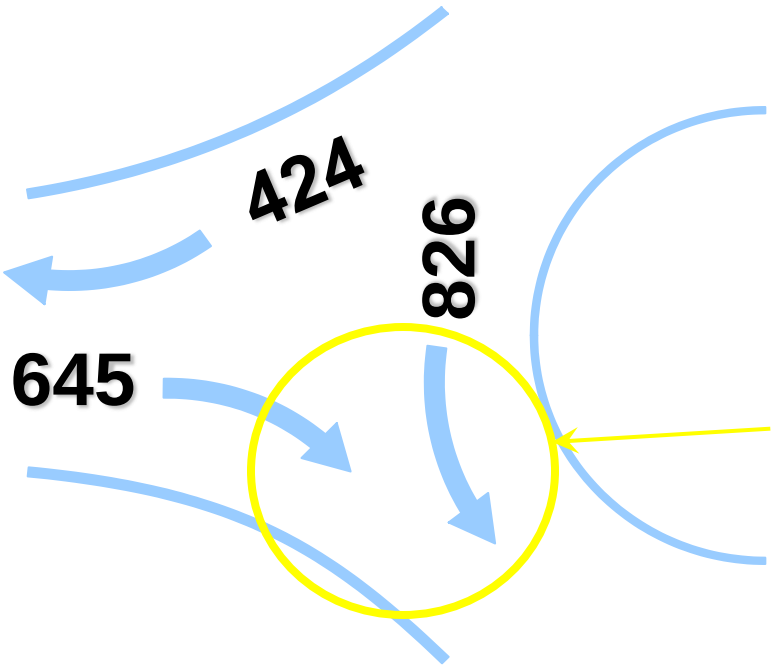
Example: Capacity Calculation

Roundabout volumes → Roundabout category?



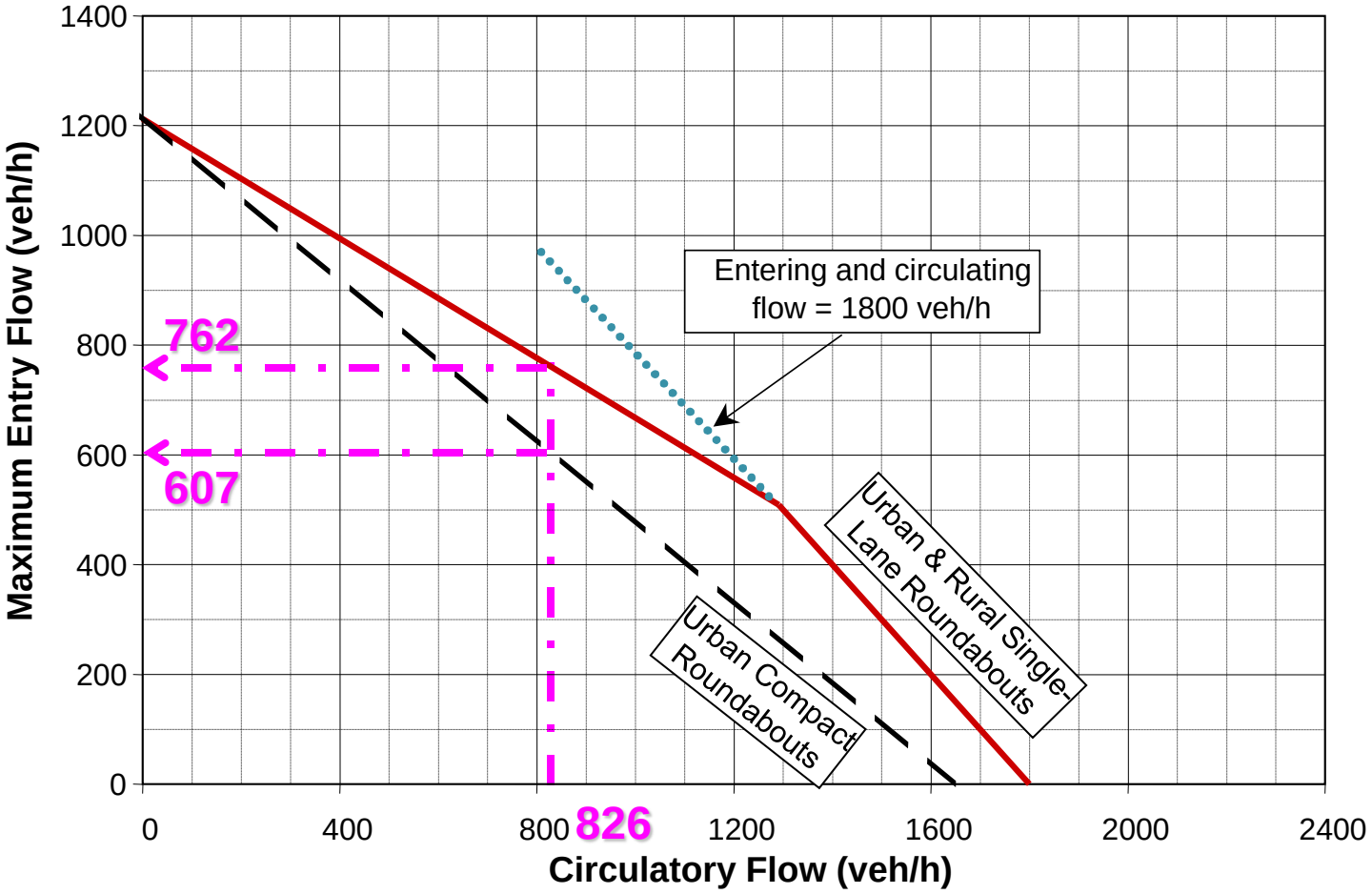


Example: Capacity Calculation



Check capacity of each entry

Example: Capacity check



Example: Capacity Check •

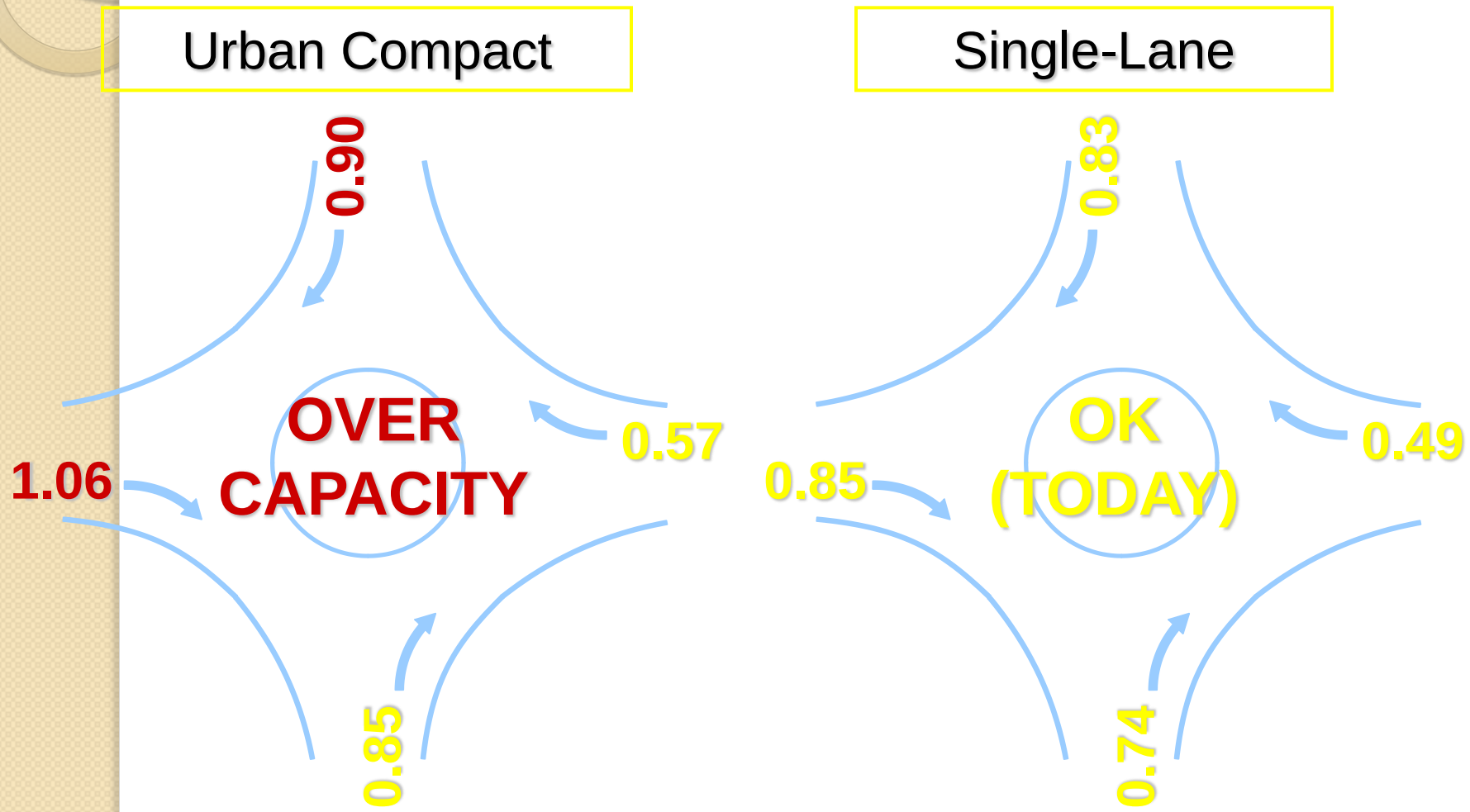
- Entering volume = 645 pce/h
- Capacity of entry:
  - Single-lane: 762 pce/h
  - Urban compact: 607 pce/h
- Volume-to-capacity ratio:
  - Single-lane:
  - Urban compact:

AT 645 / 762 = 0.85

OVER 645 / 607 = 1.06

- Repeat calculation for other approaches

Solution: Capacity Calculation



Operational Analysis

- Capacity
- Performance measures
  - Delay
  - Queues
  - Level of service
- Field evaluation of existing roundabouts

Delay

- Control delay
  - Includes initial deceleration delay, queue move-up time, stopped delay, and final acceleration delay
- Geometric delay
  - Delay experienced by a single vehicle with no conflicting flows
  - Caused by geometric features
- Total delay = Control + Geometric
- Typical measure used: control delay

Control Delay

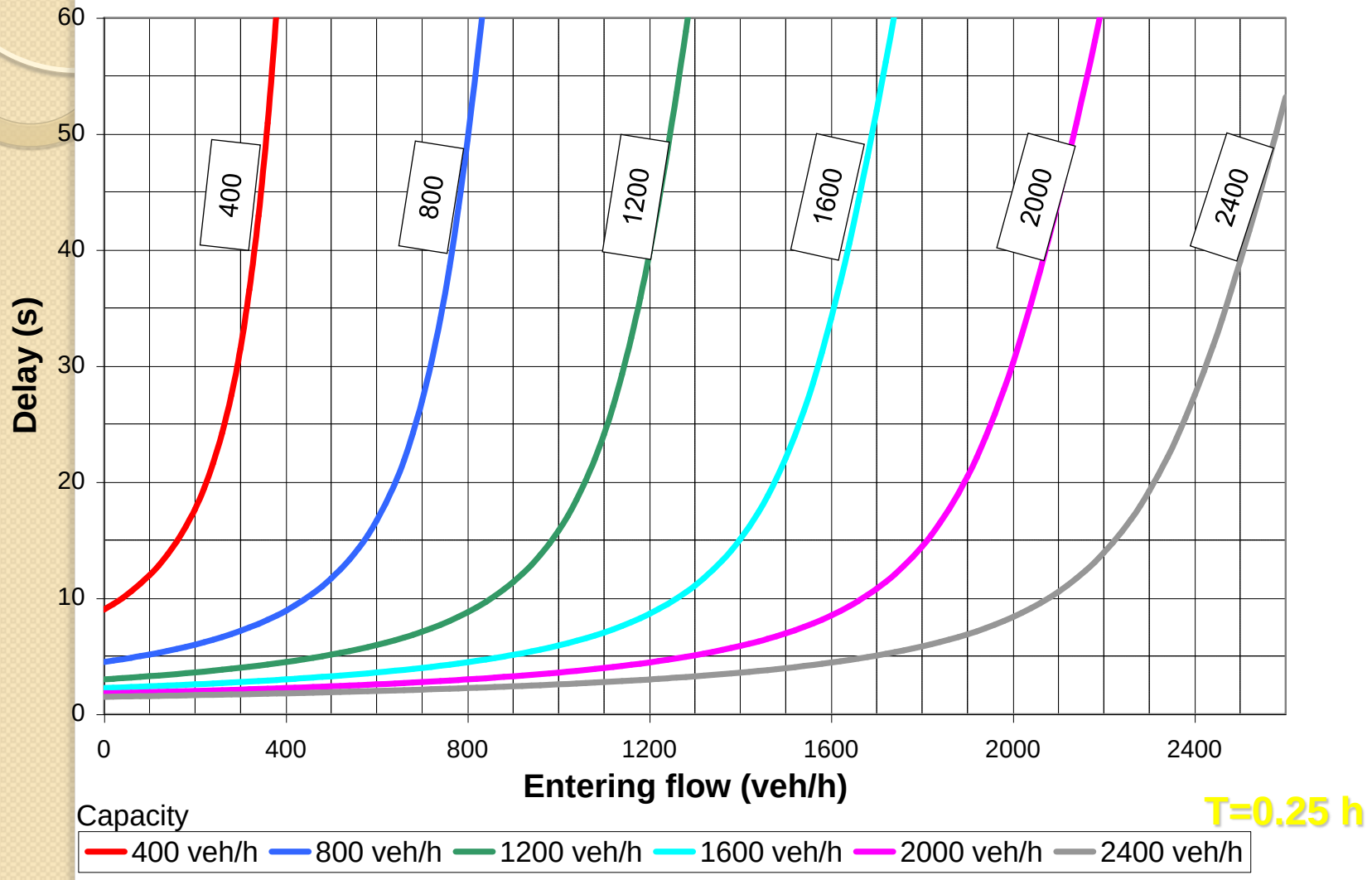
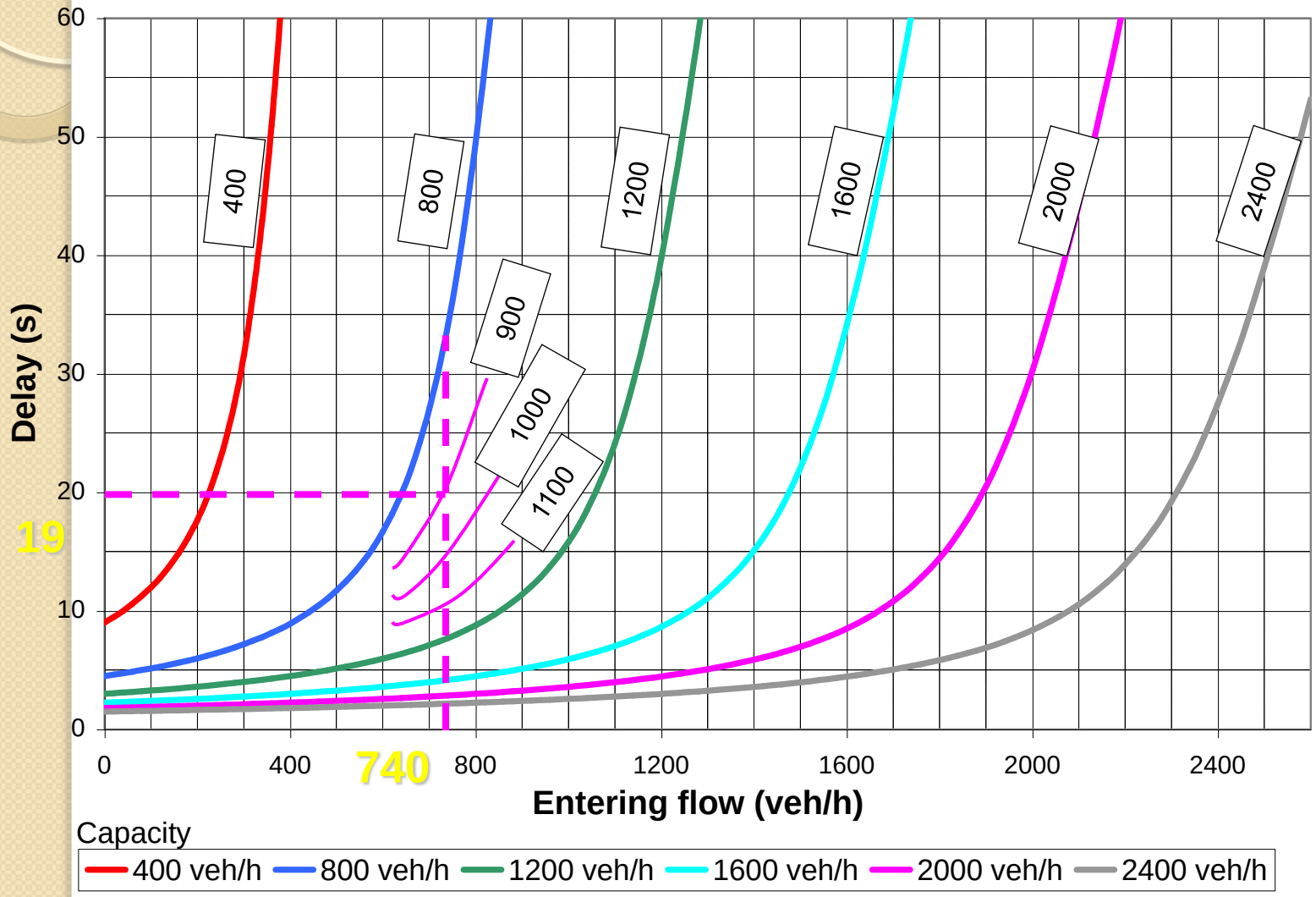


Exhibit 4-9, p. 93

Delay: Example

- Approach with following characteristics:
  - Capacity = 900 veh/h
  - Entering flow = 740 veh/h
  - T = 15 min (0.25 h)
- Delay = ?

Delay: Example



Delay: Example

- Approach with following characteristics:
  - Capacity = 900 veh/h
  - Entering flow = 740 veh/h
  - T = 15 min (0.25 h)
- Delay = 19 s (19.5 s by equation)

Average Delay for the Entire Intersection

- Use for comparison with signalized and AWSC intersections

$$D_{\text{intersection}} = \frac{\sum_i D_i V_i}{\sum_i V_i}$$

where:

$D_{intersection}$ = intersection delay, s/veh

$D_{approach\ i}$ = delay on approach *i*, s/veh

$V_{approach\ i}$ = volume on approach *i*, veh/h

Queue Estimation

- Average queue (50th percentile)
  - Equivalent to vehicle-hours of delay per hour on an approach
  - Useful for comparing performance with other intersection forms
- Maximum queue (95th percentile)
  - Used for design purposes
  - Most common queue parameter

50th Percentile (Average) Queue Estimation

Little's rule:

$$L = v * d / 3600$$

where:

L = queue length, veh

v = entry flow, veh/h

d = average delay, s/veh

95th Percentile Queue Estimation

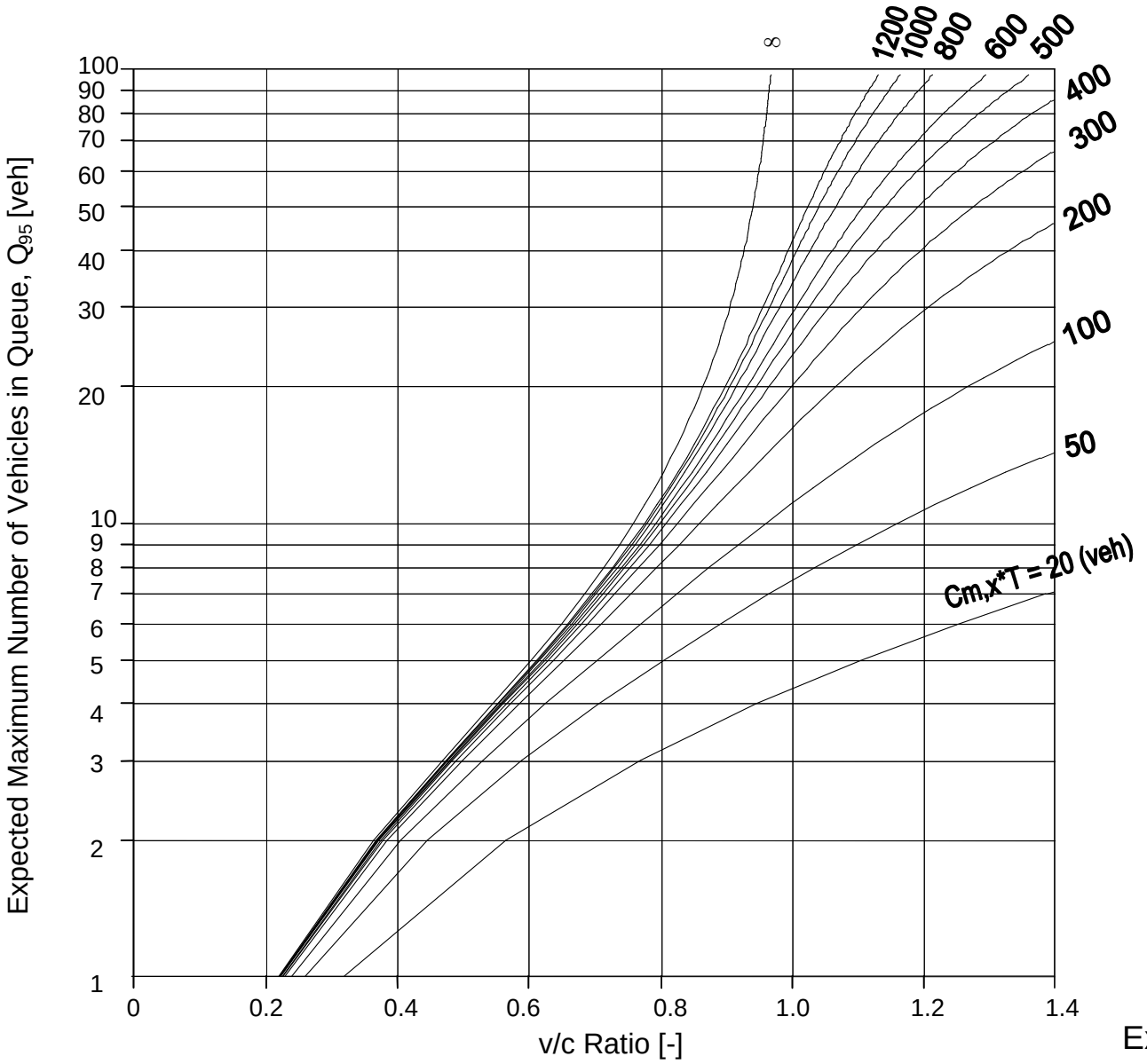
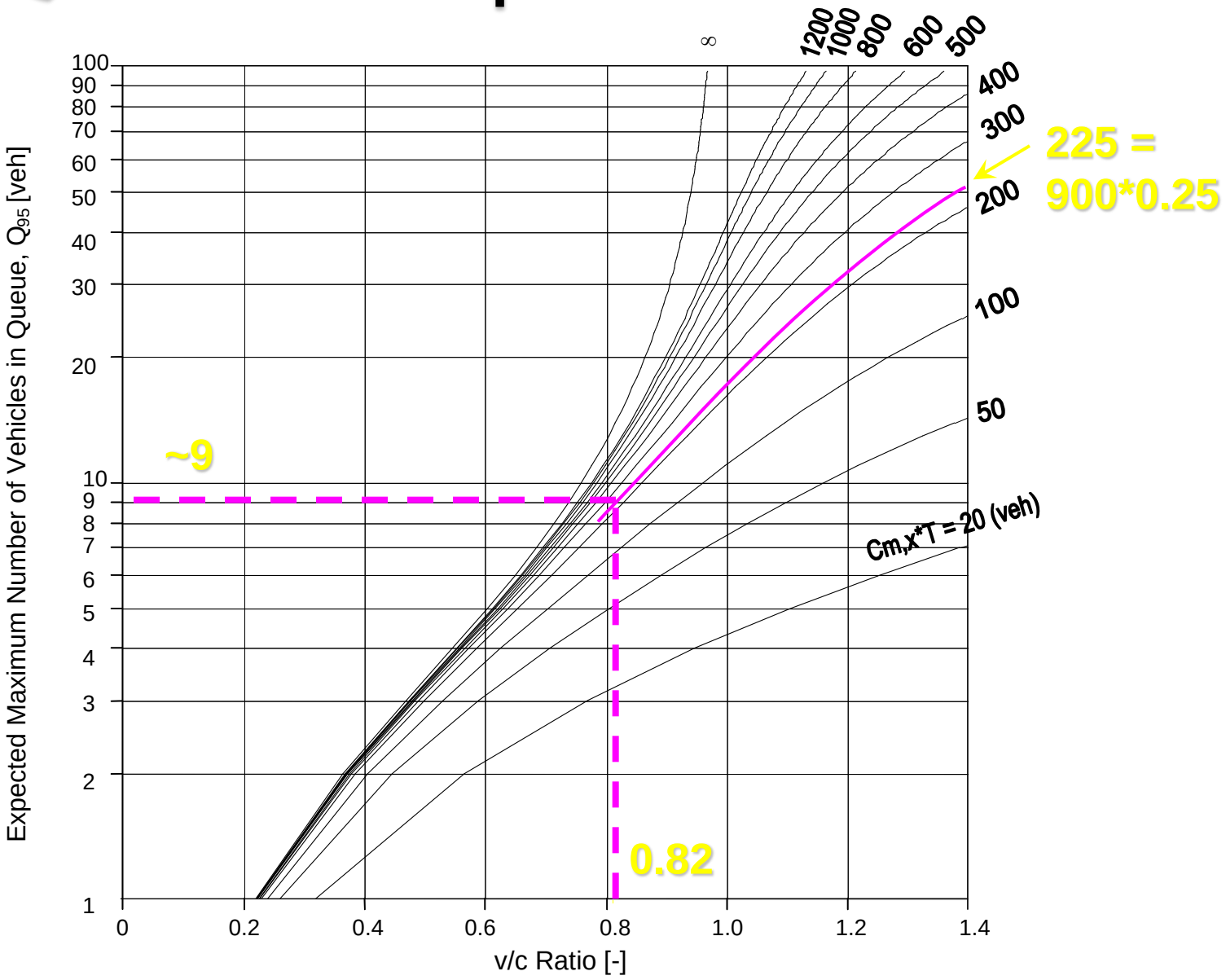


Exhibit 4-10, p. 95

Queue: Example

- Same approach as for delay example:
  - Capacity = 900 veh/h
  - Entering flow = 740 veh/h (v/c = 0.82)
  - T = 15 min (0.25 h)
- Design (95th %ile) Queue = ?

Queue: Example



Queue: Example

- Same approach as for delay example:
  - Capacity = 900 veh/h
  - Entering flow = 740 veh/h (v/c = 0.82)
  - T = 15 min (0.25 h)
- 95^{th} %ile Queue = 9-10 veh (9.4 by eqn)
- Design Queue = 10 veh

Level of Service

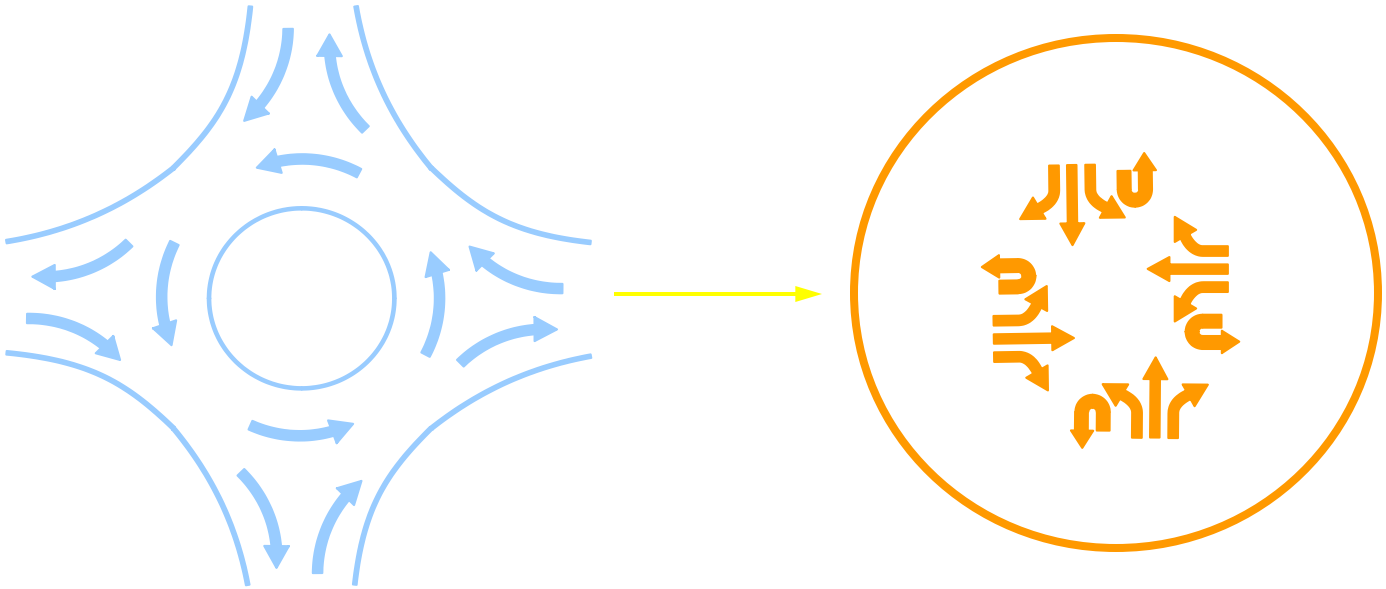
- Level of service not currently defined for roundabouts in HCM
- The dilemma:
  - Delay for all movements, critical approach, or critical movement?
  - What thresholds between letter grades?
- As substitute, report degree of saturation and delay

Operational Analysis

- Capacity
- Performance measures
- Field evaluation of existing roundabouts

Field Evaluation of Existing Roundabouts

- Three methods
  - Direct turning movement count
  - Hose counts + O-D sample
  - Hose counts + right turns



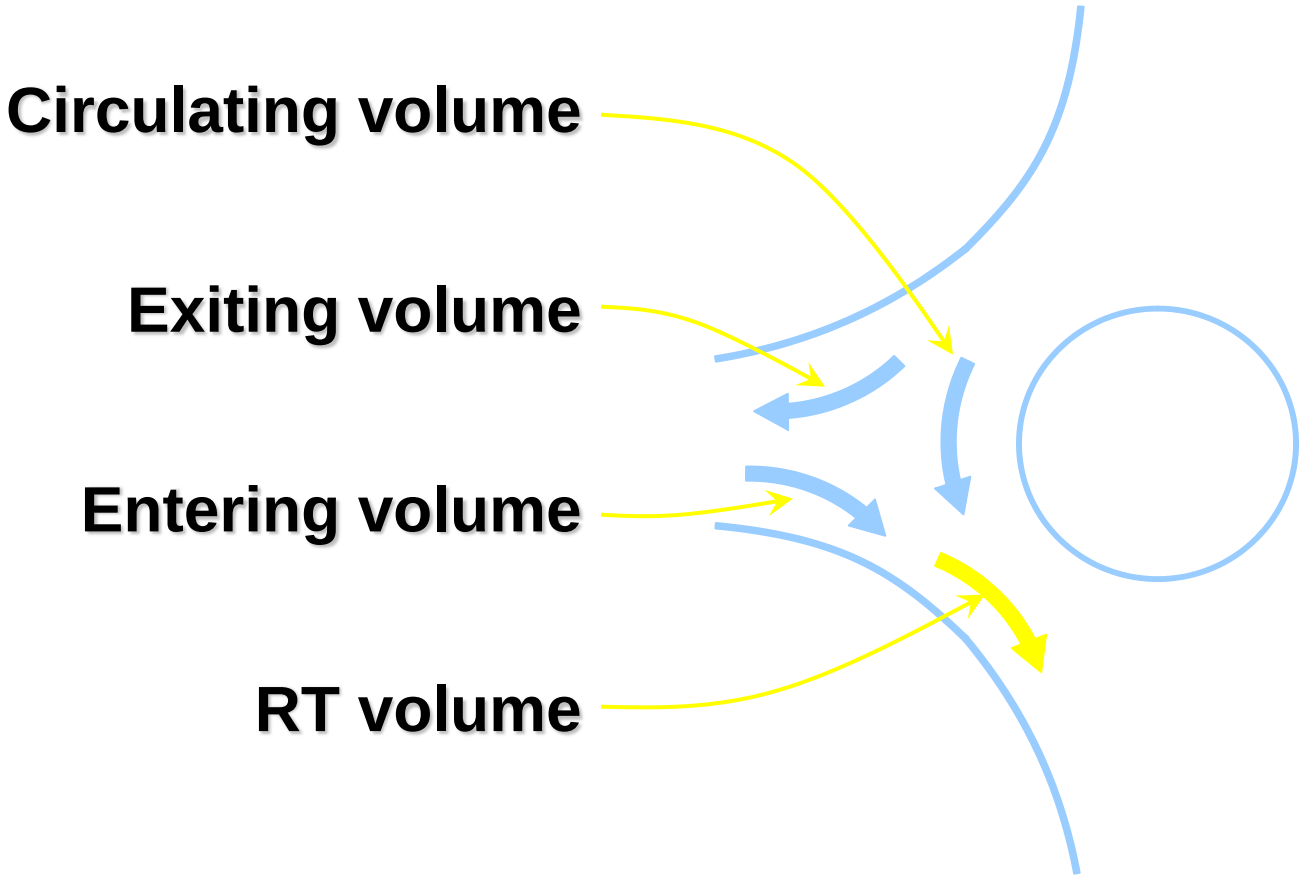
Method 1: Direct Turning Movement Count

- Requires person to track vehicles traveling through the roundabout
- Only feasible at small roundabouts with low volumes
- Video analysis

Method 2: Hose Counts + O-D Sample

- Hose counts across entries, exits, and circulatory roadway
- Origin-destination sample by matching license plates or other method
- Need to check that inbound and outbound flows balance at each junction
- O-D survey is labor intensive

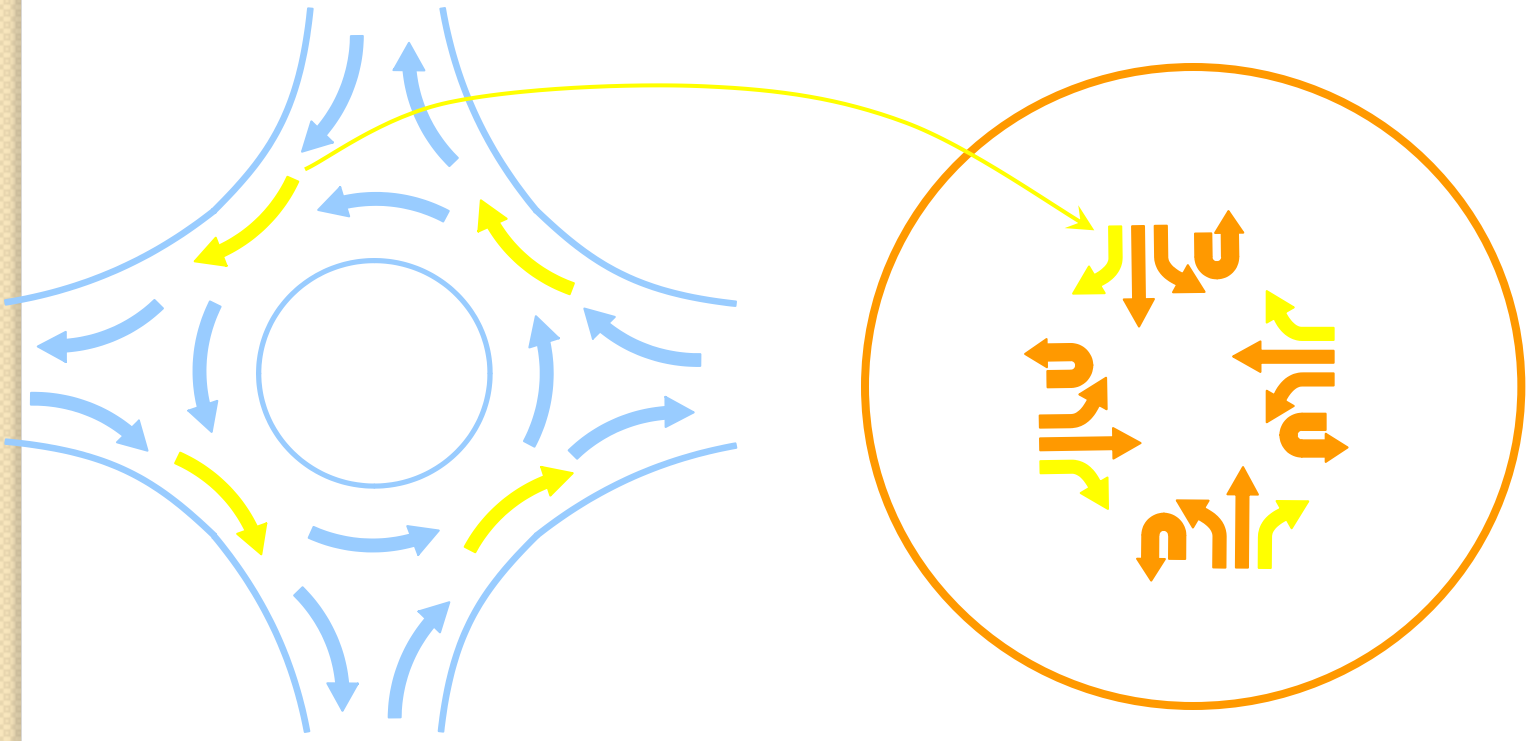
Method 3: Hose Counts + Right Turns



- Method assumes negligible U-turns

Step 1: Measure Right Turns

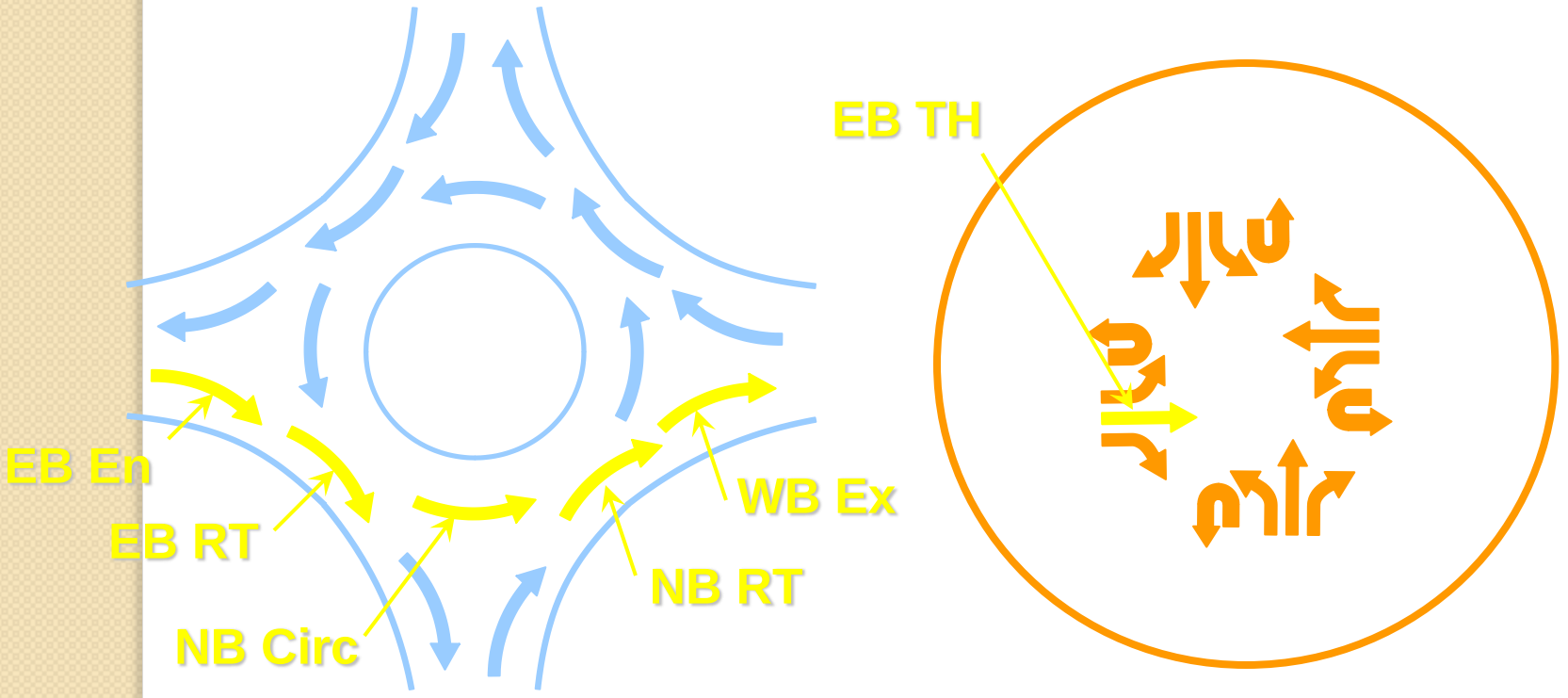
Right turns: Need to be collected in field



Step 2: Calculate Through Movements

Through movements:

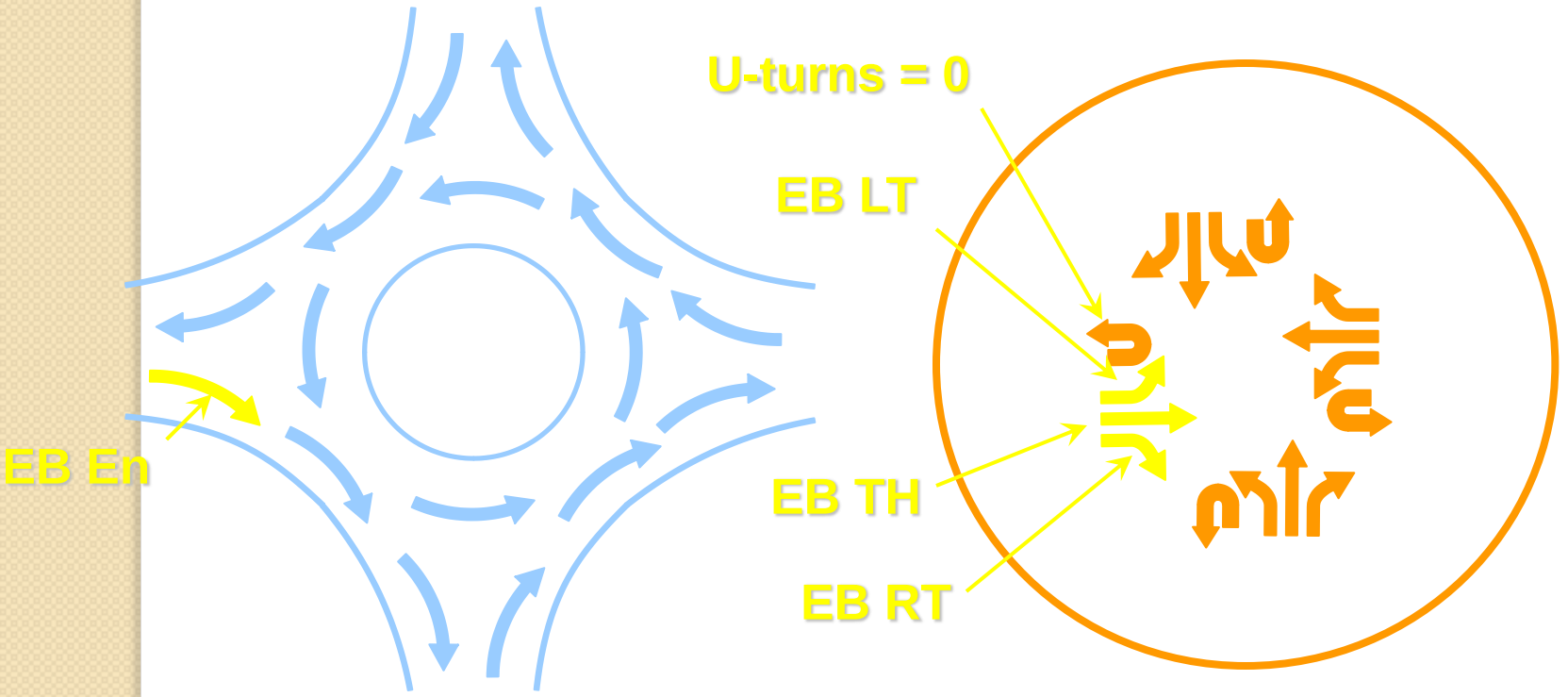
EB TH = EB En + WB Ex - (EB RT + NB Circ + NB RT)



Step 3: Calculate Left Turns

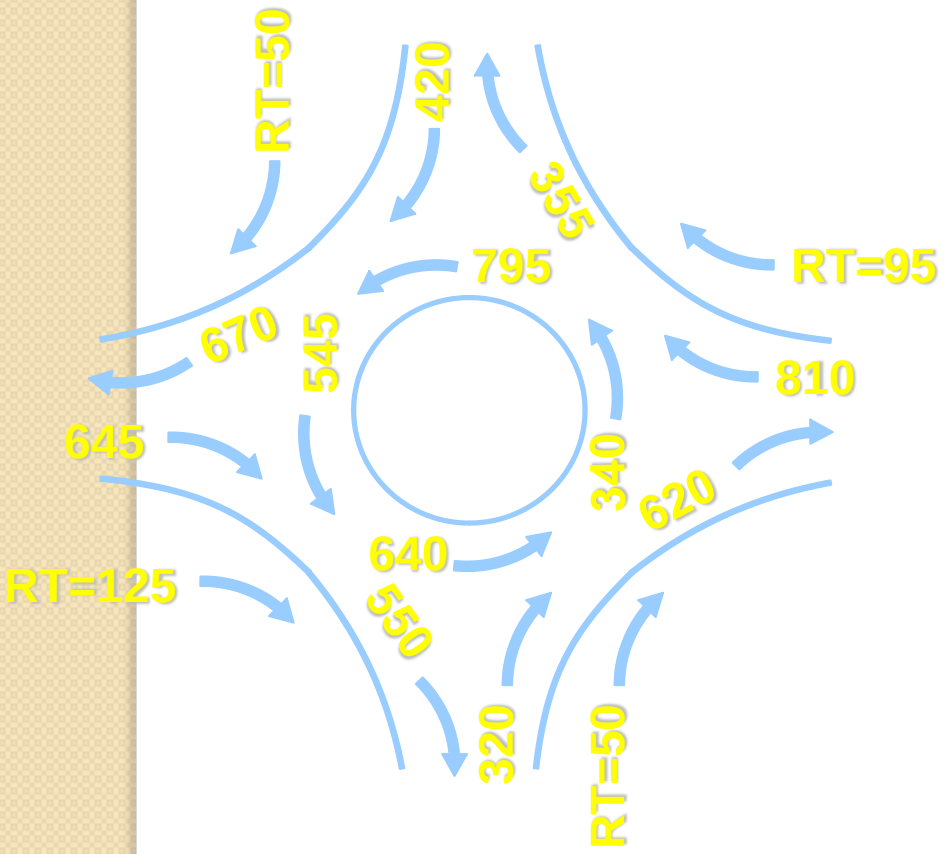
Left turns:

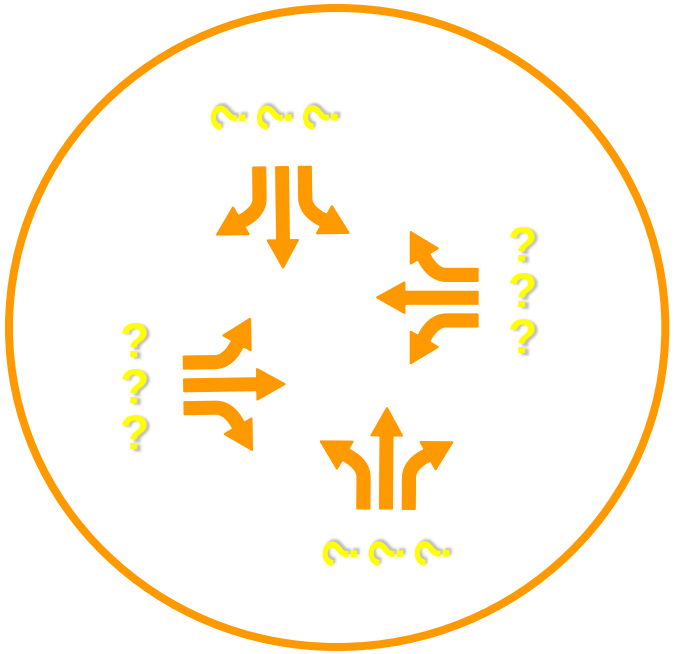
EB LT = EB En - (EB TH + EB RT)



Example: Existing Roundabout

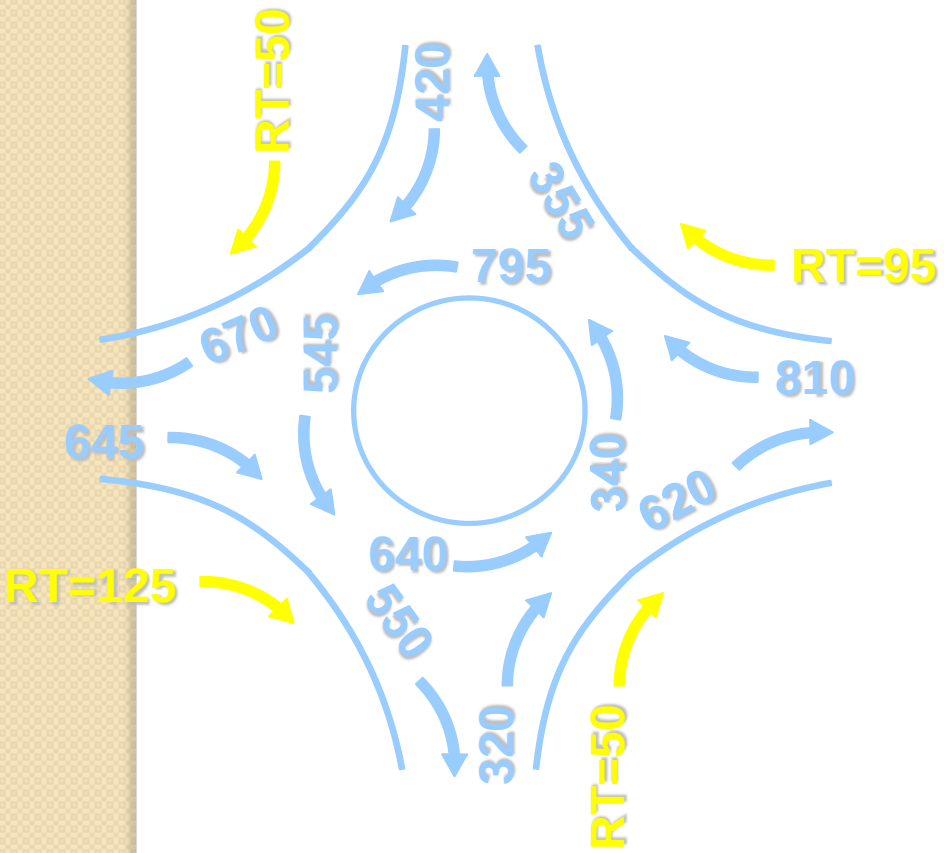
Roundabout volumes → **Turning movements**

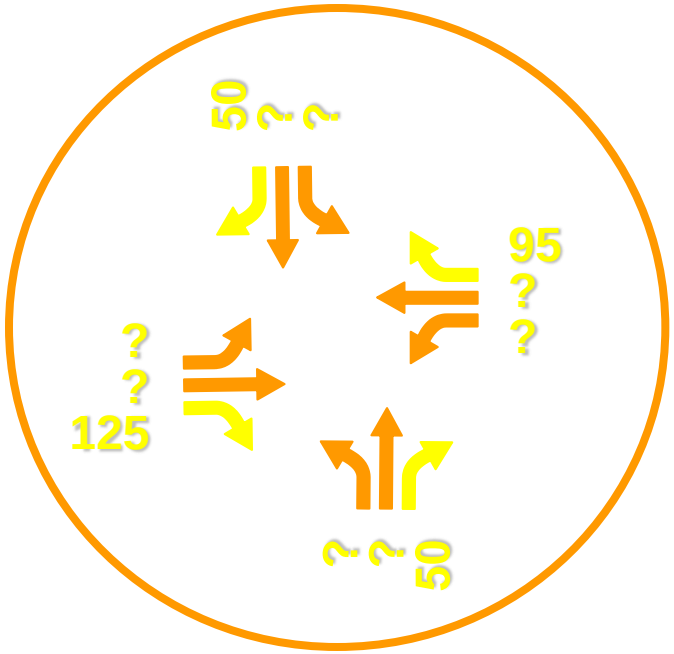




Step 1: Measure Right Turns

Right turns: Need to be collected in field



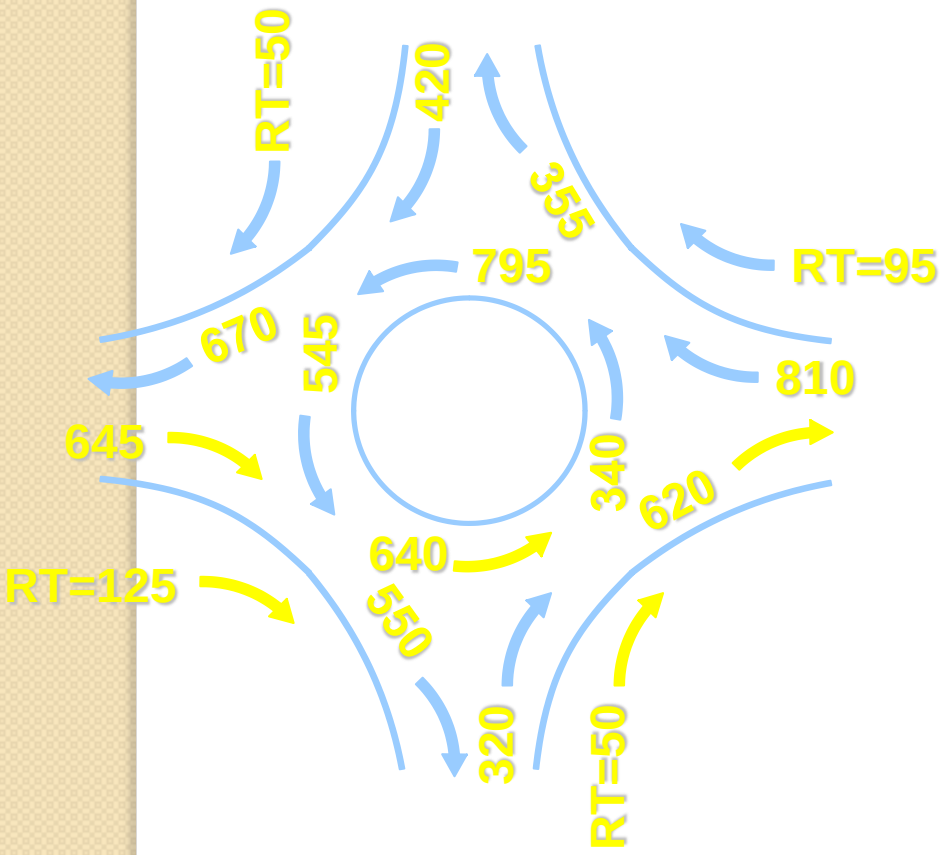


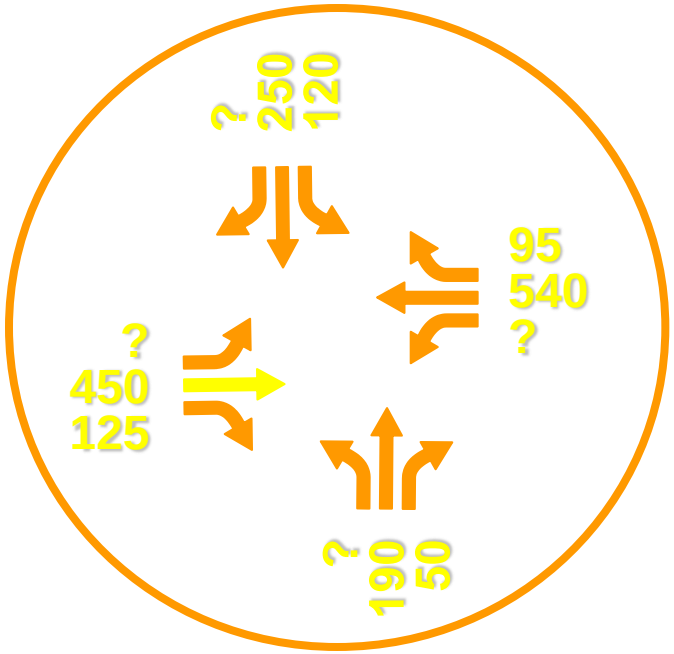
Step 2: Calculate Through Movements

Through movements:

EB TH = EB En + WB Ex - (EB RT + NB Circ + NB RT)

= 645 + 620 – (125 + 640 + 50) = 450

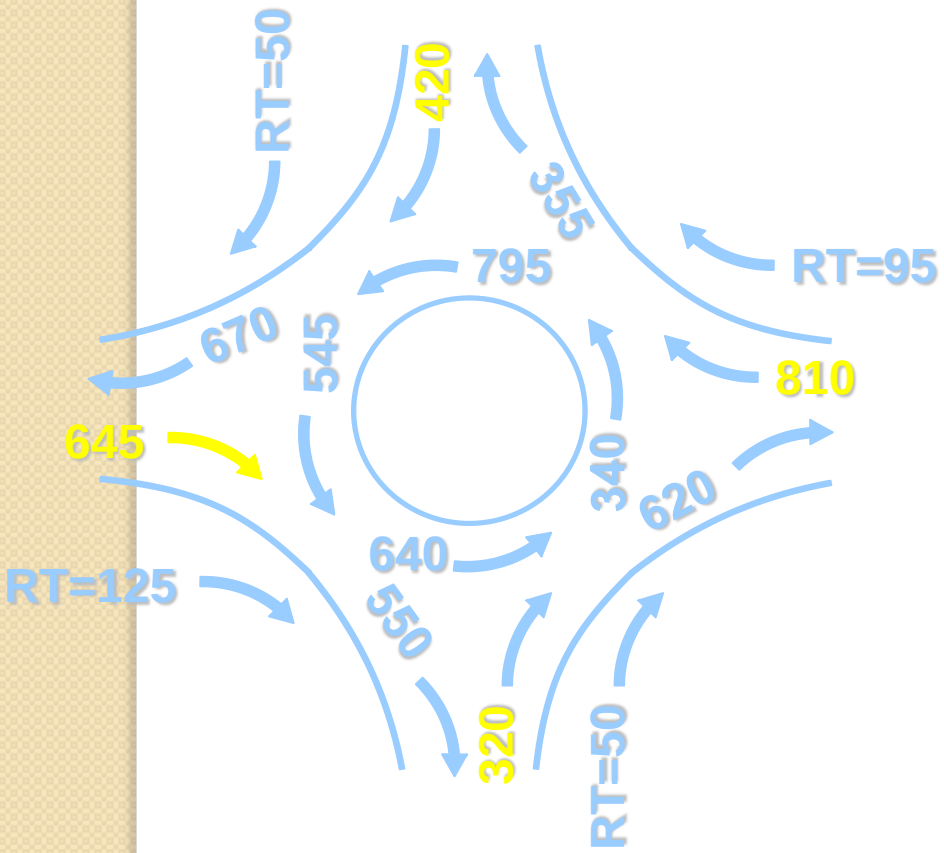


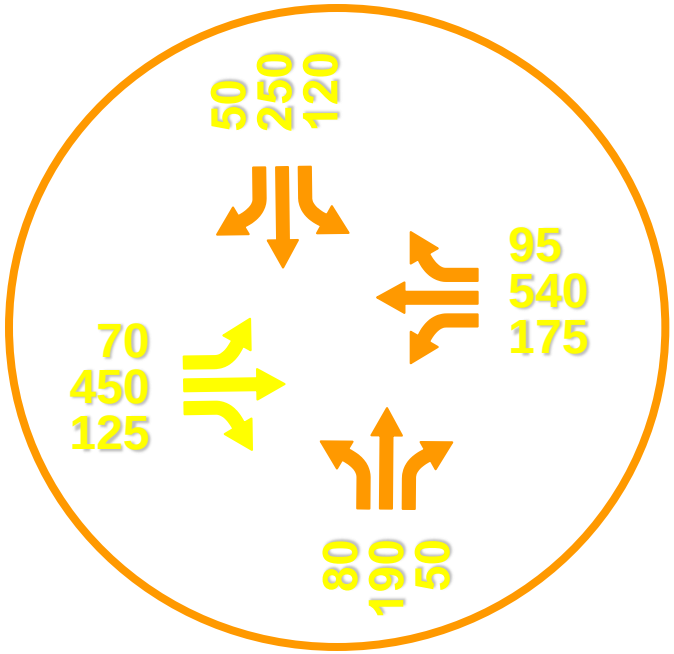


Step 3: Calculate Left Turns

Left turns:

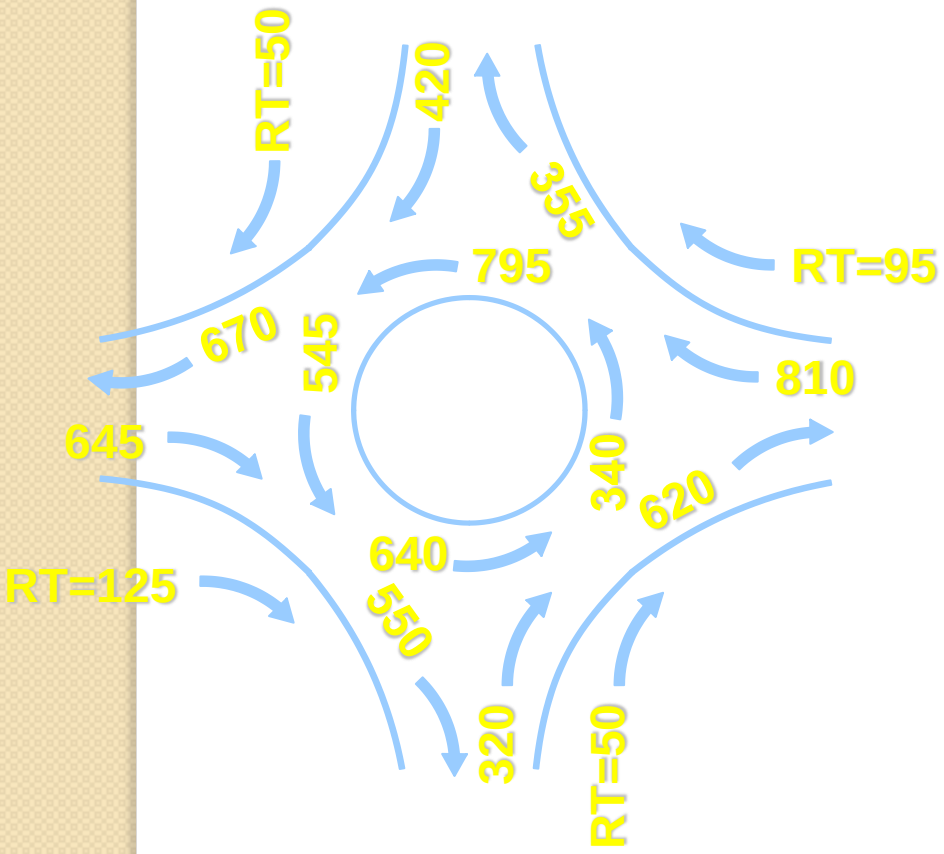
EB LT = EB En - (EB TH + EB RT)
= 645 – (450 + 125) = 70

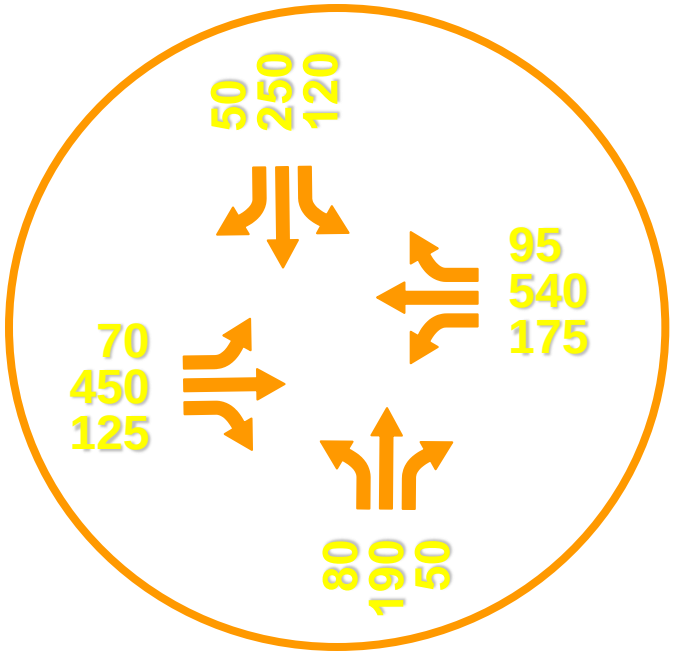




Solution: Existing Roundabout

Roundabout volumes → **Turning movements**





Other Field Evaluation

- Delays and queues can be measured directly using standard techniques
- Good for before-after studies

Conclusion

- Operational analysis
  - Capacity
  - Delay
  - Queuing
- Conversion of turning movements to roundabout volumes and vice versa
- Field evaluation of completed roundabouts good for before-after studies