



**Università degli Studi di Trieste**  
**Dipartimento di Ingegneria e Architettura**  
**Laurea Magistrale: Ingegneria Civile**  
**Corso: Progettazione Funzionale delle Strade (492MI-2)**



## **Lezione 04: Rotatorie e zone di scambio**

**Roberto Roberti**

**Tel.: 040 558 3588**

**E-mail: roberto.roberti@dia.units.it**



**Anno accademico 2024/2025**

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# Obiettivi e Sommario

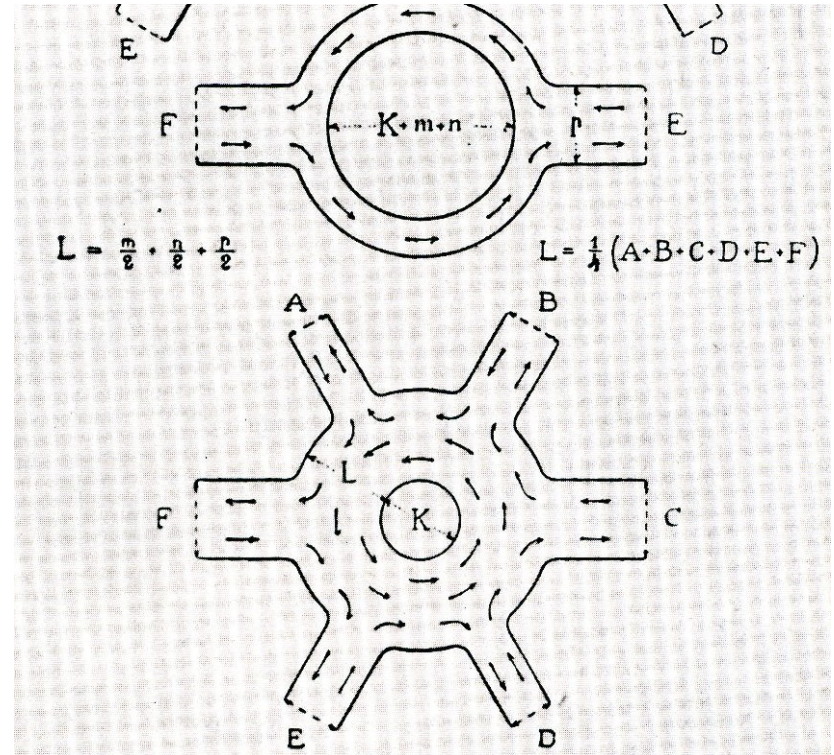
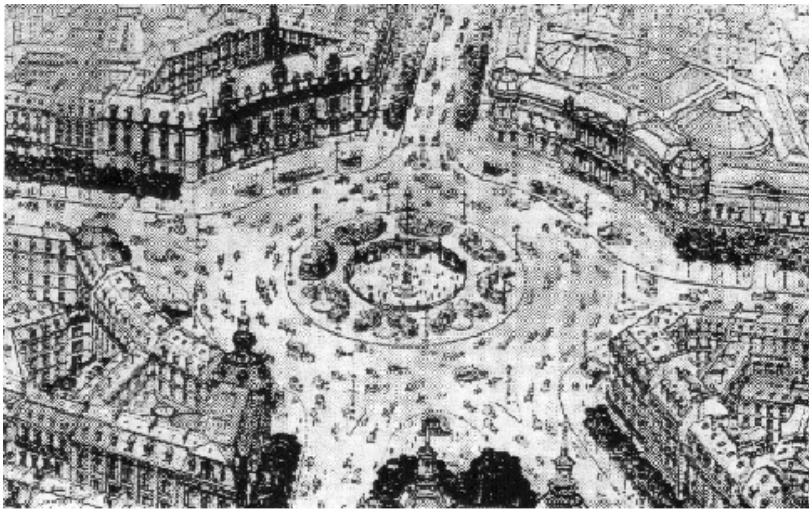
## **Obiettivi Lezione 04:**

- **Progettazione geometrica e funzionale delle rotatorie e dei tronchi di scambio.**

## **Sommario Lezione 04:**

- **Cenni storici sulle rotatorie;**
- **Tipi di rotatorie;**
- **Classificazione delle rotatorie;**
- **Vantaggi e svantaggi delle rotatorie;**
- **Sicurezza nelle rotatorie;**
- **Caratteristiche geometriche delle rotatorie;**
- **Capacità delle rotatorie;**
- **Zone di scambio.**

# Cenni storici sulle rotatorie (1)



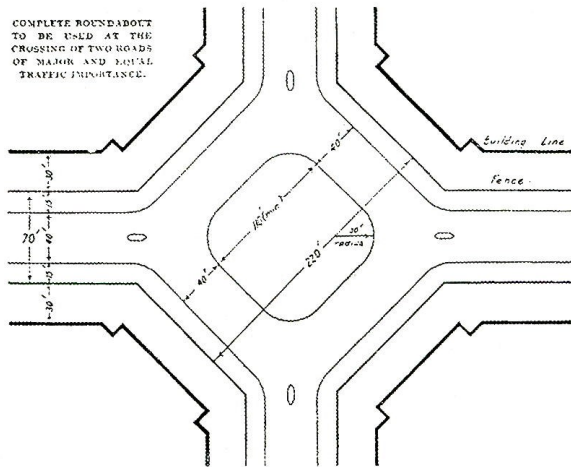
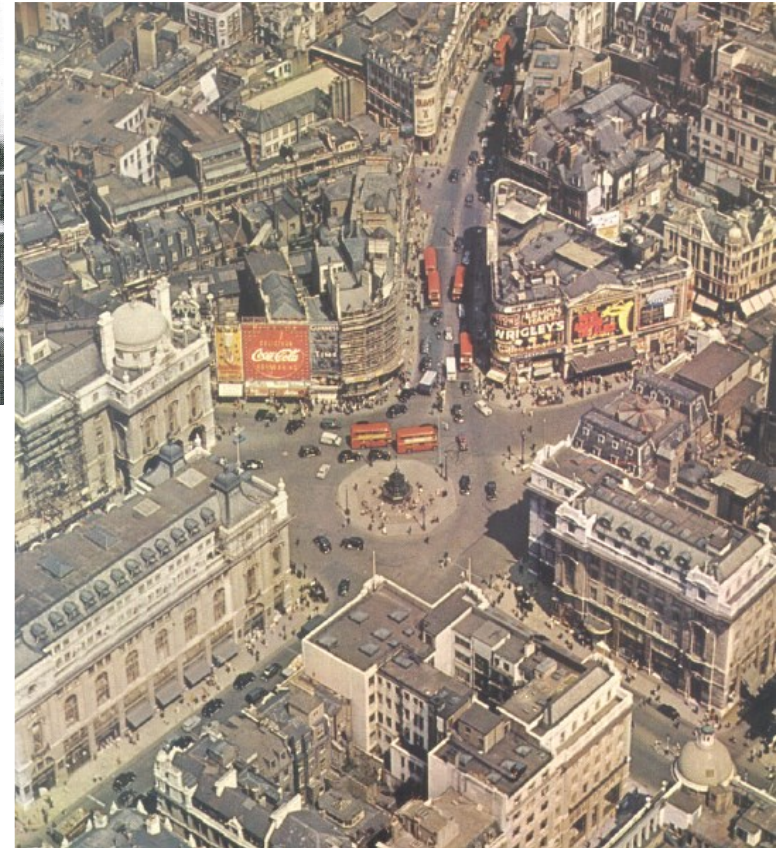
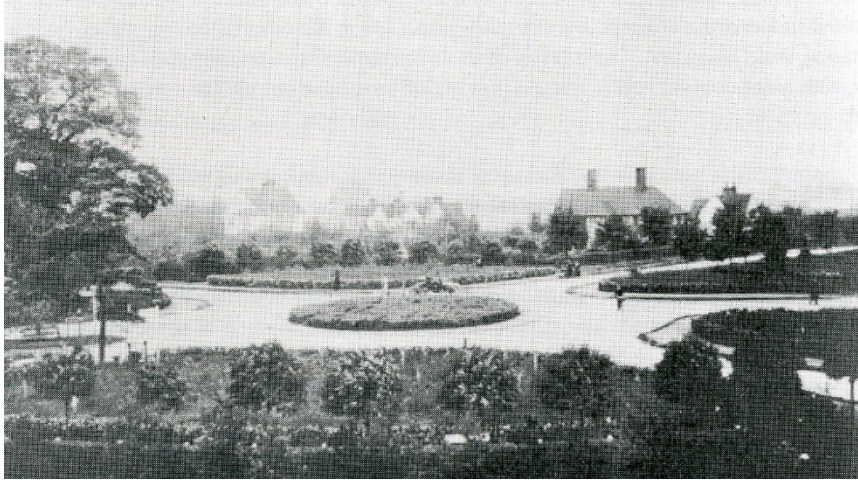


## Cenni storici sulle rotatorie (2)



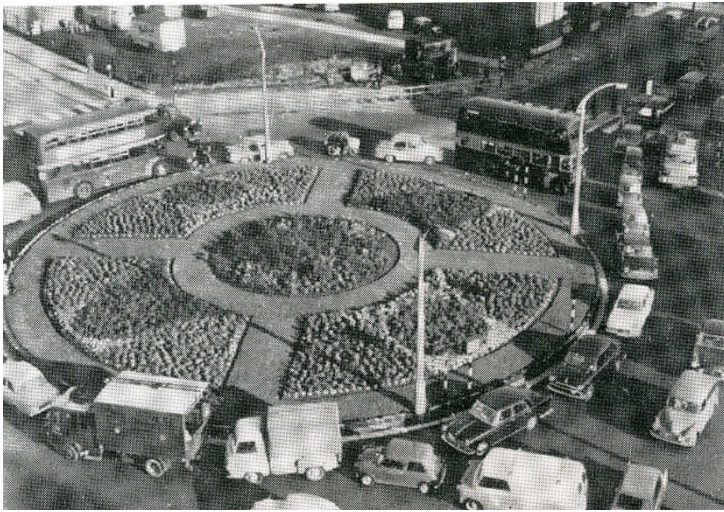
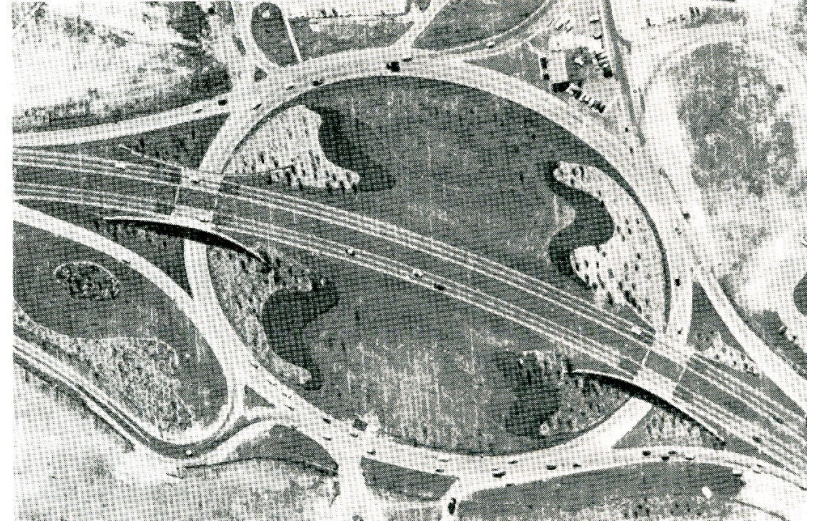
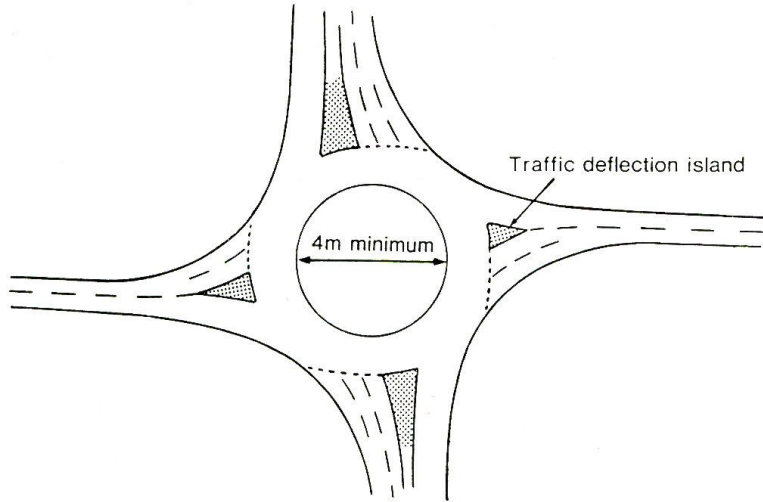


# Cenni storici sulle rotatorie (3)





# Cenni storici sulle rotatorie (4)





# Definizione di rotatoria

Intersezione a raso costituita da un anello, in cui confluiscono i bracci dell'intersezione, che viene percorso a senso unico in direzione antioraria.

Un'intersezione stradale risolta a rotatoria va accompagnata lungo i rami di approccio da idonea segnaletica, se necessario anche integrativa rispetto a quella di preavviso, e da eventuali ulteriori strumenti di regolazione della velocità.



Figura II 27 Art. 96

## CIRCOLAZIONE ROTATORIA

Presegnala sulle strade extraurbane una intersezione regolata con circolazione rotatoria.

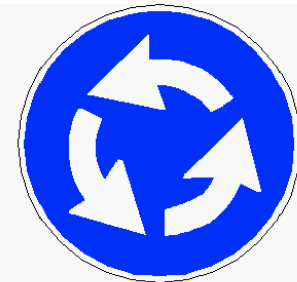


Figura II 84 Art. 122

## ROTATORIA

Indica la presenza di una intersezione, un'area, una piazza, ecc. nella quale la circolazione è regolata a rotatoria secondo il senso indicato dalle frecce.

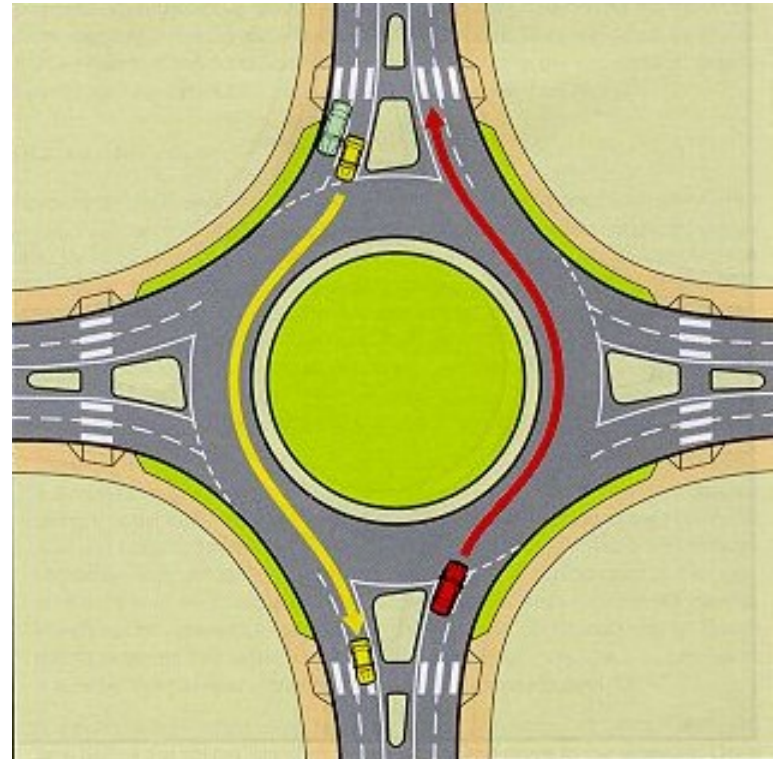
# Caratteristiche delle rotatorie

Isola centrale inaccessibile circondata da un anello percorso dal traffico proveniente da più entrate

Circolazione nell'anello a senso unico antiorario **non necessariamente** con diritto di precedenza

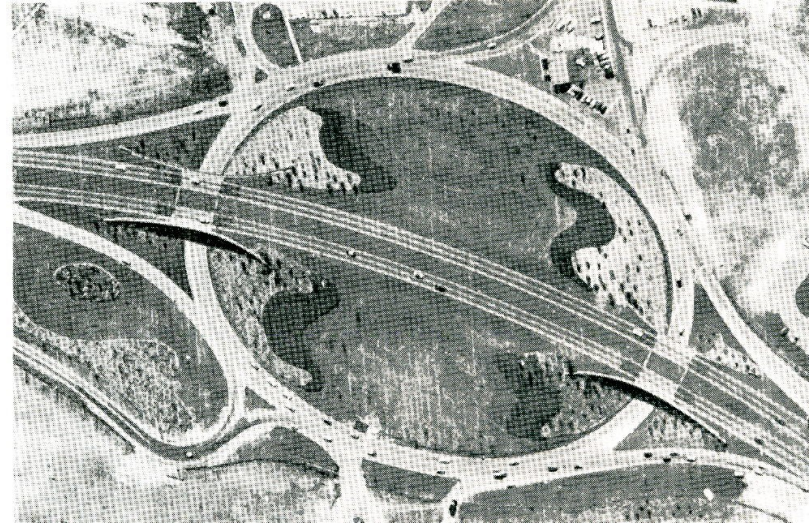
Riduzione di velocità imposta dalla deflessione delle traiettorie

La regolazione della circolazione è affidata all'utente con il criterio della precedenza **non necessariamente** sull'anello





# Tipi di rotatorie

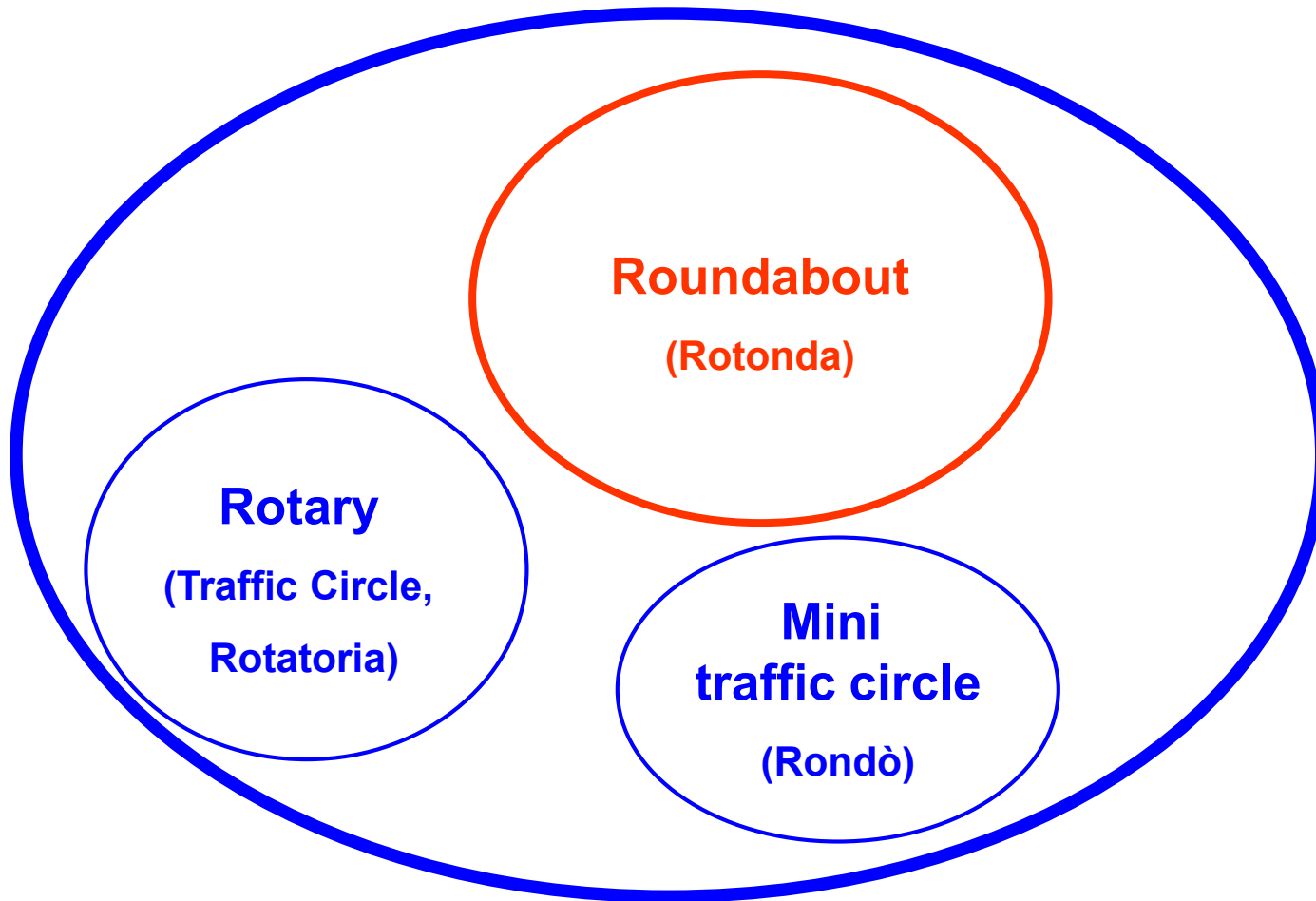


Traffic circle used in residential area to calm traffic



Hollywood Roundabout, MD

# Rotatorie, rotonde e .. (1)





# Rotatorie, rotonde e .. (2)



**Table S.1: Distinguishing Features of Roundabouts and Traffic Circles**

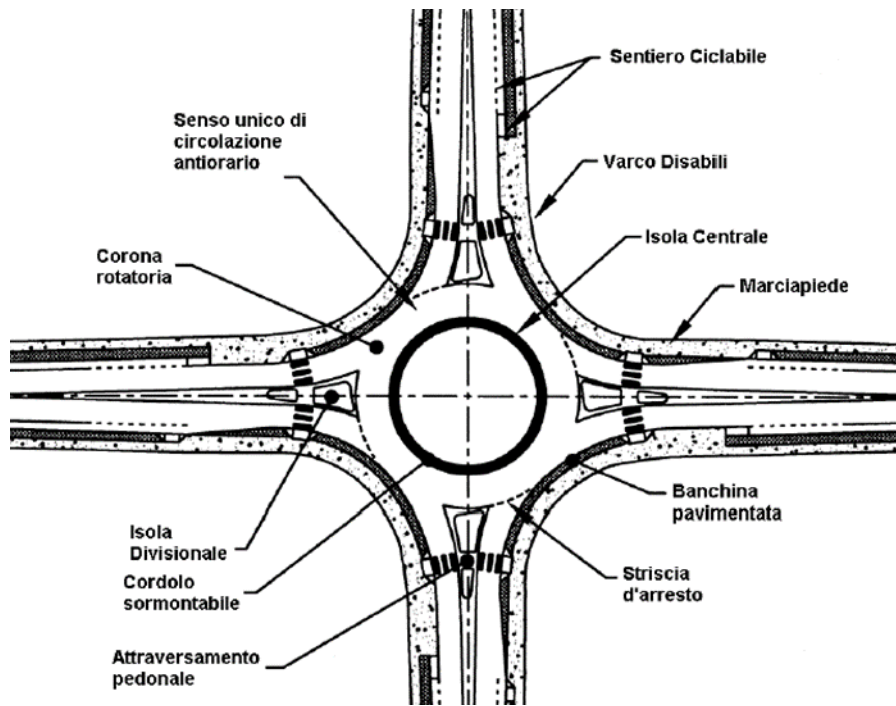
|                             | <b>Modern Roundabout</b>   | <b>Traffic Circle</b>  |
|-----------------------------|--|--|
| Control at Entry            | Yield sign for entering vehicles.  | Stop, signal, or give priority to entering vehicles.   |
| Operational Characteristics | Vehicles in the roundabout will have a priority over the entering vehicle. | Allow weaving areas to resolve the conflicted movement.  |
| Deflection                  | Use deflection to control the low speed operation through roundabout.      | Some large traffic circles provide straight path for major movement with higher speed.                 |
| Parking                     | No parking is allowed on the circulating roadway.                          | Some larger traffic circles permit parking within the circulating roadway.                             |
| Pedestrian Crossing         | No pedestrian activities take place on the central island.                 | Some larger traffic circles provide for pedestrian crossing to, and activities on, the central island. |
| Turning Movement            | All vehicles circulate around the central island.                          | Mini-traffic circles, left-turning vehicles are expected to pass to the left of the central island.    |
| Splitter Island             | Required.  | Optional.  |

## Rotatorie, rotonde e .. (3)





# Classificazione delle rotatorie (1)



Si considerano tre tipologie fondamentali di rotatorie in base al diametro della circonferenza esterna (limite della corona rotatoria):

- rotatorie **CONVENZIONALI** con diametro esterno compreso tra 40 e 50 m;
- rotatorie **COMPATTE** con diametro esterno compreso tra 25 e 40 m;
- **MINI** rotatorie con diametro esterno compreso tra 14 e 25 m.

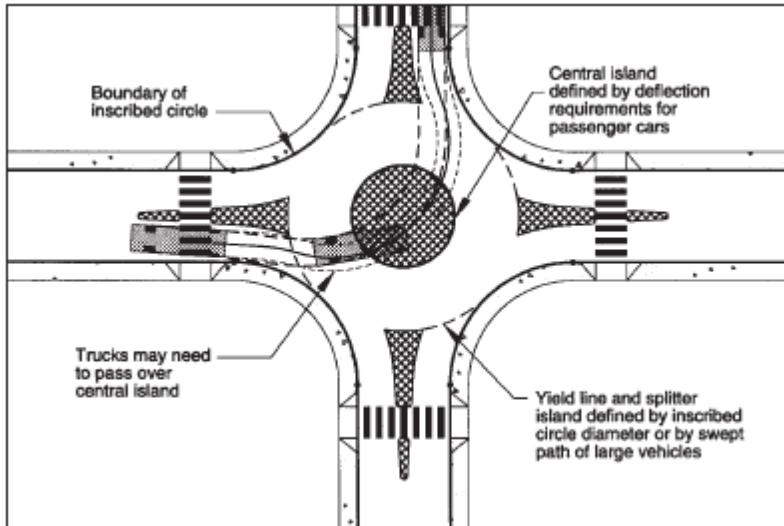
Per sistemazioni con "circolazione rotatoria", che non rientrano nelle tipologie su esposte, il dimensionamento e la composizione geometrica debbono essere definiti con il principio dei tronchi di scambio tra due bracci contigui. In questi casi le immissioni devono essere organizzate con appositi dispositivi.

# Classificazione delle rotatorie (2)

| <b>Design Element</b>                                       | <b>Mini-Roundabout</b>                      | <b>Urban Compact</b>       | <b>Urban Single-Lane</b>   | <b>Urban Double-Lane</b>      | <b>Rural Single-Lane</b>                | <b>Rural Double-Lane</b>                |
|---|---|----------------------------|----------------------------|-------------------------------|---|---|
| Recommended maximum entry design speed                      | 25 km/h (15 mph)                            | 25 km/h (15 mph)           | 35 km/h (20 mph)           | 40 km/h (25 mph)              | 40 km/h (25 mph)                        | 50 km/h (30 mph)                        |
| Maximum number of entering lanes per approach               | 1   | 1                          | 1                          | 2                             | 1                                       | 2                                       |
| Typical inscribed circle diameter <sup>1</sup>              | 13 m to 25 m (45 ft to 80 ft)               | 25 to 30 m (80 to 100 ft)  | 30 to 40 m (100 to 130 ft) | 45 to 55 m (150 to 180 ft)    | 35 to 40 m (115 to 130 ft)              | 55 to 60 m (180 to 200 ft)              |
| Splitter island treatment                                   | Raised if possible, crosswalk cut if raised | Raised, with crosswalk cut | Raised, with crosswalk cut | Raised, with crosswalk cut    | Raised and extended, with crosswalk cut | Raised and extended, with crosswalk cut |
| Typical daily service volumes on 4-leg roundabout (veh/day) | 10,000                                      | 15,000                     | 20,000                     | Refer to Chapter 4 procedures | 20,000                                  | Refer to Chapter 4 procedures           |

1. Assumes 90-degree entries and no more than four legs.

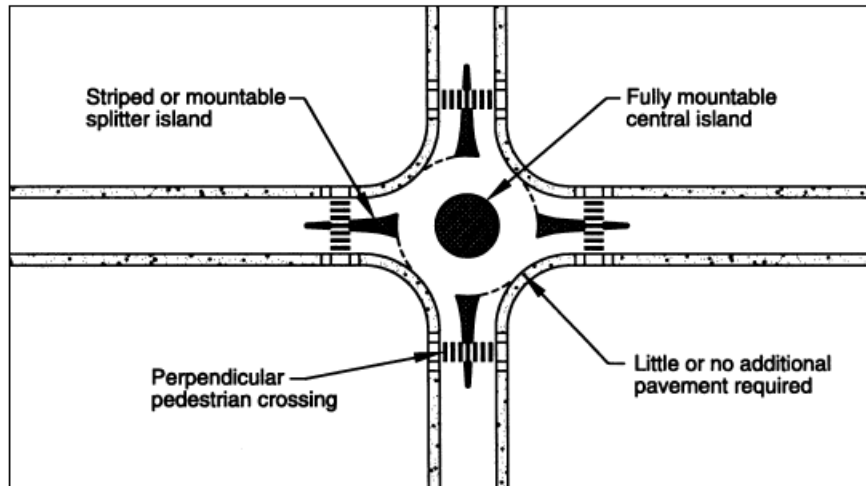
# Mini rotatorie (1)



**Un ulteriore elemento distintivo tra le tre tipologie fondamentali di attrezzatura rotatoria e rappresentato dalla sistemazione dell'isola circolare centrale, che può essere resa in parte transitabile per le manovre dei veicoli pesanti, nel caso di mini-rotatorie con diametro esterno compreso fra 25 e 18 m, mentre lo diventa completamente per quelle con diametro compreso fra 18 e 14 m;**



## Mini rotatorie (2)



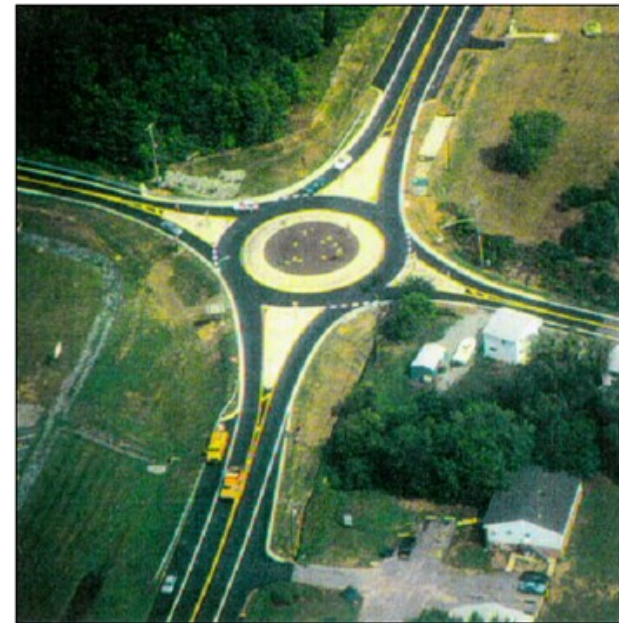
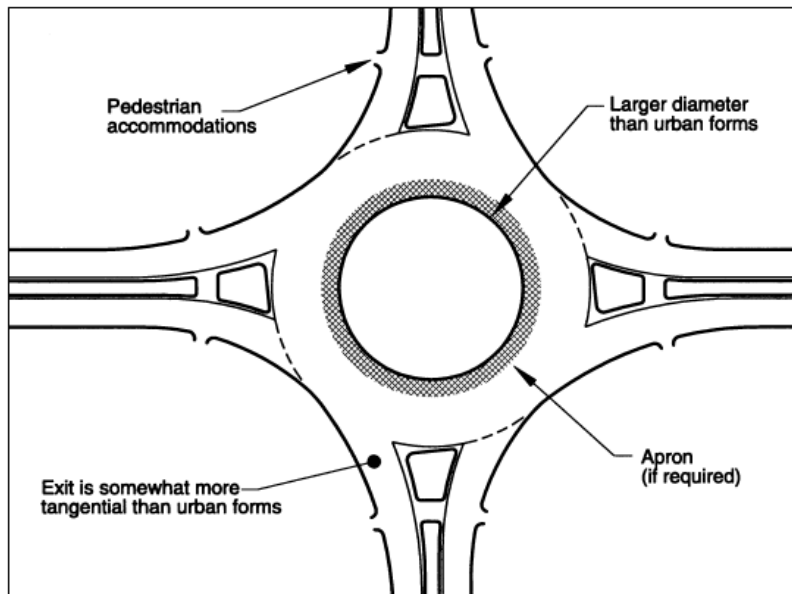
**In base alla classificazione delle intersezioni riportata nel capitolo 3 (delle norma del 2006), in ambito extraurbano l'adozione di mini rotatorie viene limitata agli incroci tipo F/F tra strade locali, .....**

# Rotatorie compatte (1)

..... le rotatorie compatte sono invece caratterizzate da bordure non sormontabili dell'isola centrale.

In ambito extraurbano le rotatorie compatte sono consentite anche per gli incroci tipo C/C, C/F, F/C.

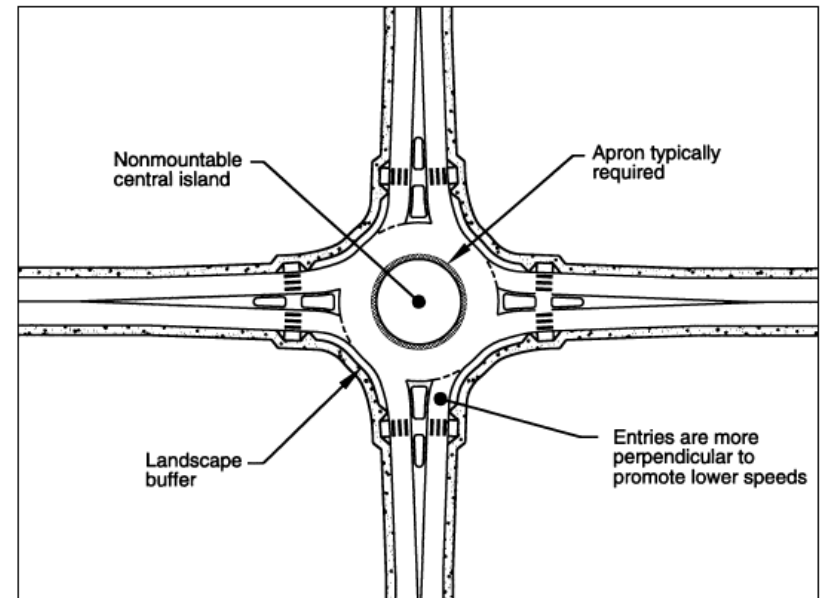
## Rotatorie Extra-urbane Compatte a singola corsia





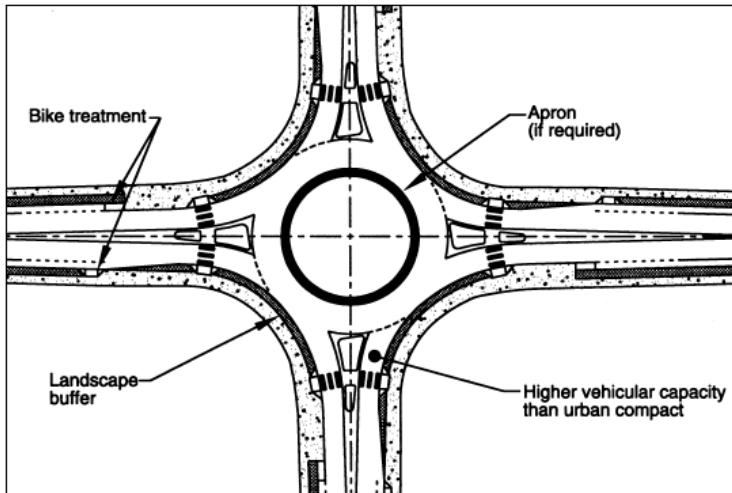
# Rotatorie Compatte (2)

## Rotatorie Urbane Compatte

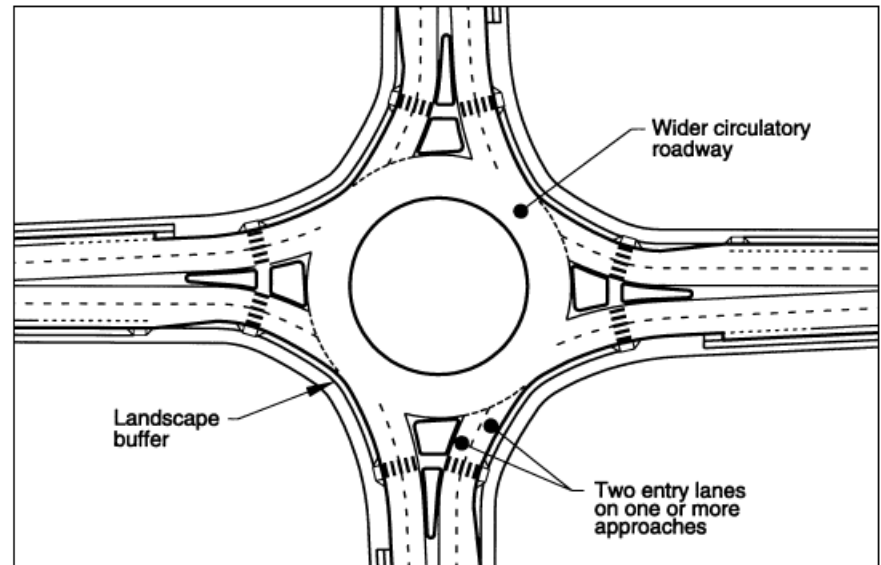


# Rotatorie convenzionali (1)

## Rotatorie Urbane a singola corsia



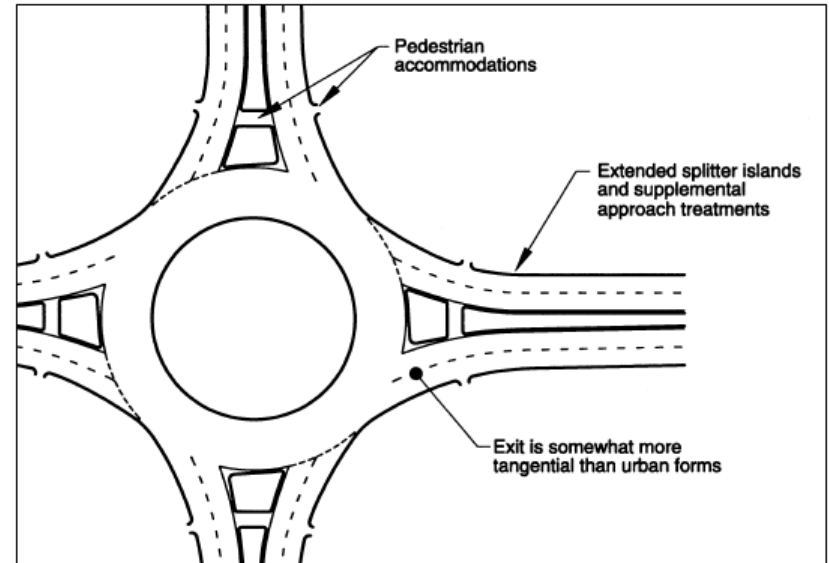
## Rotatorie Urbane a doppia corsia





# Rotatorie convenzionali (2)

## Rotatorie Extra-urbane a doppia corsia



# Vantaggi e svantaggi delle rotatorie (1)

Table S.2: Advantages and Disadvantages Comparison

| Category                   | Advantages  | Disadvantages  |
|----------------------------|---|--|
| Safety                     | <ul style="list-style-type: none"> <li>- There are a reduced number of conflict points compared to uncontrolled intersection.</li> <li>- Lower operational speeds yield less severe and fewer accidents.</li> <li>- Slower speeds because of intersection geometry reduce accidents.</li> </ul>   | <ul style="list-style-type: none"> <li>- Since roundabouts are unfamiliar to the average driver in the US, there is likely to be an initial period where accidents increase.</li> <li>- Signalized intersections can preempt control for emergency vehicles.</li> </ul>  |
| Capacity                   | <ul style="list-style-type: none"> <li>- Traffic <i>yields</i> rather than <i>stops</i>, often resulting in the acceptance of smaller gaps.</li> <li>- For isolated intersections, roundabouts should give higher capacity/lane than signalized intersections due to the omission of lost time (red and yellow) at signalized intersections.</li> </ul>   | <ul style="list-style-type: none"> <li>- Where the coordinated signal network can be used, a signalized intersection will increase the overall capacity of the network.</li> <li>- Signals may be preferred at intersections that periodically operate at higher than designed capacities.</li> </ul>  |
| Delay                      | <ul style="list-style-type: none"> <li>- Overall delay will probably be less than for an equivalent volume signalized intersection (this does not equate to a higher level of service).</li> <li>- During the off-peak, signalized intersections with no retiming produce unnecessary delays to stopped traffic when gaps on the other flow are available.</li> </ul>   | <ul style="list-style-type: none"> <li>- Drivers may not like the geometric delays which force them to divert their cars from straight paths.</li> <li>- When queuing develops, entering drivers tend to force into the circulating streams with shorter gaps. This may increase the delays on other legs and the number of accidents.</li> </ul>  |
| Cost                       | <ul style="list-style-type: none"> <li>- In general, less right-of-way is required.</li> <li>- Maintenance costs of signalized intersections include electricity, maintenance of loops, signal heads, controller, timing plans (roundabout maintenance includes only landscape maintenance, illumination, and occasional sign replacement).</li> <li>- Accident costs are low due to the low number of accidents and severity.</li> </ul> | <ul style="list-style-type: none"> <li>- Construction costs may be higher.</li> <li>- In some locations, roundabouts may require more illumination, increasing costs.</li> </ul>   |
| Pedestrians and Bicyclists | <ul style="list-style-type: none"> <li>- A splitter island provides a refuge for pedestrians that will increase safety.</li> <li>- At low speed and low traffic volume, roundabouts should improve safety for bicyclists.</li> </ul>  | <ul style="list-style-type: none"> <li>- A splitter island may cause difficulty to people using wheelchairs.</li> <li>- Tight dimensions of roundabouts create an uncomfortable feeling to bicyclists.</li> <li>- Longer paths increase travel distances for both pedestrians and bicyclists.</li> <li>- Roundabouts may increase delay for pedestrians seeking acceptable gaps to cross.</li> </ul> |

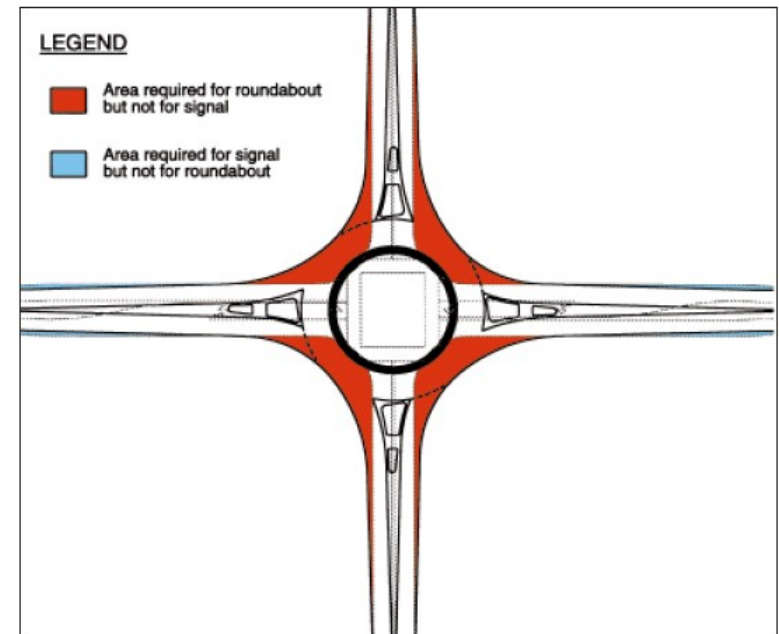


# Vantaggi e svantaggi delle rotatorie (2)

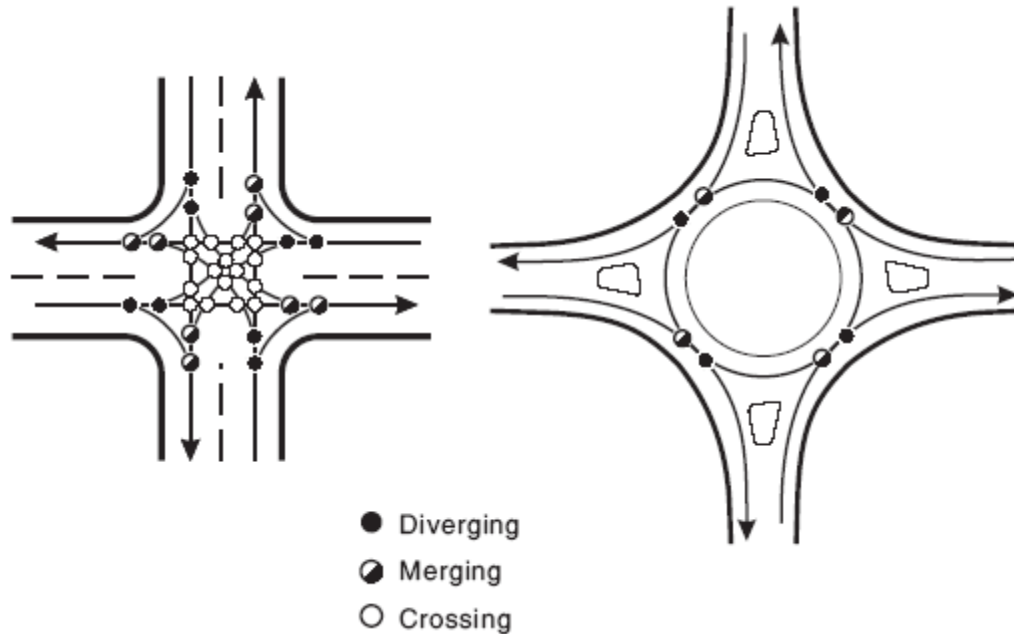
| Type of Roundabout          | Sites | Before Roundabout       |                  |      | Roundabout |     |      | Percent Change <sup>5</sup> |      |      |
|-----------------------------|-------|-------------------------|------------------|------|------------|-----|------|-----------------------------|------|------|
|                             |       | Total Inj. <sup>3</sup> | PDO <sup>4</sup> |      | Total Inj. | PDO |      | Total Inj.                  | PDO  |      |
| Small/Moderate <sup>1</sup> | 8     | 4.8                     | 2.0              | 2.4  | 2.4        | 0.5 | 1.6  | -51%                        | 73%  | -32% |
| Large <sup>2</sup>          | 3     | 21.5                    | 5.8              | 15.7 | 15.3       | 4.0 | 11.3 | -29%                        | -31% | -10% |
| Total                       | 11    | 9.3                     | 3.0              | 6.0  | 5.9        | 1.5 | 4.2  | -37%                        | -51% | -29% |

Notes:

1. Mostly single-lane roundabouts with an inscribed circle diameter of 30 to 35 m (100 to 115 ft).
2. Multilane roundabouts with an inscribed circle diameter greater than 50 m (165 ft).
3. Inj. = Injury crashes
4. PDO = Property Damage Only crashes
5. Only injury crash reductions for small/moderate roundabouts were statistically significant.



# Riduzione dei punti di conflitto

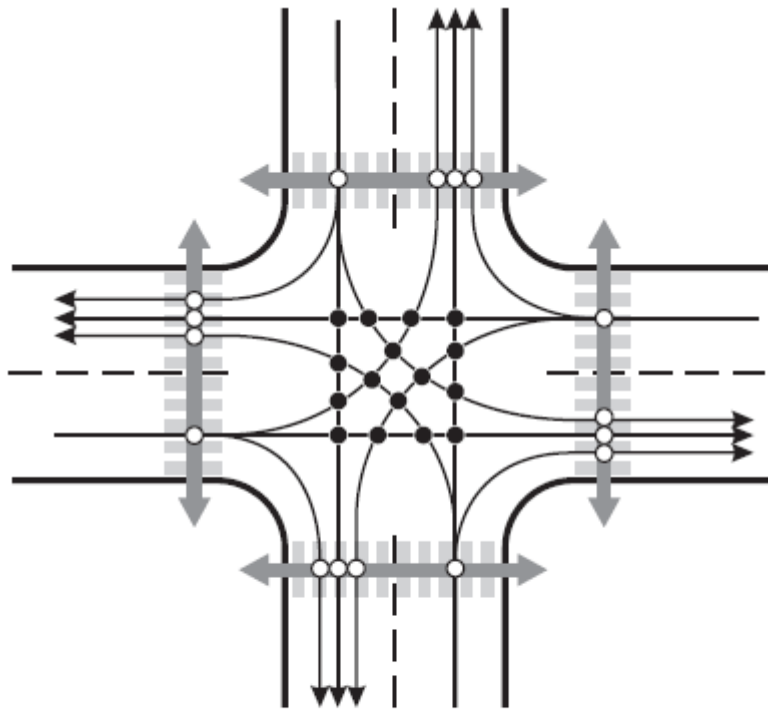


**PUNTI DI CONFLITTO**

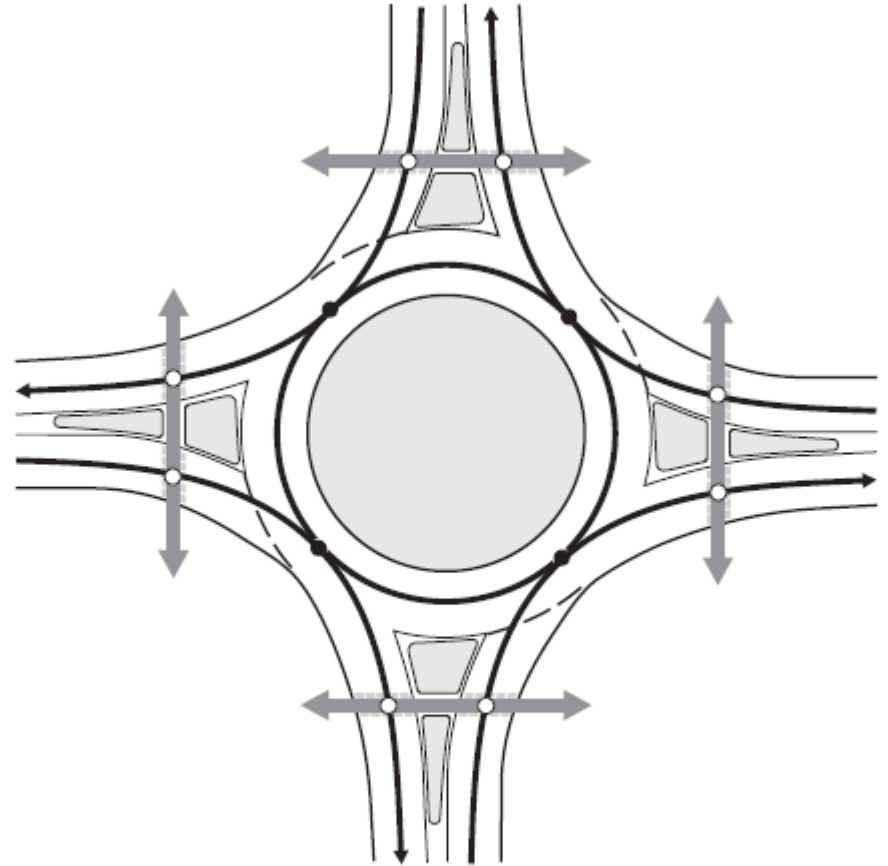
**32**

**8**

# Rotatorie e pedoni (1)



- Vehicle/Pedestrian Conflicts
- Vehicle/Vehicle Conflicts



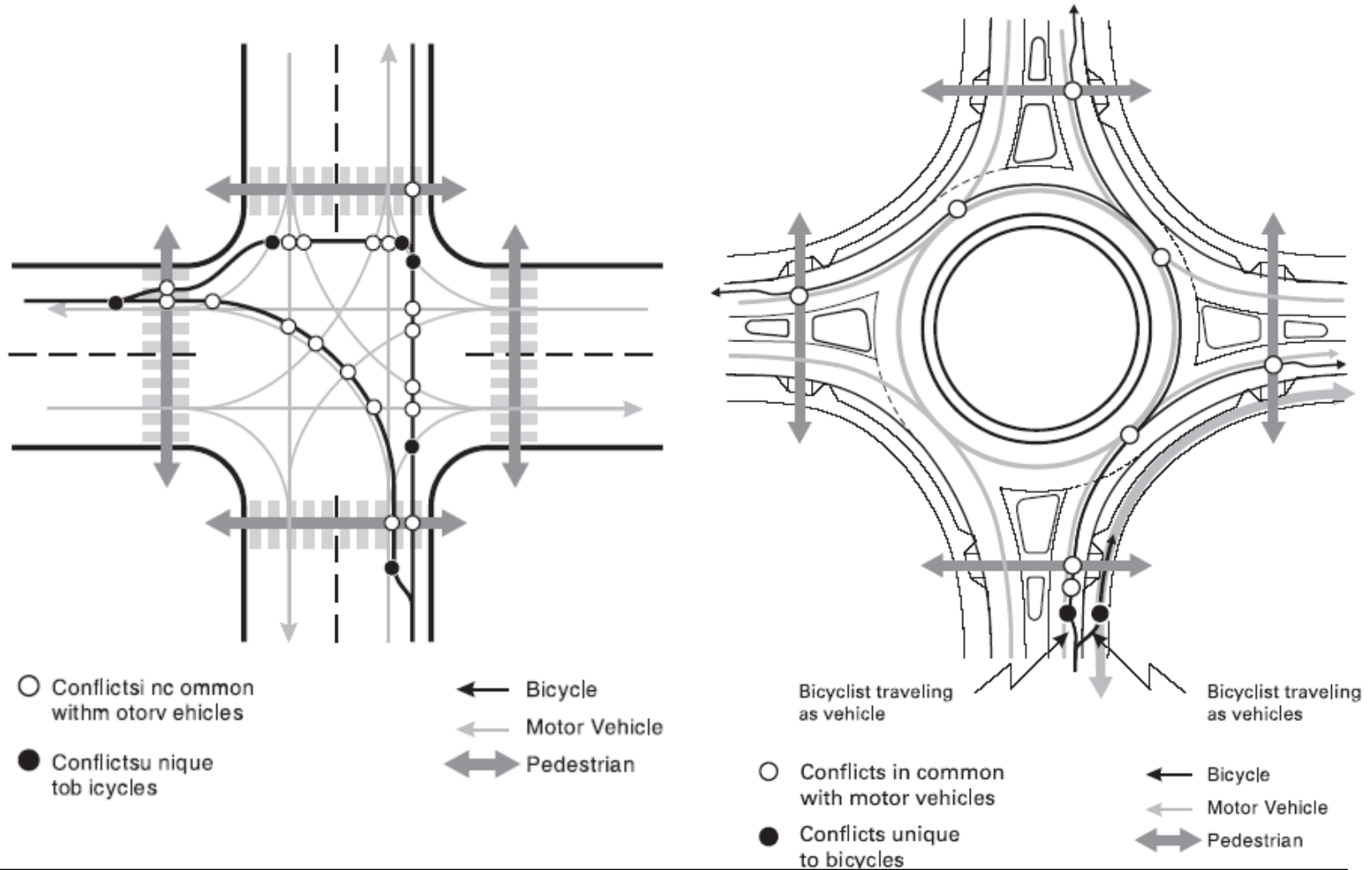
- Vehicle/Pedestrian Conflicts
- Vehicle/Vehicle Conflicts



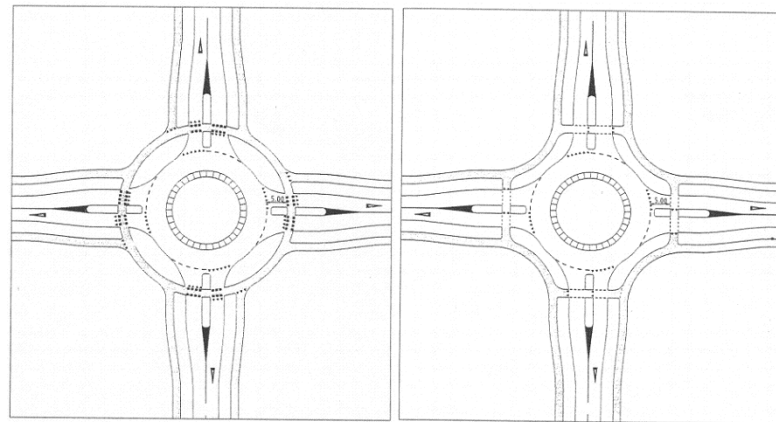
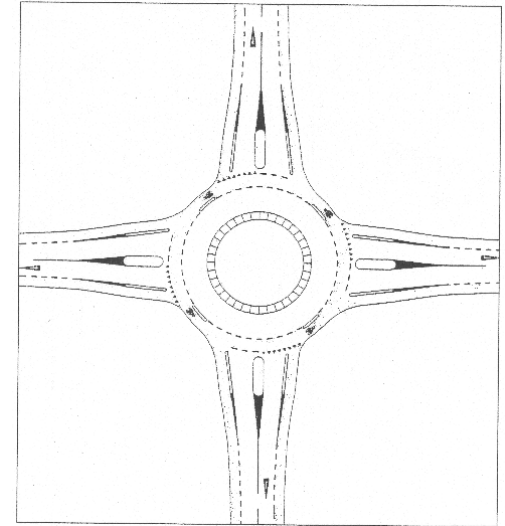
## Rotatorie e pedoni (2)



# Rotatorie e ciclisti (1)



## Rotatorie e ciclisti (2)

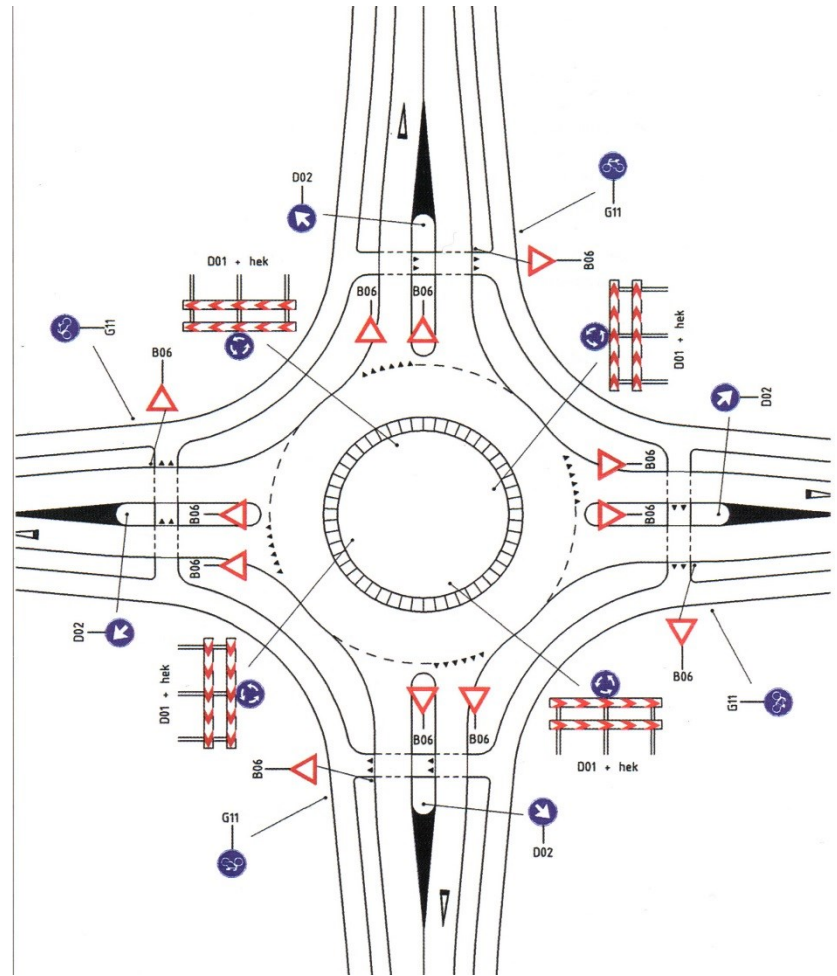
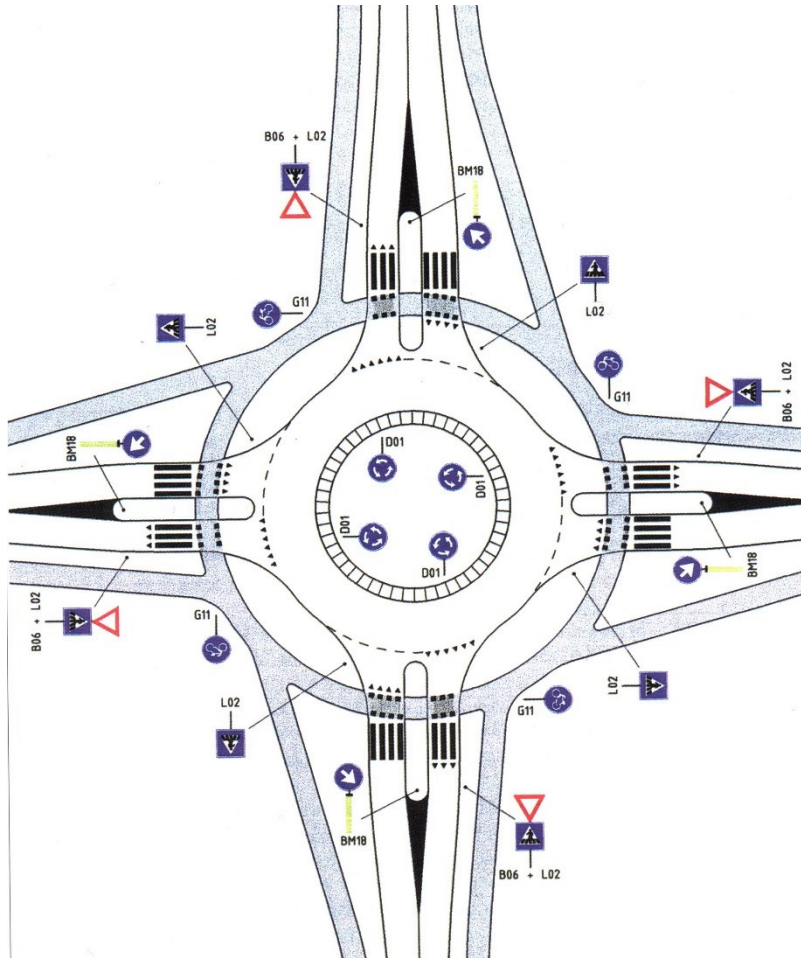




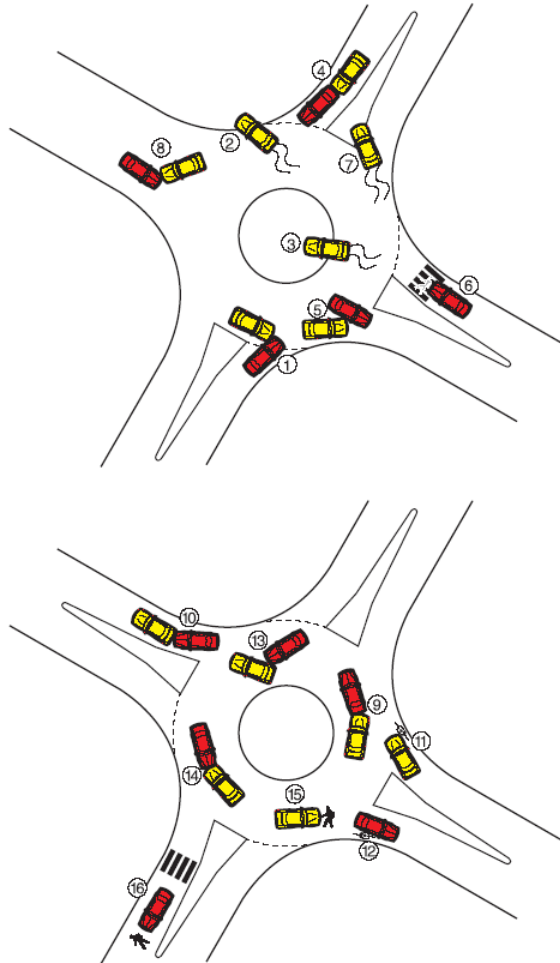
## Rotatorie e ciclisti (3)



# Rotatorie e ciclisti (4)



# Tipologia di incidenti



| Collision Type                                      | France | Queensland (Australia) | United Kingdom <sup>1</sup> |
|---|--------|------------------------|-----------------------------|
| 1. Failure to yield at entry (entering-circulating) | 36.6%  | 50.8%                  | 71.1%                       |
| 2. Single-vehicle run off the circulatory roadway   | 16.3%  | 10.4%                  | 8.2% <sup>2</sup>           |
| 3. Single vehicle loss of control at entry          | 11.4%  | 5.2%                   | <sup>2</sup>                |
| 4. Rear-end at entry                                | 7.4%   | 16.9%                  | 7.0% <sup>3</sup>           |
| 5. Circulating-exiting                              | 5.9%   | 6.5%                   |                             |
| 6. Pedestrian on crosswalk                          | 5.9%   |                        | 3.5% <sup>4</sup>           |
| 7. Single vehicle loss of control at exit           | 2.5%   | 2.6%                   | <sup>2</sup>                |
| 8. Exiting-entering                                 | 2.5%   |                        |                             |
| 9. Rear-end in circulatory roadway                  | 0.5%   | 1.2%                   |                             |
| 10. Rear-end at exit                                | 1.0%   | 0.2%                   |                             |
| 11. Passing a bicycle at entry                      | 1.0%   |                        |                             |
| 12. Passing a bicycle at exit                       | 1.0%   |                        |                             |
| 13. Weaving in circulatory roadway                  | 2.5%   | 2.0%                   |                             |
| 14. Wrong direction in circulatory roadway          | 1.0%   |                        |                             |
| 15. Pedestrian on circulatory roadway               | 3.5%   |                        | <sup>4</sup>                |
| 16. Pedestrian at approach outside crosswalk        | 1.0%   |                        | <sup>4</sup>                |
| Other collision types                               |        | 2.4%                   | 10.2%                       |
| Other sideswipe crashes                             |        | 1.6%                   |                             |

#### Notes:

1. Data are for "small" roundabouts (curbed central islands > 4 m [13 ft] diameter, relatively large ratio of inscribed circle diameter to central island size)

2. Reported findings do not distinguish among single-vehicle crashes.

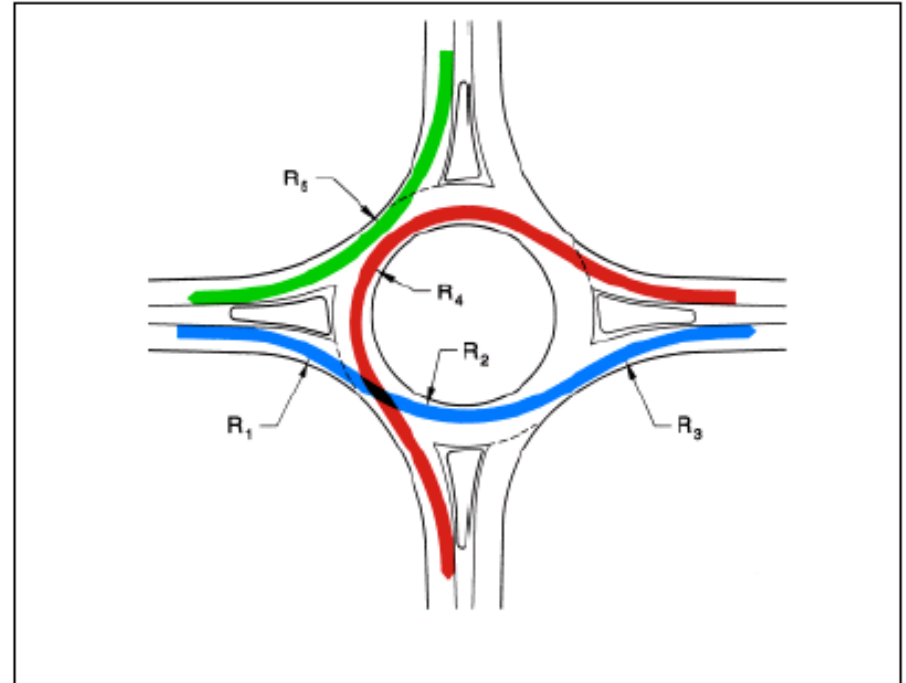
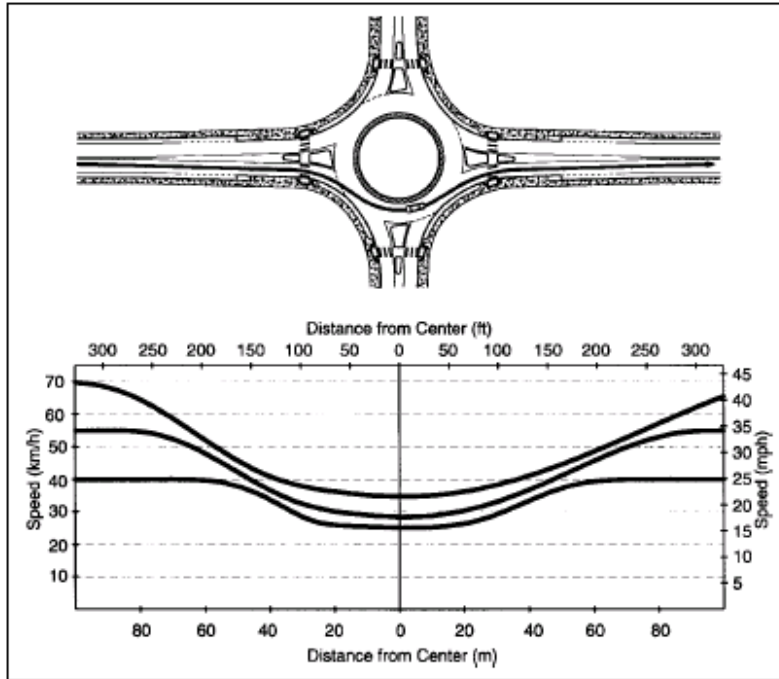
3. Reported findings do not distinguish among approaching crashes.

4. Reported findings do not distinguish among pedestrian crashes.

Sources: France (12), Australia (13), United Kingdom (1)



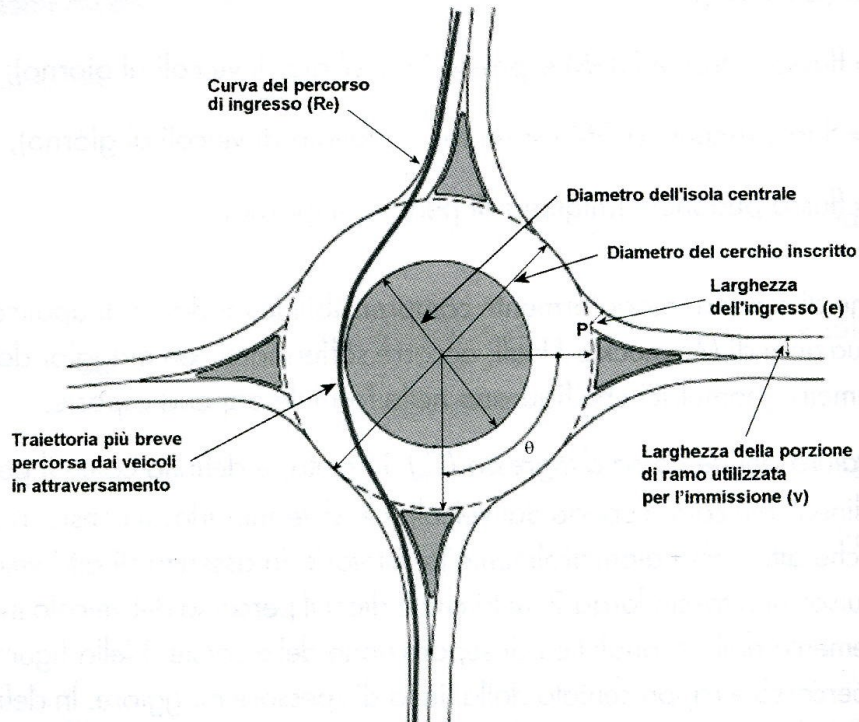
# Congruenza delle velocità operative



$$R_1 < R_2 < R_3$$

| Site Category     | Recommended Maximum Entry Design Speed |
|-------------------|--|
| Mini-Roundabout   | 25 km/h (15 mph)                       |
| Urban Compact     | 25 km/h (15 mph)                       |
| Urban Single Lane | 35 km/h (20 mph)                       |
| Urban Double Lane | 40 km/h (25 mph)                       |
| Rural Single Lane | 40 km/h (25 mph)                       |
| Rural Double Lane | 50 km/h (30 mph)                       |

# Modelli di incidentalità (1)



## Modello di Maycock ed Hall

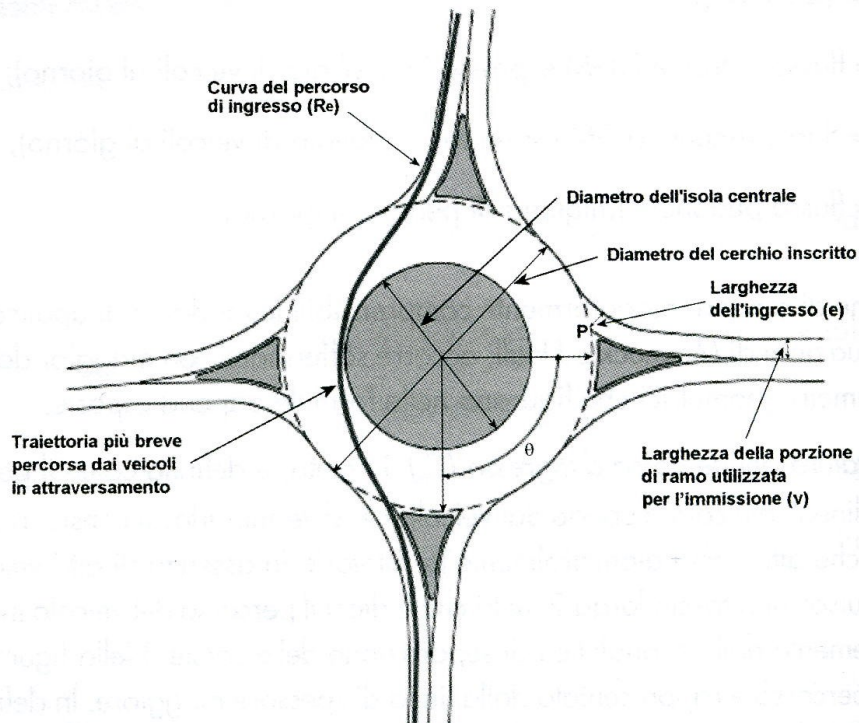
### 1) Incidenti tra veicoli entranti e circolanti

$$A = 0,052 \cdot Q_e^{0,7} \cdot Q_c^{0,4} \cdot \exp\left(-40 \cdot C_e + 0,14 \cdot e - 0,007 \cdot e \cdot v - \frac{1}{1 + \exp(4 \cdot R - 7)} + 0,2 \cdot P_m - 0,01 \cdot \theta\right)$$

dove:

- > A = incidenti annui (con feriti e/o morti) per ramo della rotatoria;
- >  $Q_e$  = flusso entrante (TGM espresso in migliaia di veicoli al giorno);
- >  $Q_c$  = flusso circolante (TGM espresso in migliaia di veicoli al giorno);
- >  $C_e$  = curvatura del percorso in ingresso =  $1 / R_e$ ;
- >  $R_e$  = raggio della traiettoria più breve percorsa dai veicoli in ingresso (m);
- > e = larghezza dell'entrata (m);
- > v = larghezza della porzione di ramo utilizzata per l'immissione (m);
- > R = rapporto tra il diametro della corona giratoria e il diametro dell'isola centrale;
- >  $P_m$  = percentuale di motocicli (%);
- >  $\theta$  = angolo formato con il ramo successivo, misurato da asse ad asse (gradi).

# Modelli di incidentalità (2)



## 2) Incidenti in entrata

$$A = 0,0057 \cdot Q_e^{1.7} \cdot \exp(20 \cdot C_e - 0,1 \cdot e)$$

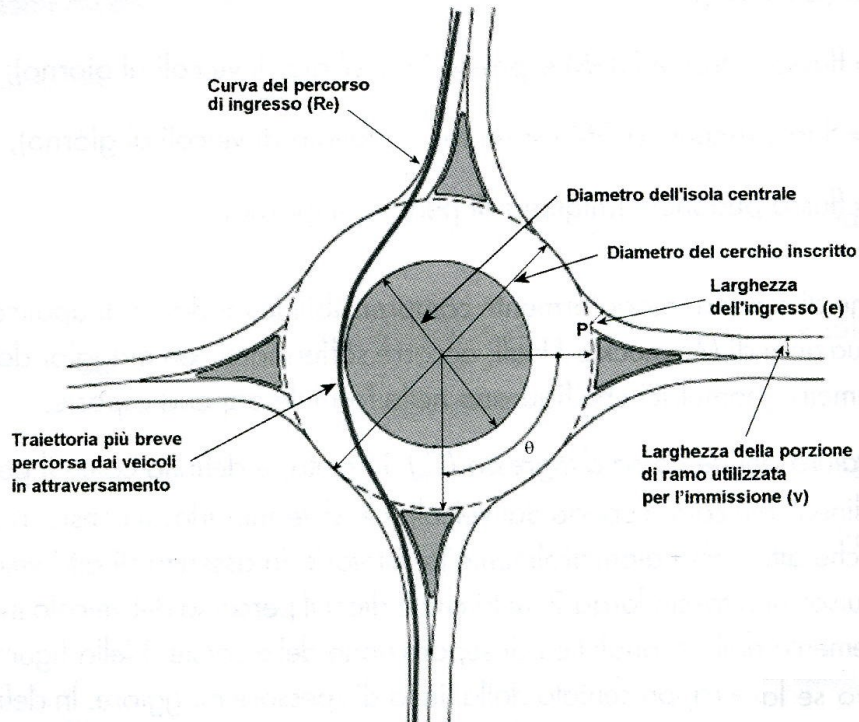
dove:

- >  $A$  = incidenti annui (con feriti e/o morti) per ingresso o ramo della rotatoria;
- >  $Q_e$  = flusso entrante (TGM espresso in migliaia di veicoli al giorno);
- >  $C_e$  = curvatura del percorso in ingresso =  $1/R_e$ ;
- >  $R_e$  = raggio della traiettoria più breve percorsa dai veicoli in ingresso (m);
- >  $e$  = larghezza dell'entrata (m).

## Modello di Maycock ed Hall



# Modelli di incidentalità (3)



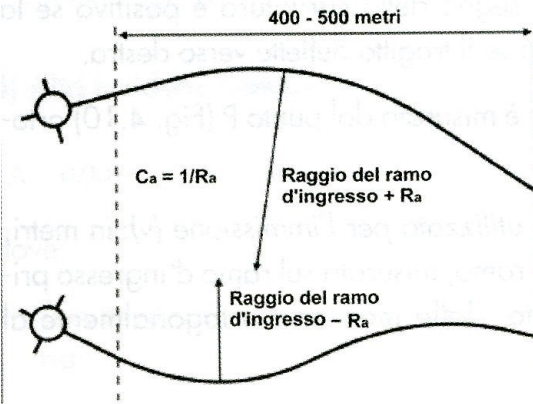
## 3) Incidenti relativi al veicolo isolato

$$A = 0,0064 \cdot Q_e^{0,8} \cdot \exp(25 \cdot C_e + 0,2 \cdot v - 45 \cdot C_a)$$

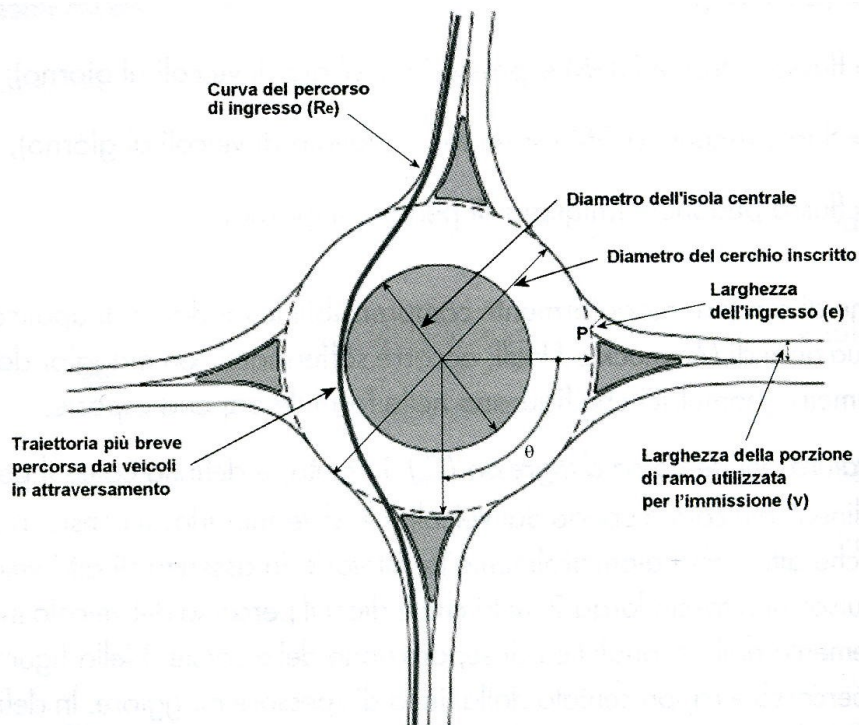
dove:

- >  $A$  = incidenti annui (con feriti e/o morti) per ingresso o ramo della rotatoria;
- >  $Q_e$  = flusso entrante (TGM espresso in migliaia di veicoli al giorno);
- >  $C_e$  = curvatura del percorso in ingresso =  $1 / R_e$ ;
- >  $R_e$  = raggio della traiettoria più breve percorsa dai veicoli in ingresso (m);
- >  $v$  = larghezza della porzione di ramo utilizzata per l'immissione (m);
- >  $C_a$  = curvatura del ramo d'ingresso =  $1 / R_a$ ;
- >  $R_a$  = raggio del ramo d'ingresso (m) (definito come il raggio della curva più vicina all'intersezione all'interno dello spazio compreso tra 50 m e 500 m dalla linea del "dare precedenza").

## Modello di Maycock ed Hall



# Modelli di incidentalità (4)



## 4) Altri incidenti (veicolari)

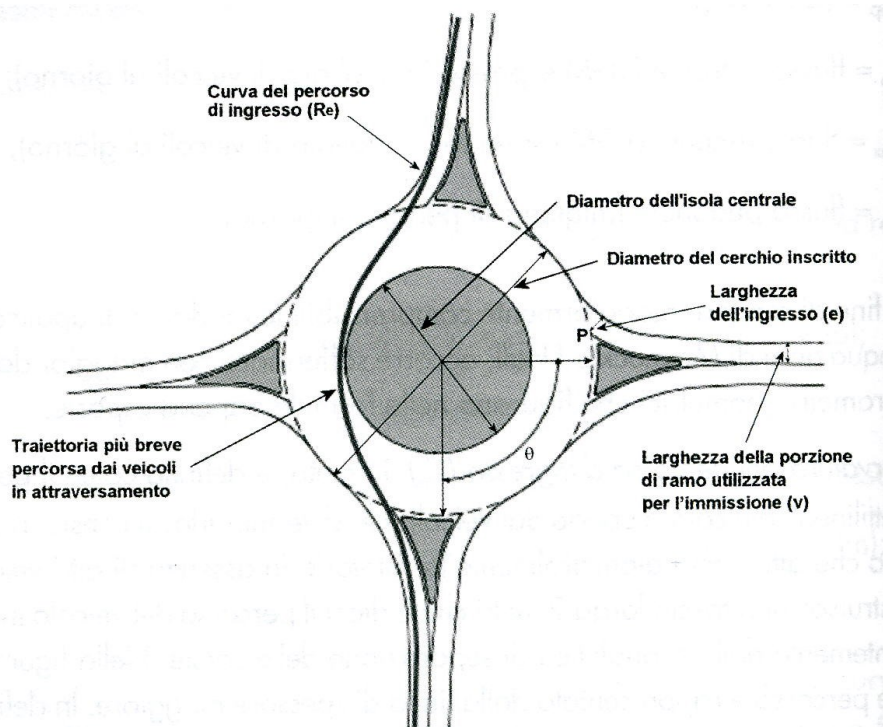
$$A = 0,0026 \cdot Q_{ec}^{0.8} \cdot \exp(0.2 \cdot P_m)$$

dove:

- > A = incidenti annui (con feriti e/o morti) per ingresso o ramo della rotatoria;
- >  $Q_{ec} = Q_e \cdot Q_c$
- >  $Q_e$  = flusso entrante (TGM espresso in migliaia di veicoli al giorno);
- >  $Q_c$  = flusso circolante (TGM espresso in migliaia di veicoli al giorno);
- >  $P_m$  = percentuale di motocicli (%).

## Modello di Maycock ed Hall

# Modelli di incidentalità (5)



## 5) Incidenti tra veicoli e pedoni

$$A = 0,029 \cdot Q_{ep}^{0.5}$$

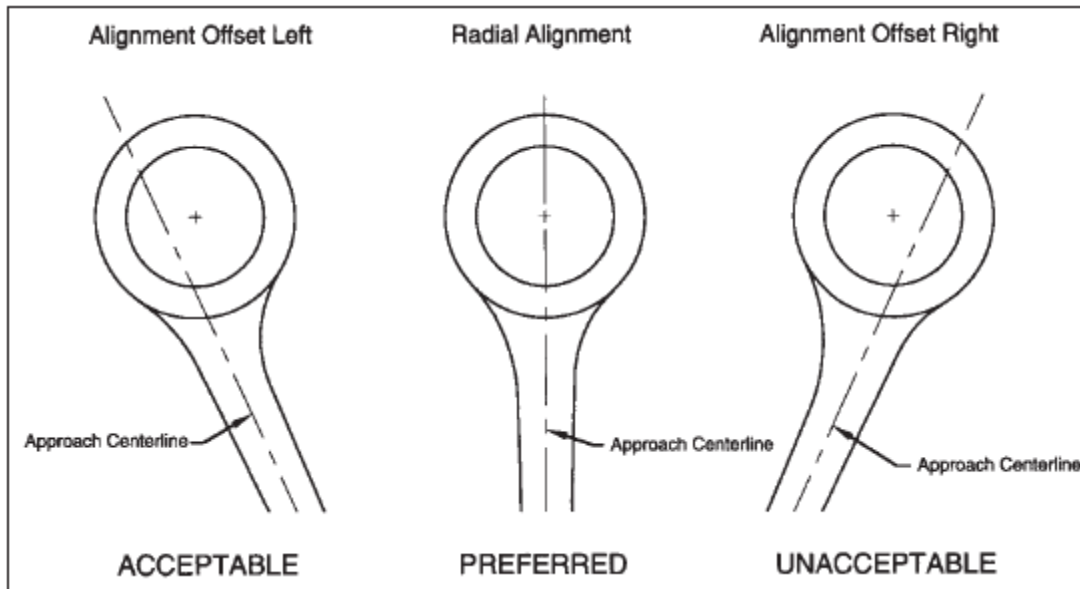
dove:

- >  $A$  = incidenti annui (con feriti e/o morti) per ingresso o ramo della rotatoria;
- >  $Q_{ep} = (Q_e + Q_{ex}) \cdot Q_p$
- >  $Q_e$  = flusso entrante (TGM espresso in migliaia di veicoli al giorno);
- >  $Q_{ex}$  = flusso uscente (TGM espresso in migliaia di veicoli al giorno);
- >  $Q_p$  = flusso pedonale (migliaia di pedoni al giorno).

## Modello di Maycock ed Hall



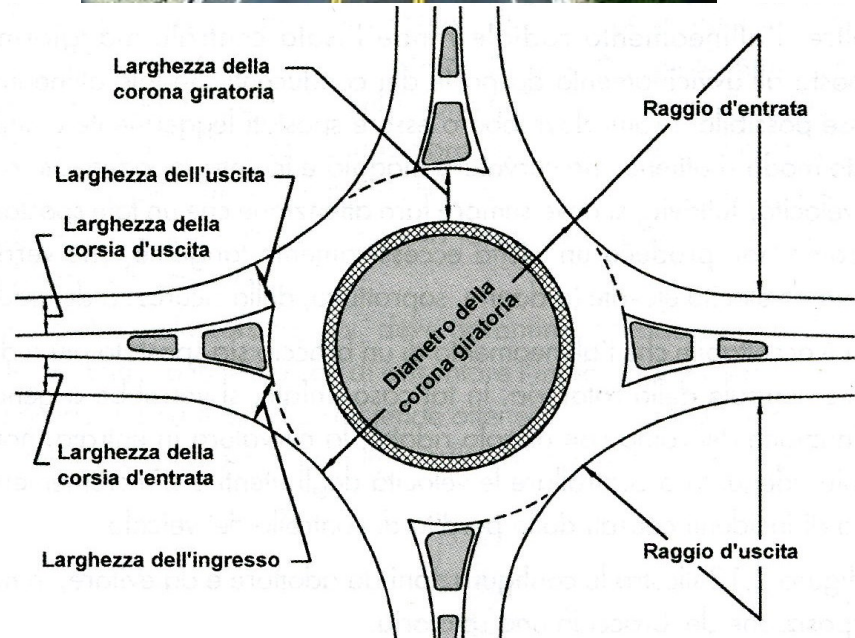
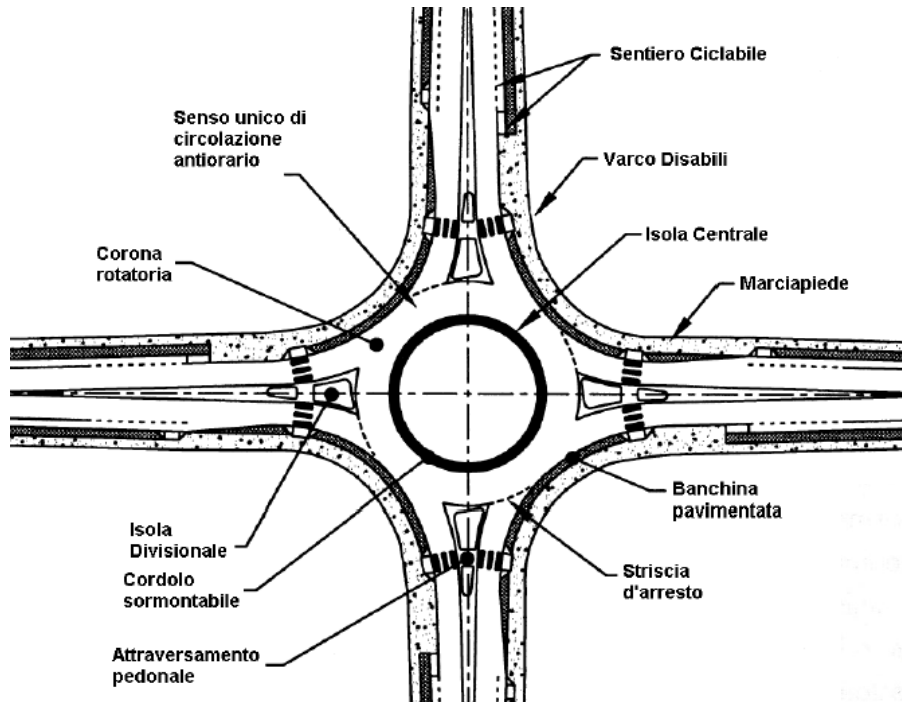
# Posizionamento rotatorie



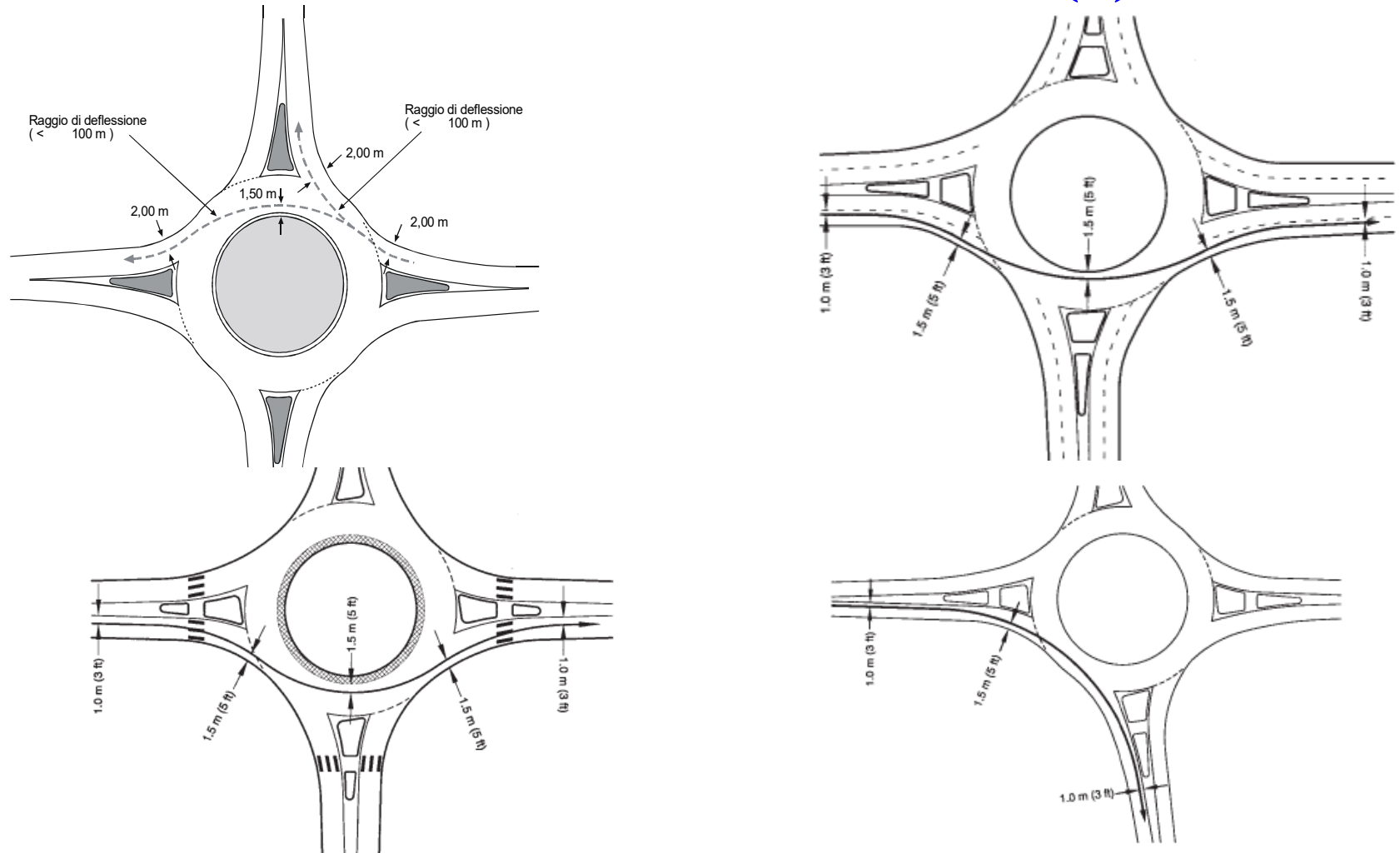
**È opportuno evitare un posizionamento dell'incrocio in curva o all'uscita da una curva; in particolare la posizione dell'isola centrale è ottimale quando tutti gli assi dei bracci che confluiscono nella rotatoria passano per il centro della rotatoria stessa**

**È opportuno escludere una configurazione dell'approccio alla rotatoria in “curva e contro-curva”; è opportuno non posizionare dei filari di alberi lungo i bracci di accesso alla rotatoria che possono dare l'illusione di continuità dell'itinerario; è da escludere un'isola centrale di forma non circolare; è da escludere un anello di larghezza variabile; è da escludersi una pendenza dell'anello circolare verso l'interno della rotatoria; è da evitare la presenza di una corsia specializzata per la svolta a destra sull'anello.**

# Elementi funzionali delle rotatorie

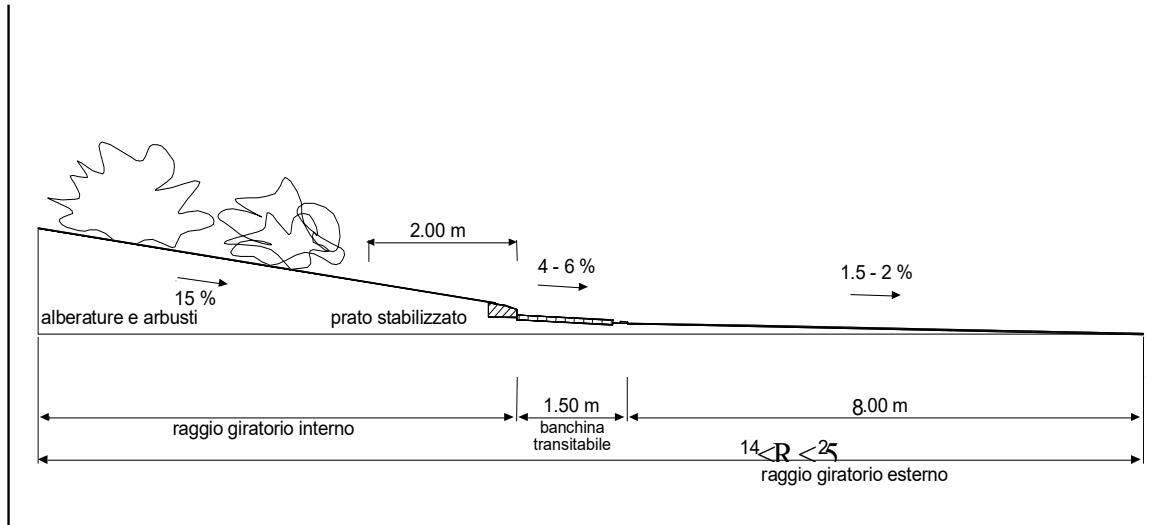


# Geometria delle rotatorie (1)





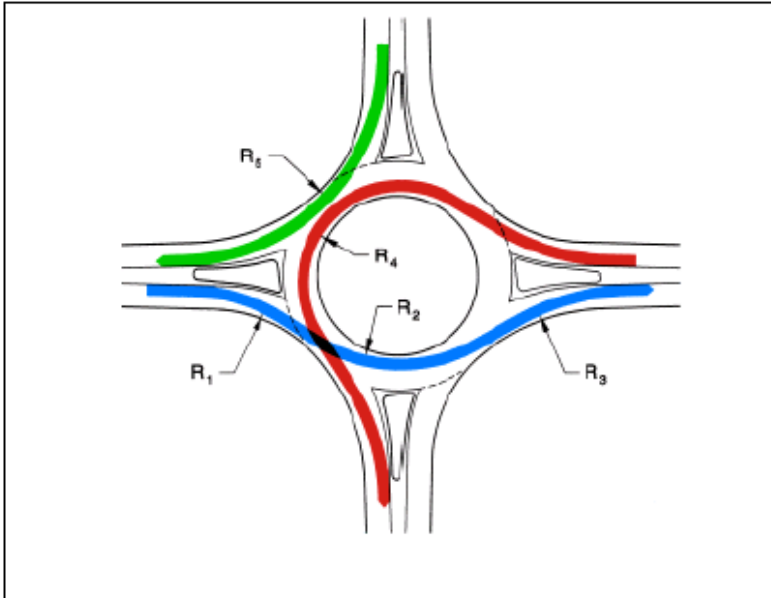
## Geometria delle rotatorie (2)



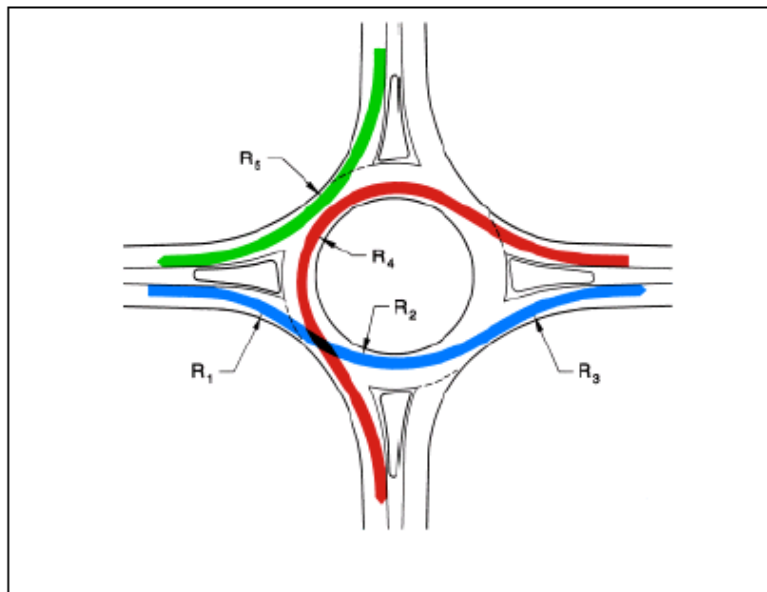
$$V = \sqrt{127 \cdot R(f + q)}$$

| V (km/h)                | 25   | 40   | 60   | 80   | 100  | 120  | 140  |
|-------------------------|------|------|------|------|------|------|------|
| Strade D, E, F urbane   | 0,22 | 0,21 | 0,20 | 0,16 |      |      |      |
| Strade A, B, C, F extr. |      | 0,21 | 0,17 | 0,13 | 0,11 | 0,10 | 0,09 |

## Geometria delle rotatorie (3)



# Geometria delle rotatorie (4)



| Inscribed Circle<br>Diameter (m) | Approximate $R_4$ Value |                 | Maximum $R_1$ Value |                 |
|----------------------------------|-------------------------|-----------------|---------------------|-----------------|
|                                  | Radius<br>(m)           | Speed<br>(km/h) | Radius<br>(m)       | Speed<br>(km/h) |
| <b>Single-Lane Roundabout</b>    |                         |                 |                     |                 |
| 30                               | 11                      | 21              | 54                  | 41              |
| 35                               | 13                      | 23              | 61                  | 43              |
| 40                               | 16                      | 25              | 69                  | 45              |
| 45                               | 19                      | 26              | 73                  | 46              |
| <b>Double-Lane Roundabout</b>    |                         |                 |                     |                 |
| 45                               | 15                      | 24              | 65                  | 44              |
| 50                               | 17                      | 25              | 69                  | 45              |
| 55                               | 20                      | 27              | 78                  | 47              |
| 60                               | 23                      | 28              | 83                  | 48              |
| 65                               | 25                      | 29              | 88                  | 49              |
| 70                               | 28                      | 30              | 93                  | 50              |

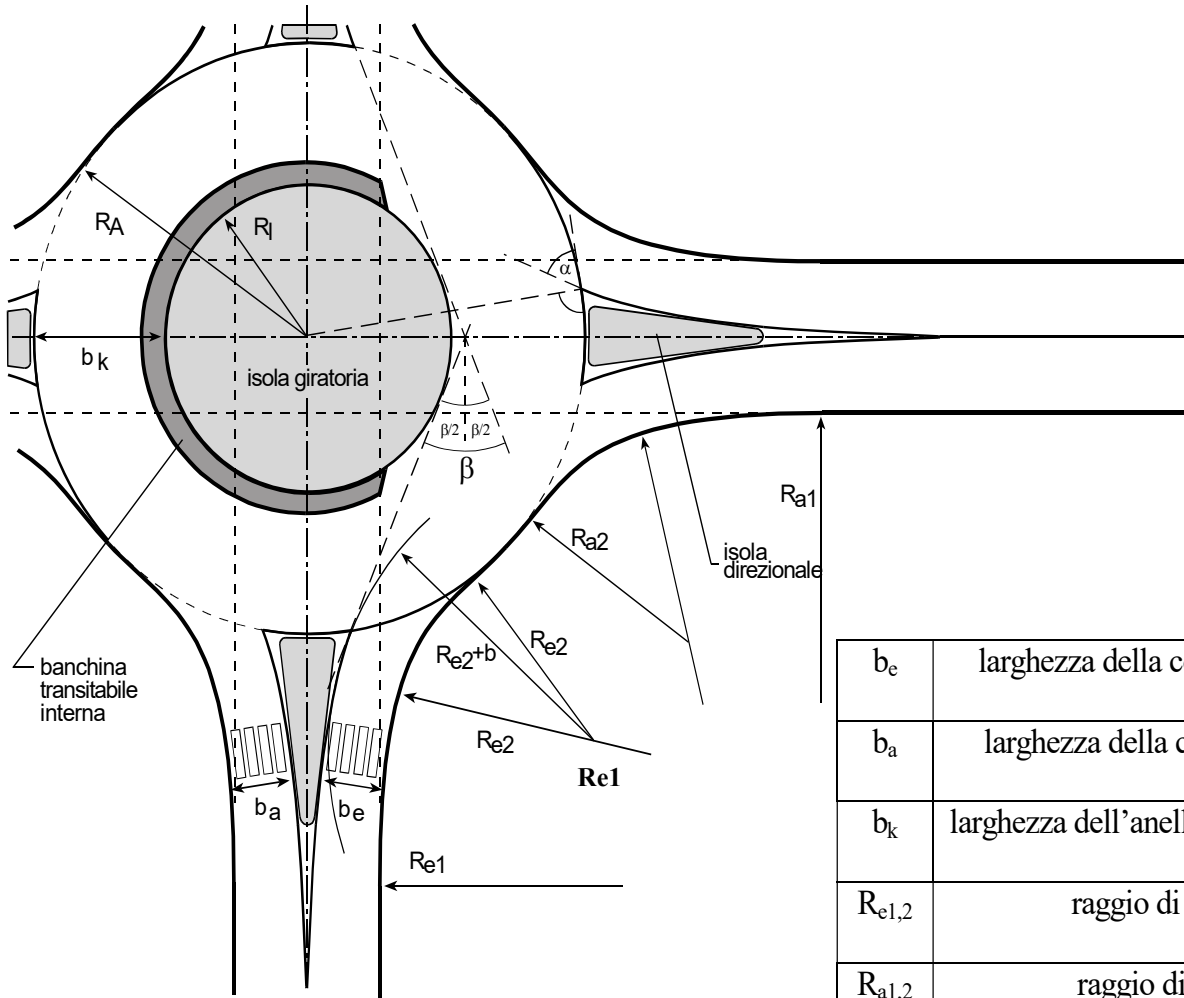
$$R_5 \leq R_1$$

$$R_5 \leq R^* = R_4 + 20$$

$R^*$  è il raggio che consente una velocità corrispondente a  $R_4 + 20$  km/h

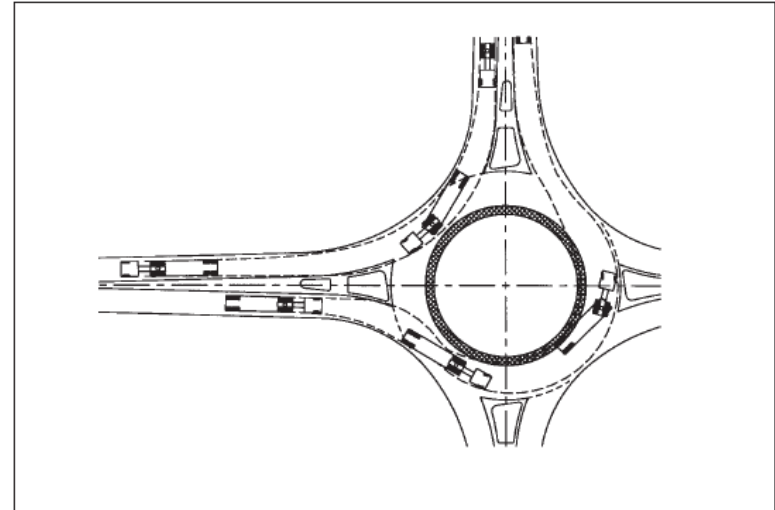
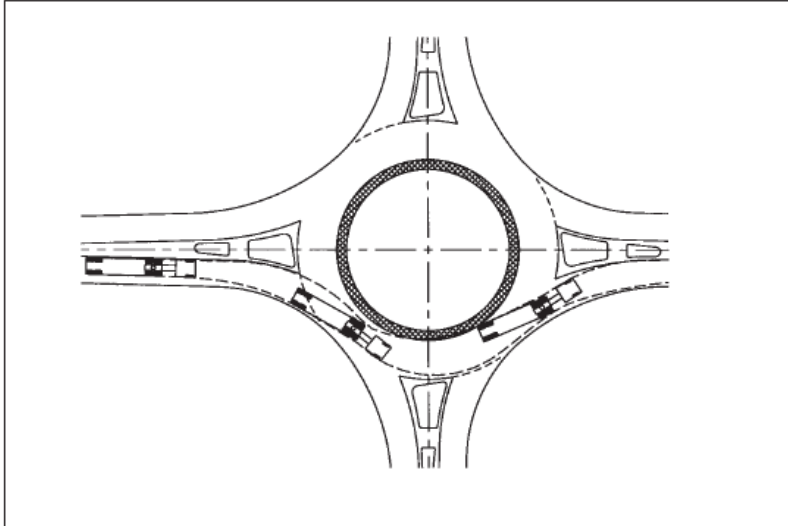


# Geometria delle rotatorie (5)



|            |                                       |          |                          |
|------------|---------------------------------------|----------|--------------------------|
| $b_e$      | larghezza della corsia in entrata     | $R_A$    | raggio esterno           |
| $b_a$      | larghezza della corsia in uscita      | $R_i$    | raggio interno           |
| $b_k$      | larghezza dell'anello di circolazione | $\alpha$ | angolo d'entrata         |
| $R_{e1,2}$ | raggio di entrata                     | $\beta$  | angolo di deviazione     |
| $R_{a1,2}$ | raggio di uscita                      | $b$      | arretramento di $R_{e2}$ |

# Geometria delle rotatorie (6)



| Site Category     | Typical Design Vehicle | Inscribed Circle Diameter Range* |
|-------------------|------------------------|----------------------------------|
| Mini-Roundabout   | Single-Unit Truck      | 13–25m (45–80 ft)                |
| Urban Compact     | Single-Unit Truck/Bus  | 25–30m (80–100 ft)               |
| Urban Single Lane | WB-15 (WB-50)          | 30–40m (100–130 ft)              |
| Urban Double Lane | WB-15 (WB-50)          | 45–55m (150–180 ft)              |
| Rural Single Lane | WB-20 (WB-67)          | 35–40m (115–130 ft)              |
| Rural Double Lane | WB-20 (WB-67)          | 55–60m (180–200 ft)              |

\* Assumes 90-degree angles between entries and no more than four legs.

# Geometria delle rotatorie (7)

## Metric

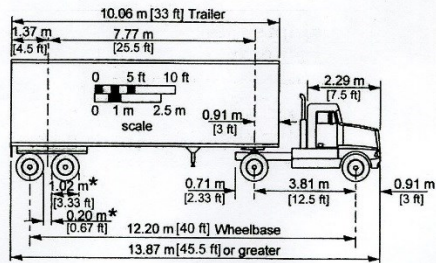
| Design Vehicle Type                 | Symbol   | Dimensions (m) |         |                  |          |                      |                 |                 |                  |                  |                 |                 | Typical Kingpin to Center of Rear Axle |           |
|-------------------------------------|----------|----------------|---------|------------------|----------|----------------------|-----------------|-----------------|------------------|------------------|-----------------|-----------------|--|-----------|
|                                     |          | Overall        |         |                  | Overhang |                      |                 |                 |                  |                  |                 |                 |  |           |
|                                     |          | Height         | Width   | Length           | Front    | Rear                 | WB <sub>1</sub> | WB <sub>2</sub> | S                | T                | WB <sub>3</sub> | WB <sub>4</sub> |  |           |
| Passenger Car                       | P        | 1.3            | 2.1     | 5.8              | 0.9      | 1.5                  | 3.4             | -               | -                | -                | -               | -               | -                                      | -         |
| Single Unit Truck                   | SU       | 3.4-4.1        | 2.4     | 9.2              | 1.2      | 1.8                  | 6.1             | -               | -                | -                | -               | -               | -                                      | -         |
| <b>Buses</b>                        |          |                |         |                  |          |                      |                 |                 |                  |                  |                 |                 |  |           |
| Inter-city Bus (Motor Coaches)      | BUS-12   | 3.7            | 2.6     | 12.2             | 1.8      | 1.9 <sup>a</sup>     | 7.3             | 1.1             | -                | -                | -               | -               | -                                      | -         |
|                                     | BUS-14   | 3.7            | 2.6     | 13.7             | 1.8      | 2.6 <sup>a</sup>     | 8.1             | 1.2             | -                | -                | -               | -               | -                                      | -         |
| City Transit Bus                    | CITY-BUS | 3.2            | 2.6     | 12.2             | 2.1      | 2.4                  | 7.6             | -               | -                | -                | -               | -               | -                                      | -         |
| Conventional School Bus (65 pass.)  | S-BUS 11 | 3.2            | 2.4     | 10.9             | 0.8      | 3.7                  | 6.5             | -               | -                | -                | -               | -               | -                                      | -         |
| Large School Bus (84 pass.)         | S-BUS 12 | 3.2            | 2.4     | 12.2             | 2.1      | 4.0                  | 6.1             | -               | -                | -                | -               | -               | -                                      | -         |
| Articulated Bus                     | A-BUS    | 3.4            | 2.6     | 18.3             | 2.6      | 3.1                  | 6.7             | 5.9             | 1.9 <sup>b</sup> | 4.0 <sup>b</sup> | -               | -               | -                                      | -         |
| <b>Trucks</b>                       |          |                |         |                  |          |                      |                 |                 |                  |                  |                 |                 |  |           |
| Intermediate Semitrailer            | WB-12    | 4.1            | 2.4     | 13.9             | 0.9      | 0.8 <sup>a</sup>     | 3.8             | 8.4             | -                | -                | -               | -               | -                                      | 8.4       |
| Intermediate Semitrailer            | WB-15    | 4.1            | 2.6     | 16.8             | 0.9      | 0.6 <sup>a</sup>     | 4.5             | 10.8            | -                | -                | -               | -               | -                                      | 11.4      |
| Interstate Semitrailer              | WB-19*   | 4.1            | 2.6     | 20.9             | 1.2      | 0.8 <sup>a</sup>     | 6.6             | 12.3            | -                | -                | -               | -               | -                                      | 13.0      |
| Interstate Semitrailer              | WB-20**  | 4.1            | 2.6     | 22.4             | 1.2      | 1.4-0.8 <sup>a</sup> | 6.6             | 13.2-13.8       | -                | -                | -               | -               | -                                      | 13.9-14.5 |
| "Double-Bottom"-Semitrailer/Trailer | WB-20D   | 4.1            | 2.6     | 22.4             | 0.7      | 0.9                  | 3.4             | 7.0             | 0.9 <sup>c</sup> | 2.1 <sup>c</sup> | 7.0             | -               | -                                      | 7.0       |
| Triple-Semitrailer/Trailers         | WB-30T   | 4.1            | 2.6     | 32.0             | 0.7      | 0.9                  | 3.4             | 6.9             | 0.9 <sup>d</sup> | 2.1 <sup>d</sup> | 7.0             | 7.0             | -                                      | 7.0       |
| Tumpike Double-Semitrailer/Trailer  | WB-33D*  | 4.1            | 2.6     | 34.8             | 0.7      | 0.8 <sup>a</sup>     | 4.4             | 12.2            | 0.8 <sup>e</sup> | 3.1 <sup>e</sup> | 13.6            | -               | -                                      | 13.0      |
| <b>Recreational Vehicles</b>        |          |                |         |                  |          |                      |                 |                 |                  |                  |                 |                 |  |           |
| Motor Home                          | MH       | 3.7            | 2.4     | 9.2              | 1.2      | 1.8                  | 6.1             | -               | -                | -                | -               | -               | -                                      | -         |
| Car and Camper Trailer              | P/T      | 3.1            | 2.4     | 14.8             | 0.9      | 3.1                  | 3.4             | -               | 1.5              | 5.8              | -               | -               | -                                      | -         |
| Car and Boat Trailer                | P/B      | -              | 2.4     | 12.8             | 0.9      | 2.4                  | 3.4             | -               | 1.5              | 4.6              | -               | -               | -                                      | -         |
| Motor Home and Boat Trailer         | MH/B     | 3.7            | 2.4     | 16.2             | 1.2      | 2.4                  | 6.1             | -               | 1.8              | 4.6              | -               | -               | -                                      | -         |
| Farm Tractor <sup>f</sup>           | TR       | 3.1            | 2.4-3.1 | 4.9 <sup>g</sup> | -        | -                    | 3.1             | 2.7             | 0.9              | 2.0              | -               | -               | -                                      | -         |

Note: Since vehicles are manufactured in U.S. Customary dimensions and to provide only one physical size for each design vehicle, the values shown in the design vehicle drawings have been soft converted from numbers listed in feet, and then the numbers in this table have been rounded to the nearest tenth of a meter.

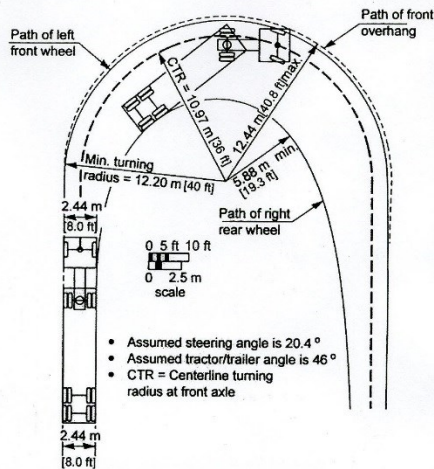
- \* = Design vehicle with 14.63 m trailer as adopted in 1982 Surface Transportation Assistance Act (STAA).
- \*\* = Design vehicle with 16.16 m trailer as grandfathered in with 1982 Surface Transportation Assistance Act (STAA).
- <sup>a</sup> = This is overhang from the back axle of the tandem axle assembly.
- <sup>b</sup> = Combined dimension is 5.91 m and articulating section is 1.22 m wide.
- <sup>c</sup> = Combined dimension is typically 3.05 m.
- <sup>d</sup> = Combined dimension is typically 3.05 m.
- <sup>e</sup> = Combined dimension is typically 3.81 m.
- <sup>f</sup> = Dimensions are for a 150-200 hp tractor excluding any wagon length.
- <sup>g</sup> = To obtain the total length of tractor and one wagon, add 5.64 m to tractor length. Wagon length is measured from front of drawbar to rear of wagon, and drawbar is 1.98 m long.
- WB<sub>1</sub>, WB<sub>2</sub>, and WB<sub>4</sub> are the effective vehicle wheelbases, or distances between axle groups, starting at the front and working towards the back of each unit.
- S is the distance from the rear effective axle to the hitch point or point of articulation.
- T is the distance from the hitch point or point of articulation measured back to the center of the next axle or center of tandem axle assembly.



# Geometria delle rotatorie (8)



\* Typical tire size and space between tires applies to all trailers.



- Assumed steering angle is 20.4°
- Assumed tractor/trailer angle is 46°
- CTR = Centerline turning radius at front axle

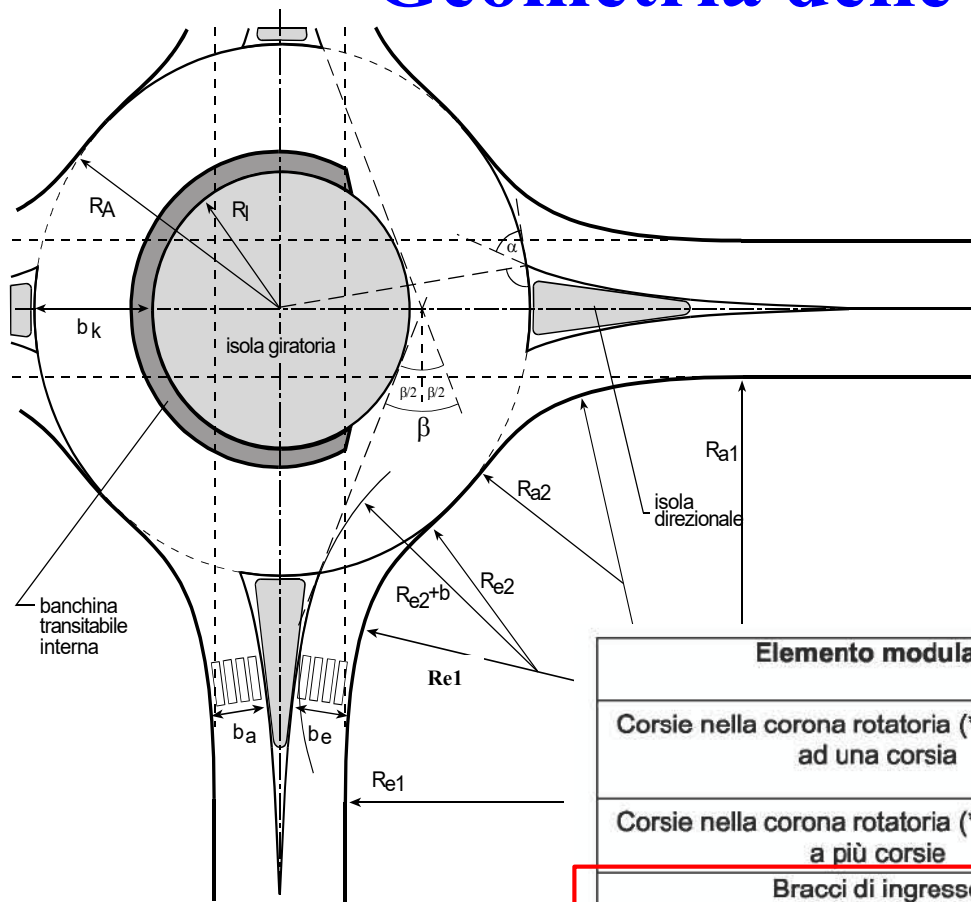
Exhibit 2-13. Minimum Turning Path for Intermediate Semitrailer (WB-12 [WB-40]) Design Vehicle

| Design Vehicle Type                              | Passenger Car           | Single Unit Truck   | Inter-city Bus (Motor Coach) |                              | City Transit Bus                     | Conventional School Bus (65 pass.) | Large <sup>2</sup> School Bus (84 pass.) | Articulated Bus      | Intermediate Semi-trailer   | Intermediate Semi-trailer |
|--|-------------------------|---------------------|------------------------------|------------------------------|--------------------------------------|------------------------------------|--|----------------------|-----------------------------|---------------------------|
| Symbol   | P                       | SU                  | BUS-12                       | BUS-14                       | CITY-BUS                             | S-BUS11                            | S-BUS12                                  | A-BUS                | WB-12                       | WB-15                     |
| Minimum Design Turning Radius (m)                | 7.3                     | 12.8                | 13.7                         | 13.7                         | 12.8                                 | 11.9                               | 12.0                                     | 12.1                 | 12.2                        | 13.7                      |
| Centerline <sup>1</sup> Turning Radius (CTR) (m) | 6.4                     | 11.6                | 12.4                         | 12.4                         | 11.5                                 | 10.6                               | 10.8                                     | 10.8                 | 11.0                        | 12.5                      |
| Minimum Inside Radius (m)                        | 4.4                     | 8.6                 | 8.4                          | 7.8                          | 7.5                                  | 7.3                                | 7.7                                      | 6.5                  | 5.9                         | 5.2                       |
| Design Vehicle Type                              | Interstate Semi-trailer |                     | "Double Bottom" Combination  | Triple Semi-trailer/trailers | Turnpike Double Semi-trailer/trailer | Motor Home                         | Car and Camper Trailer                   | Car and Boat Trailer | Motor Home and Boat Trailer | Farm Tractor w/One Wagon  |
| Symbol   | WB-19 <sup>1</sup>      | WB-20 <sup>**</sup> | WB-20D                       | WB-30T                       | WB-33D <sup>*</sup>                  | MH                                 | P/T                                      | P/B                  | MH/B                        | TR/W                      |
| Minimum Design Turning Radius (m)                | 13.7                    | 13.7                | 13.7                         | 13.7                         | 18.3                                 | 12.2                               | 10.1                                     | 7.3                  | 15.2                        | 5.5                       |
| Centerline <sup>1</sup> Turning Radius (CTR) (m) | 12.5                    | 12.5                | 12.5                         | 12.5                         | 17.1                                 | 11.0                               | 9.1                                      | 6.4                  | 14.0                        | 4.3                       |
| Minimum Inside Radius (m)                        | 2.4                     | 1.3                 | 5.9                          | 3.0                          | 4.5                                  | 7.9                                | 5.3                                      | 2.8                  | 10.7                        | 3.2                       |

Note: Numbers in table have been rounded to the nearest tenth of a meter.  
<sup>\*</sup> = Design vehicle with 14.63 m trailer as adopted in 1982 Surface Transportation Assistance Act (STAA).  
<sup>\*\*</sup> = Design vehicle with 16.16 m trailer as grandfathered in with 1982 Surface Transportation Assistance Act (STAA).  
<sup>1</sup> = The turning radius assumed by a designer when investigating possible turning paths and is set at the centerline of the front axle of a vehicle. If the minimum turning path is assumed, the CTR approximately equals the minimum design turning radius minus one-half the front width of the vehicle.  
<sup>2</sup> = School buses are manufactured from 42 passenger to 84 passenger sizes. This corresponds to wheelbase lengths of 3,350 mm to 6,020 mm, respectively. For these different sizes, the minimum design turning radii vary from 8.78 m to 12.01 m and the minimum inside radii vary from 4.27 m to 7.74 m.  
<sup>3</sup> = Turning radius is for 150–200 hp tractor with one 5.64 m long wagon attached to hitch point. Front wheel drive is disengaged and without brakes being applied.

Exhibit 2-2. Minimum Turning Radii of Design Vehicles

# Geometria delle rotatorie (9)

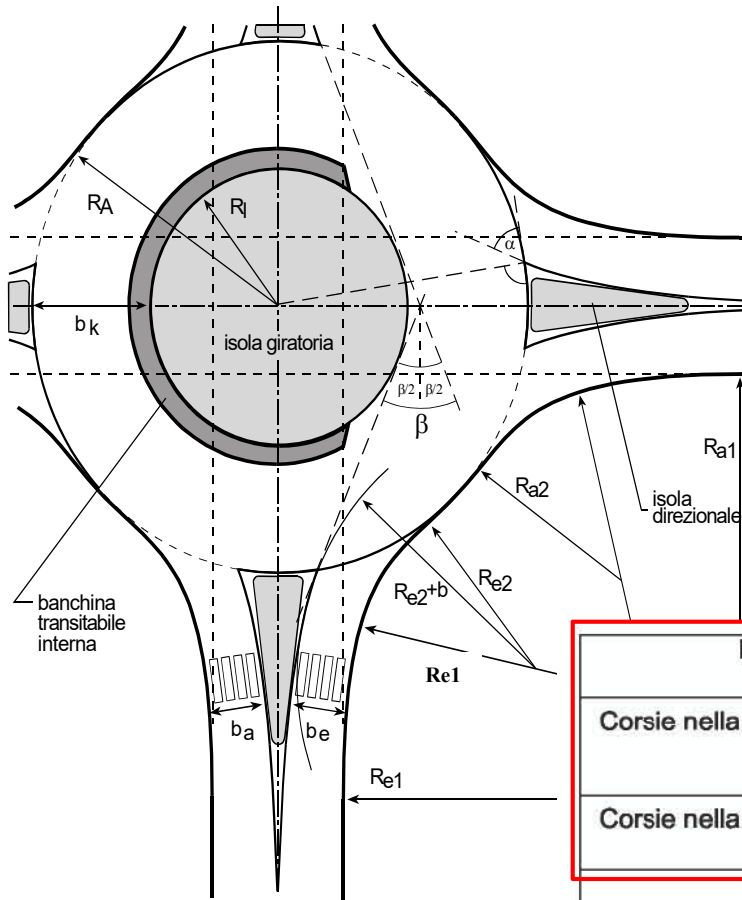


| Elemento modulare   | Diametro esterno della rotatoria (m) | Larghezza corsie (m)                       |
|---|--------------------------------------|--|
| Corsie nella corona rotatoria (*), per ingressi ad una corsia | $\geq 40$                            | 6,00                                       |
|   | Compreso tra 25 e 40                 | 7,00                                       |
|   | Compreso tra 14 e 25                 | 7,00 - 8,00                                |
| Corsie nella corona rotatoria (*), per ingressi a più corsie  | $\geq 40$                            | 9,00                                       |
|   | $< 40$                               | 8,50 - 9,00                                |
| Bracci di ingresso (**)                                       |                                      | 3,50 per una corsia<br>6,00 per due corsie |
| Bracci di uscita (*)  | $< 25$                               | 4,00                                       |
|   | $\geq 25$                            | 4,50                                       |

(\*) deve essere organizzata sempre su una sola corsia.

(\*\*) organizzati al massimo con due corsie.

# Geometria delle rotatorie (10)



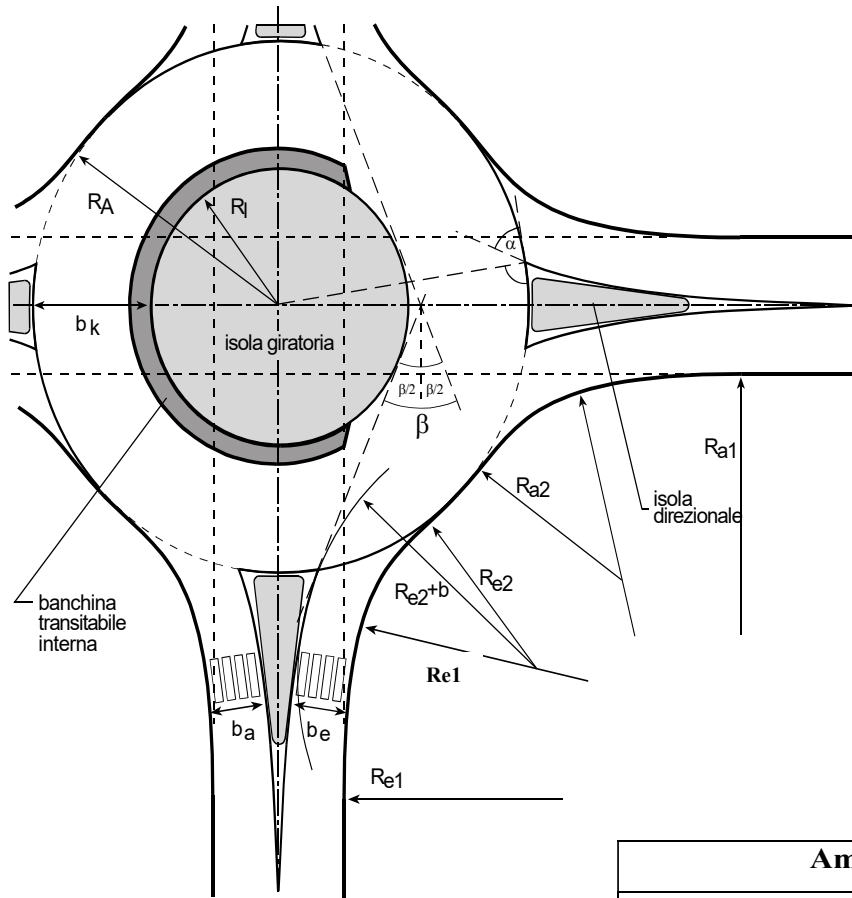
| Elemento modulare   | Diametro esterno della rotatoria (m) | Larghezza corsie (m)                       |
|---|--------------------------------------|--|
| Corsie nella corona rotatoria (*), per ingressi ad una corsia | $\geq 40$                            | 6,00                                       |
|   | Compreso tra 25 e 40                 | 7,00                                       |
|   | Compreso tra 14 e 25                 | 7,00 - 8,00                                |
| Corsie nella corona rotatoria (*), per ingressi a più corsie  | $\geq 40$                            | 9,00                                       |
|   | $< 40$                               | 8,50 - 9,00                                |
| Bracci di ingresso (**)                                       |                                      | 3,50 per una corsia<br>6,00 per due corsie |
| Bracci di uscita (*)  | $< 25$                               | 4,00                                       |
|   | $\geq 25$                            | 4,50                                       |

(\*) deve essere organizzata sempre su una sola corsia.

(\*\*) organizzati al massimo con due corsie.



# Geometria delle rotatorie (11)

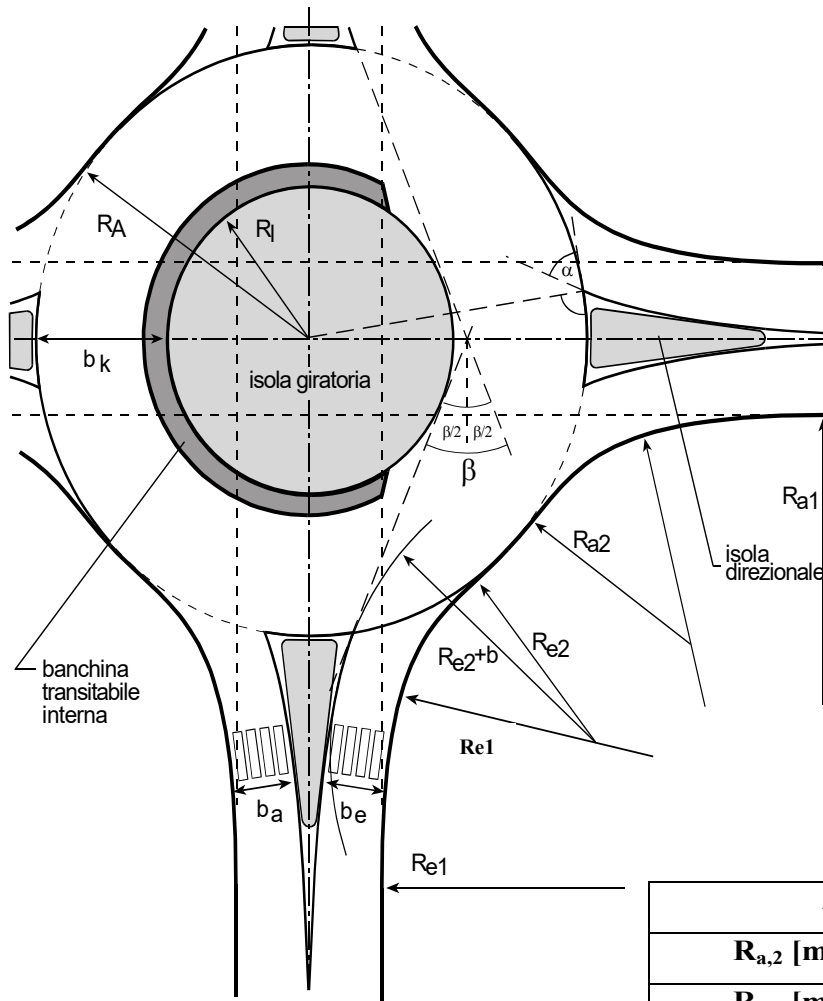


**Re 1,2 – Il ciglio destro della carreggiata del braccio di ingresso è raccordato con il ciglio esterno dell'anello di circolazione centrale per mezzo di un raccordo costituito da due archi di cerchio.**

|               | Ambito urbano     | Ambito extraurbano |                   |
|---------------|-------------------|--------------------|-------------------|
| $R_{e,2}$ [m] | 10,00             | $R_{e,2}$ [m]      | 12,00             |
| $R_{e,1}$ [m] | $5 \cdot R_{e,2}$ | $R_{e,1}$ [m]      | $5 \cdot R_{e,2}$ |



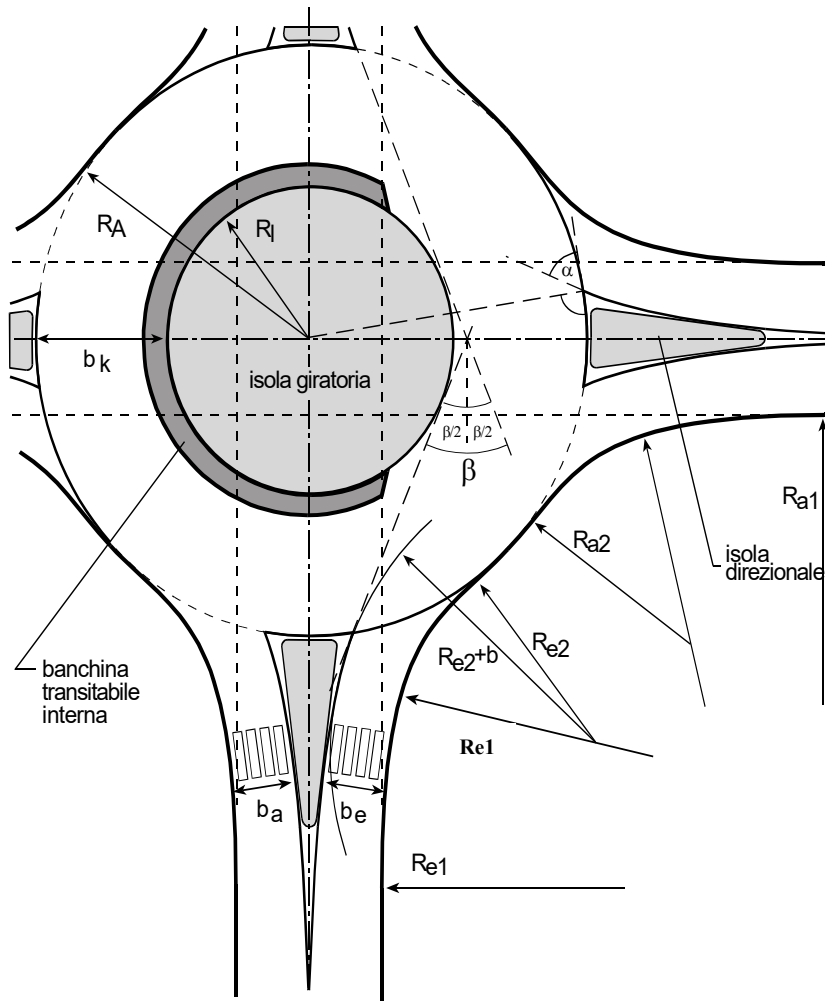
# Geometria delle rotatorie (12)



**R<sub>a1,2</sub>** – Il ciglio destro dell'anello di circolazione è raccordato con il ciglio della carreggiata del braccio di uscita per mezzo del raggio di uscita  $R_a$ . In analogia con quanto detto per il raggio di entrata, la geometria del bordo di connessione adotta una curva costituita da due archi di cerchio

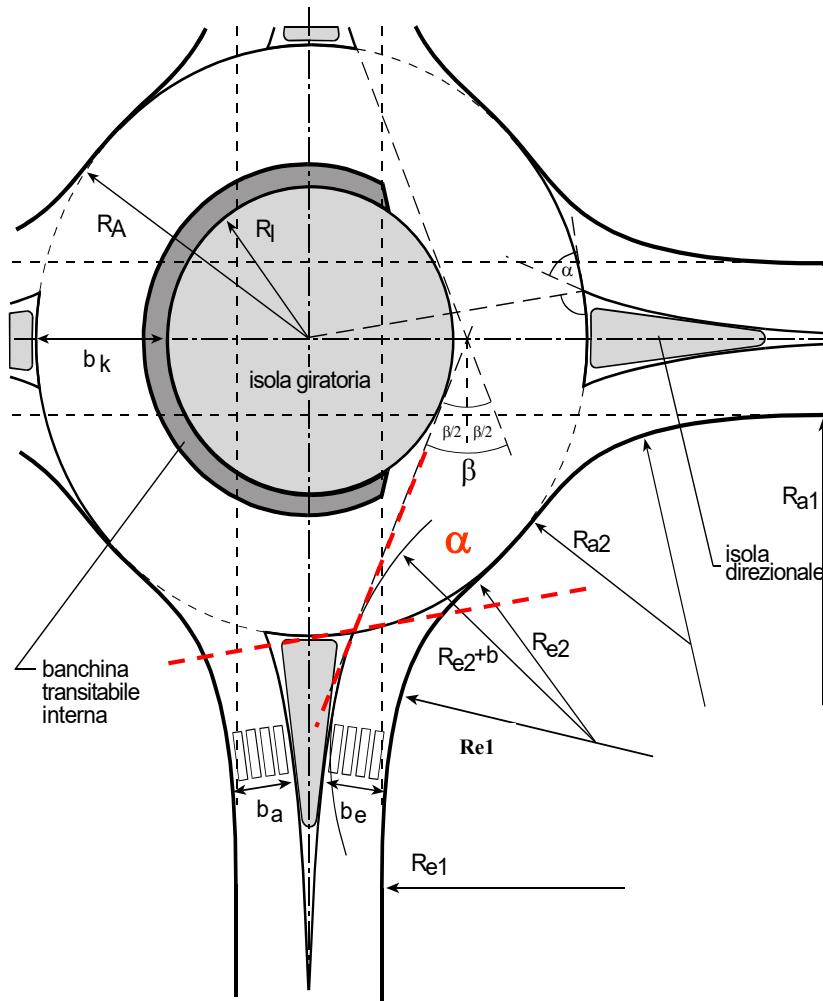
| Ambito urbano |                   | Ambito extraurbano |                   |
|---------------|-------------------|--------------------|-------------------|
| $R_{a,2}$ [m] | 12,00             | $R_{a,2}$ [m]      | 14,00             |
| $R_{a,1}$ [m] | $4 \cdot R_{e,2}$ | $R_{a,1}$ [m]      | $4 \cdot R_{e,2}$ |

# Geometria delle rotatorie (13)



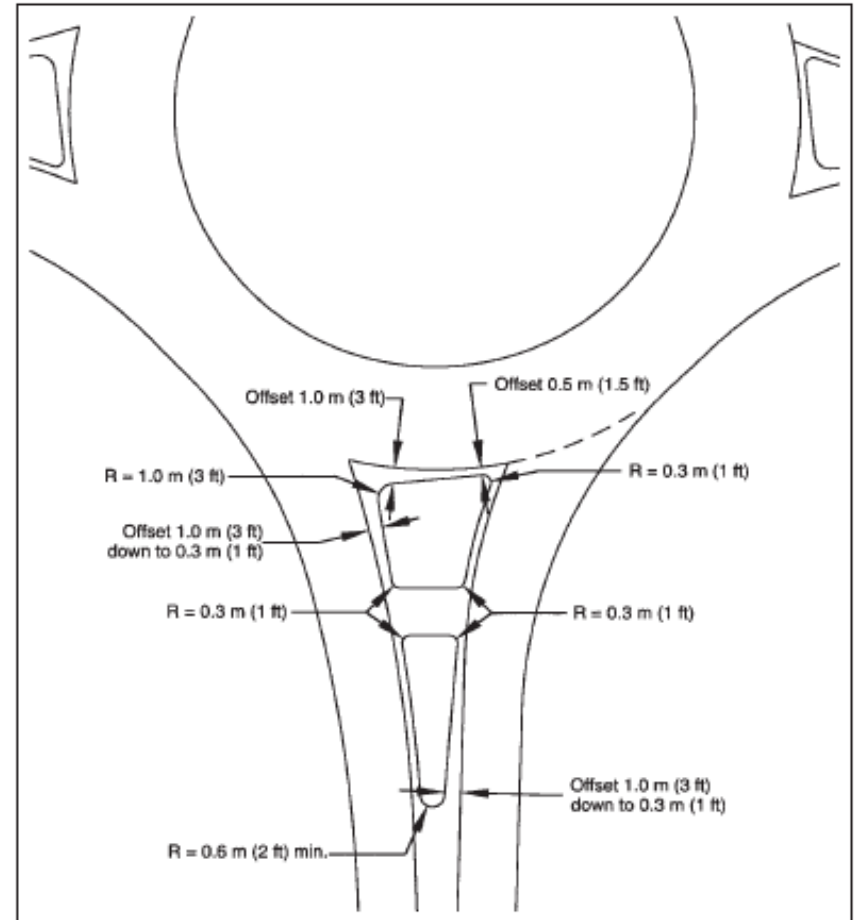
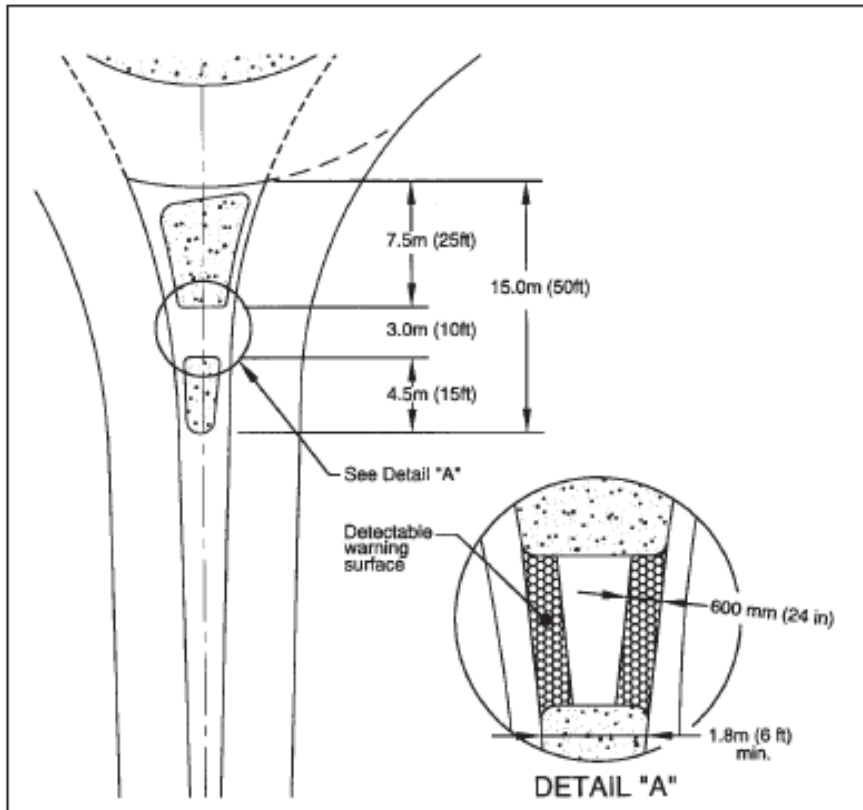
**La valutazione del valore della deviazione viene effettuata per mezzo dell'angolo di deviazione  $\beta$ . Per determinare la tangente al ciglio dell'isola centrale corrispondente all'angolo di deviazione  $\beta$ , bisogna aggiungere, al raggio di entrata  $R_{e,2}$ , un incremento  $b$  pari a 3,50 m. Per ciascun braccio di immissione si raccomanda un valore dell'angolo di deviazione  $\beta$  di almeno  $45^\circ$**

# Geometria delle rotatorie (13)



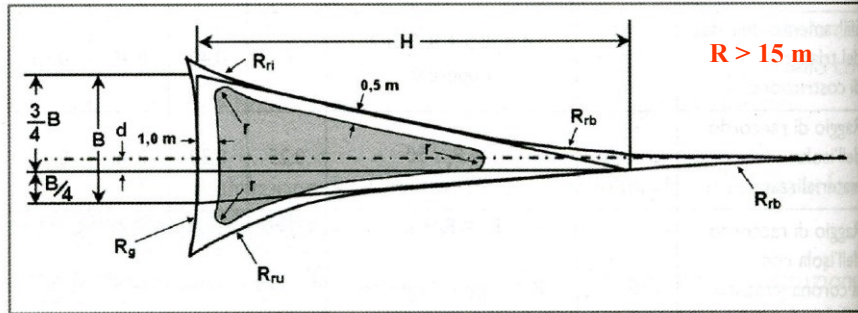
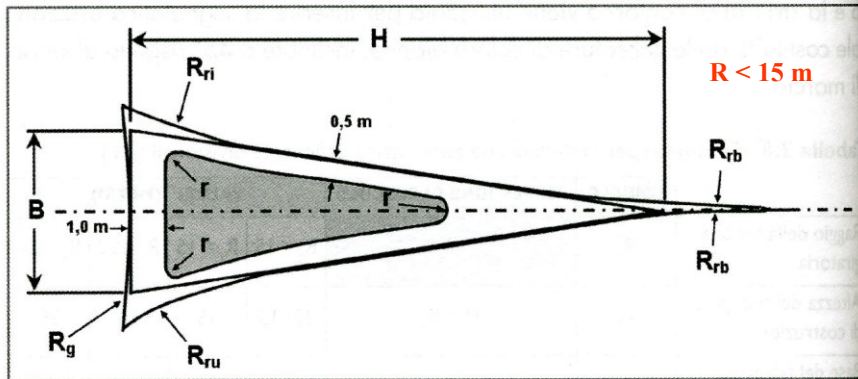
**$\alpha$**  – L'angolo di entrata  $\alpha$  caratterizza l'angolo d'intersezione tra la direzione di ingresso e la tangente all'anello di circolazione; tale angolo dovrebbe assumere valori tra a  $80^\circ$  e  $90^\circ$  per evitare velocità elevate e il mancato rispetto della precedenza; se non si possono evitare angoli di entrata minori di  $70^\circ$  è opportuno, per ragioni di sicurezza, realizzare una deviazione ben marcata per mezzo di un angolo  $\beta > 45^\circ$ .

# Geometria delle rotatorie (14)





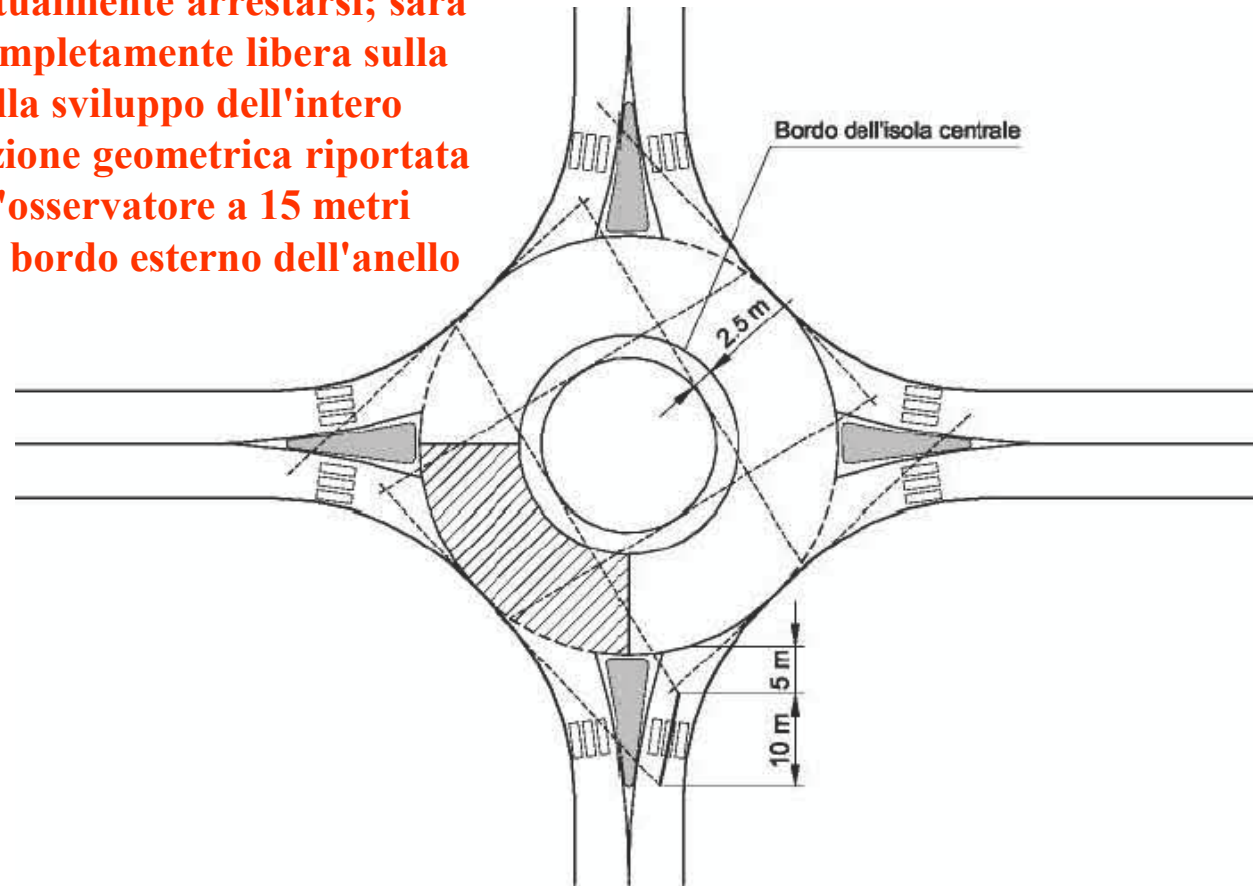
# Geometria delle rotatorie (15)



|   | SIMBOLO  | ESPRESSIONE DI CALCOLO  | VALORI (METRI) |            |            |            |
|---|----------|---|----------------|------------|------------|------------|
| Raggio della corona giratoria   | $R_g$    |   | $R_g < 15$     | $R_g = 15$ | $R_g = 20$ | $R_g = 25$ |
| Altezza del triangolo di costruzione  | H        | $H = R_g$   | 12÷15          | 15         | 20         | 25         |
| Base del triangolo di costruzione   | B        | $B = R_g / 4$   | 3÷3,75         | 3,75       | 5,00       | 6,25       |
| Sfalsamento dell'asse del triangolo di costruzione                                  | d        | $d = (0,5 + R_g/50)/2$<br>oppure 0  | 0              | 0,40       | 0,45       | 0,50       |
| Raggio di raccordo dell'isola materializzata  | r        | $r = R_g / 50$  | 0,25           | 0,30       | 0,40       | 0,50       |
| Raggio di raccordo dell'isola con la corona giratoria (in prossimità dell'ingresso) | $R_{ri}$ | $R_{ri} = R_i + L_i$<br>$R_i$ = raggio d'ingresso<br>$L_i$ = larghezza dell'entrata |                |            |            |            |
| Raggio di raccordo dell'isola con la corona giratoria (in prossimità dell'uscita)   | $R_{ru}$ | $R_{ru} = R_u + L_u$<br>$R_u$ = raggio d'uscita<br>$L_u$ = larghezza dell'uscita    |                |            |            |            |
| Raggio di raccordo dell'isola con l'asse del braccio                                | $R_{rb}$ | $R_{rb} = 4 \cdot R_g$  |                |            |            |            |

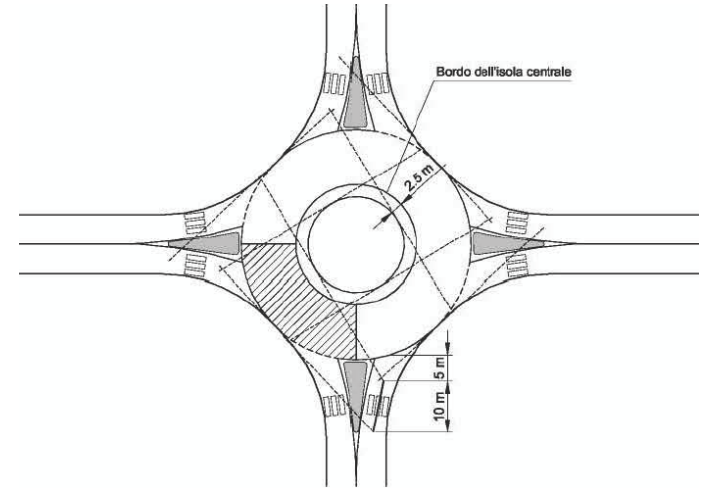
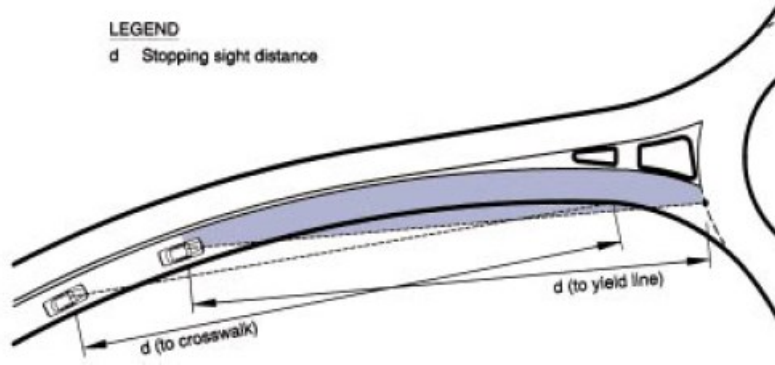
# Visuali libere (1)

Negli incroci a rotatoria, i conducenti che si approssimano alla rotatoria devono vedere i veicoli che percorrono l'anello centrale al fine di cedere ad essi la precedenza o eventualmente arrestarsi; sarà sufficiente una visione completamente libera sulla sinistra per un quarto della sviluppo dell'intero anello, secondo la costruzione geometrica riportata in Figura, posizionando l'osservatore a 15 metri dalla linea che delimita il bordo esterno dell'anello giratorio.

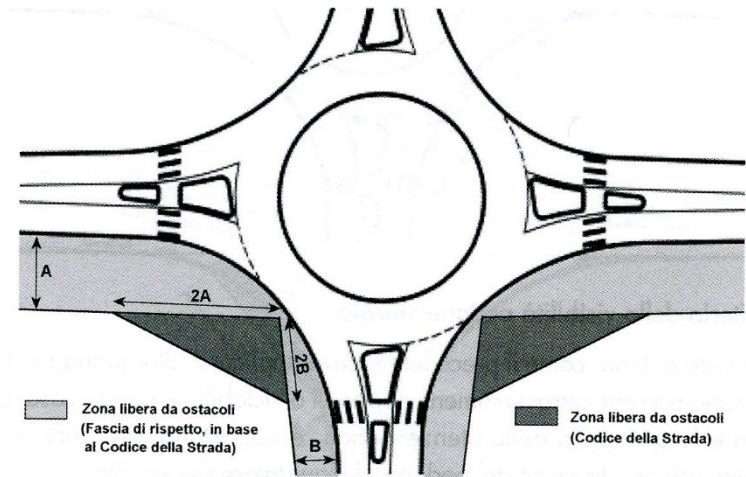
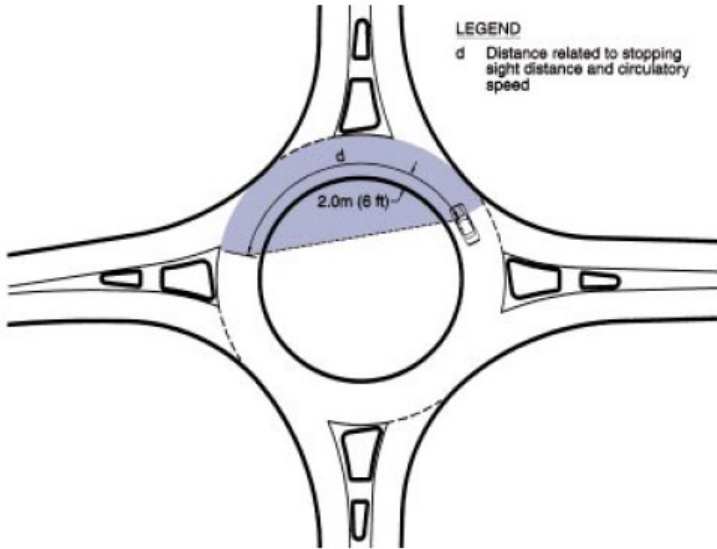


# Visuali libere (2)

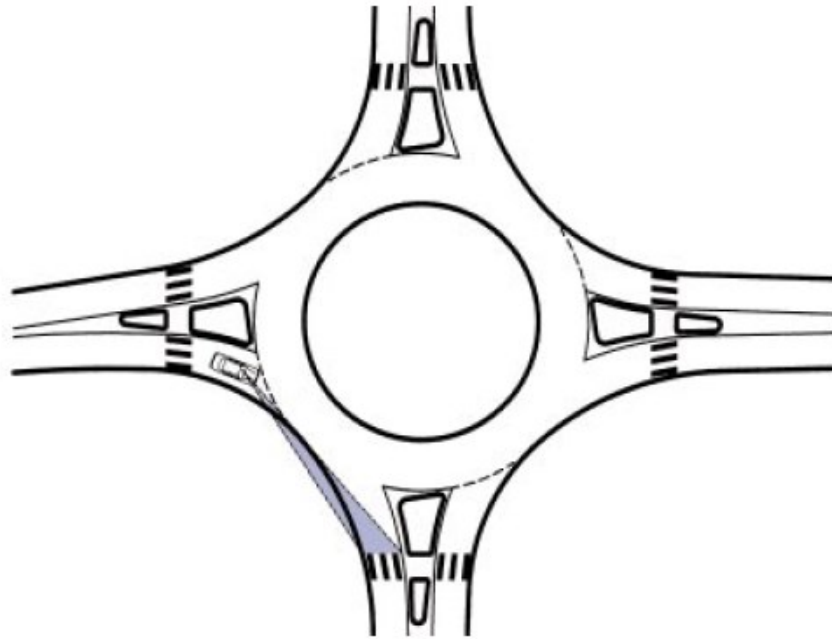
LEGEND  
d Stopping sight distance



LEGEND  
d Distance related to stopping sight distance and circulatory speed



## Visuali libere (3)





# Capacità rotatorie (1)

**La Federal Highway Association da alcune regole generali per le capacità di una rotatoria a singola corsia:**

**1800 veic/h circolanti sulla rotatoria;**

**1200 veic/h in uscita;**

**Le norme Francesi e Olandesi indicano come limite massimo, per una rotatoria a una sola corsia, 1500 veic/h circolanti + entranti in un braccio.**

**Mediamente si può approssimare la capacità totale entrante in una rotatoria a corsia singola a 2500 veic/h; 3500 – 4000 veic/h per una rotatoria a due corsie.**

# Capacità rotatorie (2)

**Capacità di un singolo braccio (o capacità di ingresso):** sono relazioni funzionali (modelli) che forniscono la capacità (numero massimo veicoli in ingresso) in funzione, oltreché delle caratteristiche geometriche della rotatoria anche dei flussi circolanti sull'anello e dei flussi uscenti.

**Capacità semplice:** è la somma dei flussi nei bracci di entrata di una rotatoria quando uno dei bracci abbia raggiunto la sua capacità, cioè determina la presenza permanente di veicoli in attesa.

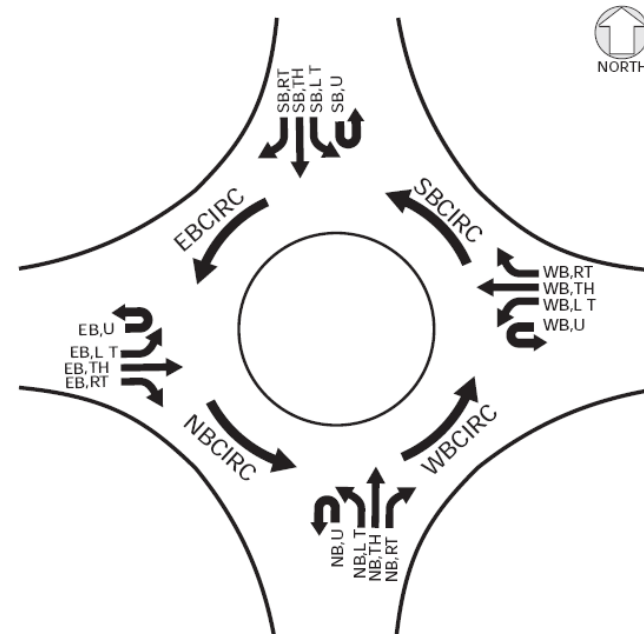
**Capacità totale della rotatoria** è la somma dei flussi in ingresso che distribuendosi fra le diverse uscite determinano il raggiungimento contemporaneo della capacità su tutti bracci.

$$V_{EB,circ} = V_{WB,LT} + V_{SB,LT} + V_{SB,TH} + V_{NB,U-turn} + V_{WB,U-turn} + V_{SB,U-turn}$$

$$V_{WB,circ} = V_{EB,LT} + V_{NB,LT} + V_{NB,TH} + V_{SB,U-turn} + V_{EB,U-turn} + V_{NB,U-turn}$$

$$V_{NB,circ} = V_{EB,LT} + V_{EB,TH} + V_{SB,LT} + V_{WB,U-turn} + V_{SB,U-turn} + V_{EB,U-turn}$$

$$V_{SB,circ} = V_{WB,LT} + V_{WB,TH} + V_{NB,LT} + V_{EB,U-turn} + V_{NB,U-turn} + V_{WB,U-turn}$$



# Capacità rotatorie (3)

$$R_c = \text{Riserva di capacità} = C - Q_e \quad \text{Riserva capacità percentuale} = R_c(\%) = \frac{C - Q_e}{C} 100$$

**C = Capacità ingresso**

**Q<sub>e</sub> = flusso in ingresso**

| Riserva di capacità (%) | Condizione di esercizio |
|-------------------------|-------------------------|
| RC > 30 %               | FLUIDO                  |
| 15 < RC ≤ 30 %          | SODDISFACENTE           |
| 0 < RC ≤ 15 %           | ALEATORIO               |
| RC ≤ 0 %                | SATURO/CRITICO          |

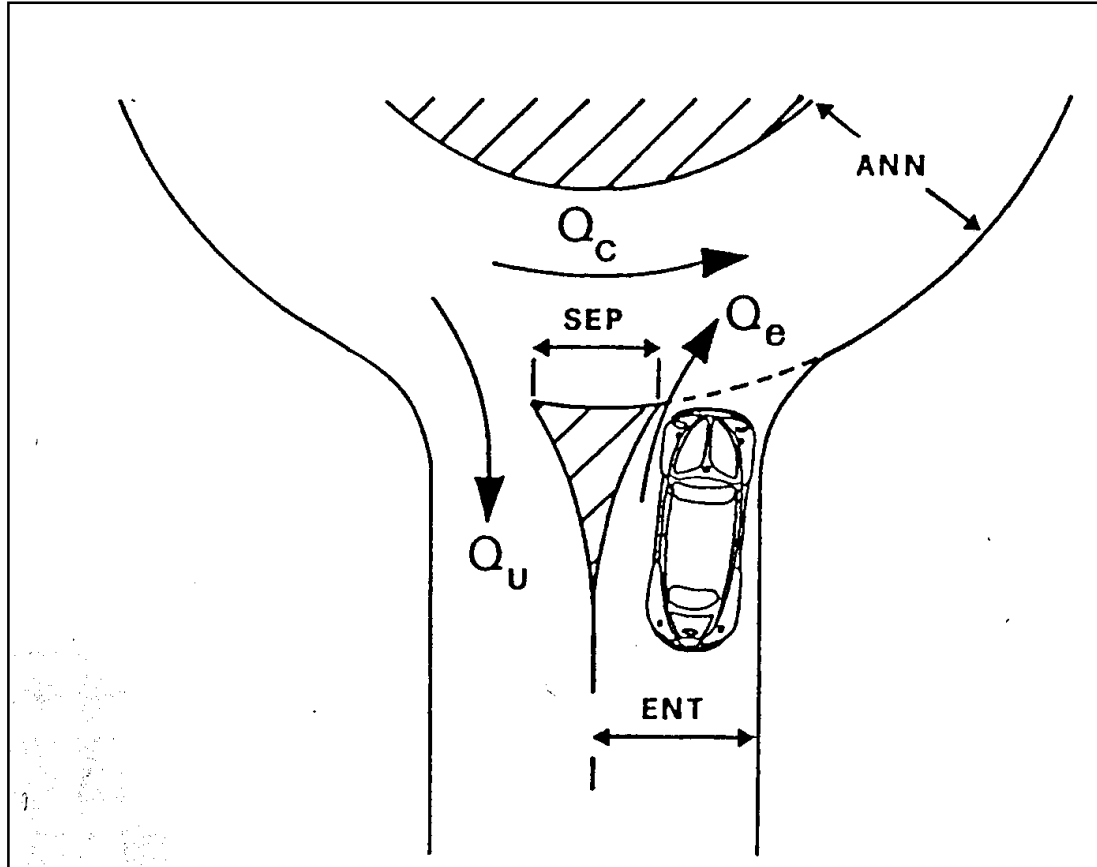
# Capacità rotatorie (4)

In letteratura esistono diversi metodi per il calcolo della capacità che si possono suddividere in tre tipi :

- a) **Metodi empirici (Es: Brilon, Kimber, Bovy, FHWA), si tratta di modelli di regressione calibrati con dati raccolti in sito e che usano le proprietà tipologiche o geometriche delle rotatorie come variabili indipendenti.**
- b) **Metodi basati sulla teoria del Gap Acceptance (Es: HCM, Tanner), si basano sul concetto che i veicoli della corrente secondaria (in questo caso l'ingresso) devono trovare un intervallo temporale sufficiente all'interno della corrente principale (in questo caso l'anello) per potersi immettere.**
- c) **Modelli di simulazione (Es: VISSIM, PARAMICS), si basano su programmi di simulazione che riproducono la situazione reale.**



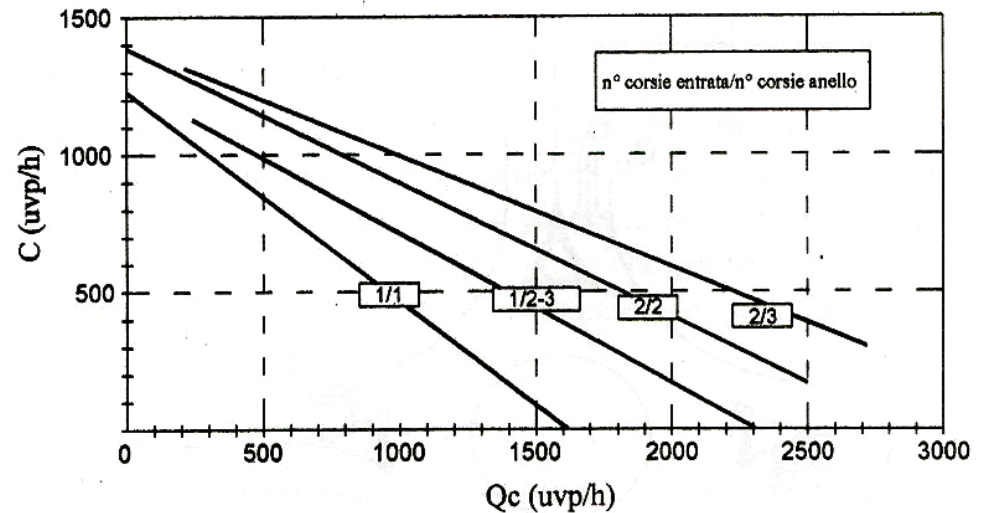
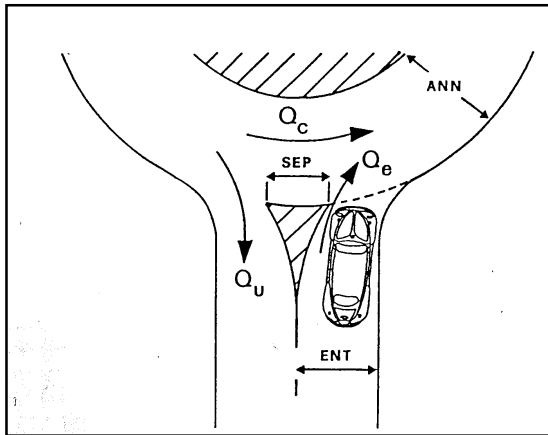
# Capacità rotatorie (5)



# Capacità rotatorie - metodo tedesco (Brilon)

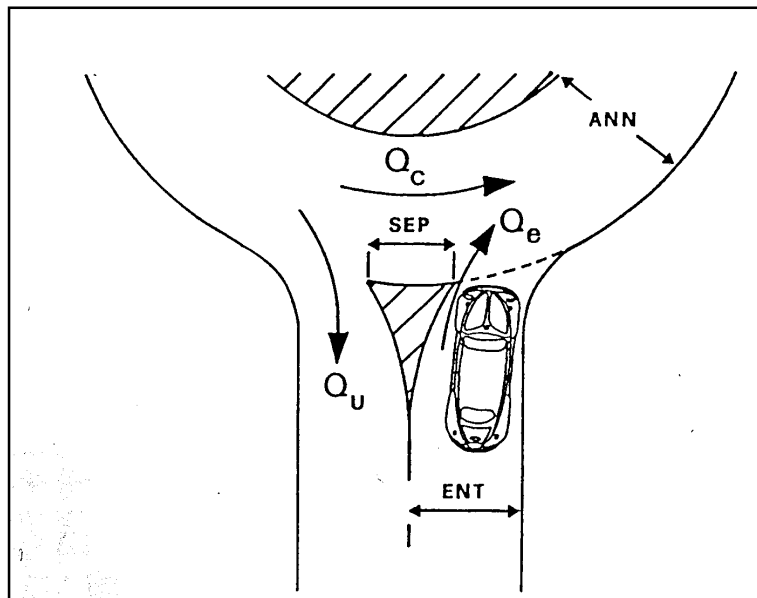
$$C_i = A - B \cdot Q_{C,i}$$

| Numero di corsie all'anello | Numero di corsie all'entrata | A    | B    | Numerosità dei campioni |
|-----------------------------|------------------------------|------|------|-------------------------|
| 3                           | 2                            | 1409 | 0,42 | 295                     |
| 2                           | 2                            | 1380 | 0,50 | 4574                    |
| 2-3                         | 1                            | 1250 | 0,53 | 879                     |
| 1                           | 1                            | 1218 | 0,74 | 1504                    |



# Metodo tedesco – Esempio (1)

Rotatoria a 4 bracci, con 2 corsie all'anello e 2 corsie agli ingressi



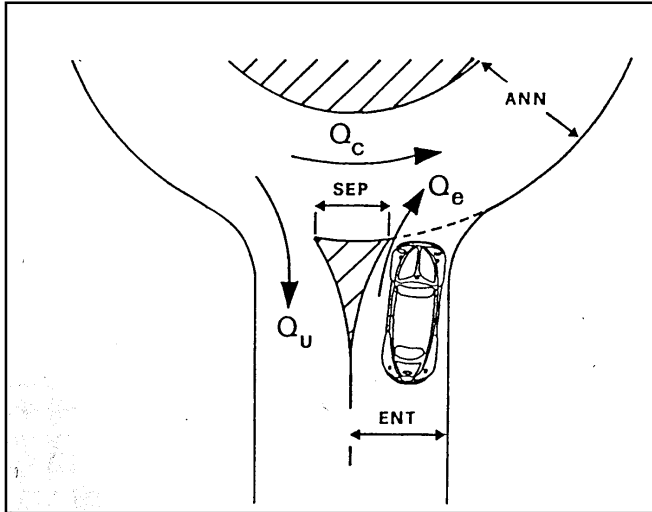
$$Q_{e,1} = 340 \text{ v/h} \quad Q_{u,1} = 380 \text{ v/h} \quad Q_{c,1} = 190 \text{ v/h}$$

$$Q_{e,2} = 236 \text{ v/h} \quad Q_{u,2} = 230 \text{ v/h} \quad Q_{c,2} = 300 \text{ v/h}$$

$$Q_{e,3} = 477 \text{ v/h} \quad Q_{u,3} = 322 \text{ v/h} \quad Q_{c,3} = 214 \text{ v/h}$$

$$Q_{e,4} = 152 \text{ v/h} \quad Q_{u,4} = 271 \text{ v/h} \quad Q_{c,4} = 418 \text{ v/h}$$

## Metodo tedesco – Esempio (2)



$$C_1 = 1380 - 0,5 * Q_{c,1} = 1380 - 0,5 * 190 = 1285 \text{ v/h}$$

$$C_2 = 1380 - 0,5 * Q_{c,2} = 1380 - 0,5 * 300 = 1230 \text{ v/h}$$

$$C_3 = 1380 - 0,5 * Q_{c,3} = 1380 - 0,5 * 214 = 1273 \text{ v/h}$$

$$C_4 = 1380 - 0,5 * Q_{c,4} = 1380 - 0,5 * 418 = 1171 \text{ v/h}$$

$$RC_1 = C_1 - Q_{e,1} = 1285 - 340 = 945 \text{ v/h}$$

$$RC_2 = C_2 - Q_{e,2} = 1230 - 236 = 994 \text{ v/h}$$

$$RC_3 = C_3 - Q_{e,3} = 1273 - 477 = 796 \text{ v/h}$$

$$RC_4 = C_4 - Q_{e,4} = 1171 - 152 = 1019 \text{ v/h}$$

$$(CT\%)_1 = 100 * Q_{e,1} / C_1 = 100 * 340 / 1285 = 26,46 \%$$

$$(CT\%)_2 = 100 * Q_{e,2} / C_2 = 100 * 236 / 1230 = 19,19 \%$$

$$(CT\%)_3 = 100 * Q_{e,3} / C_3 = 100 * 477 / 1273 = 37,47 \%$$

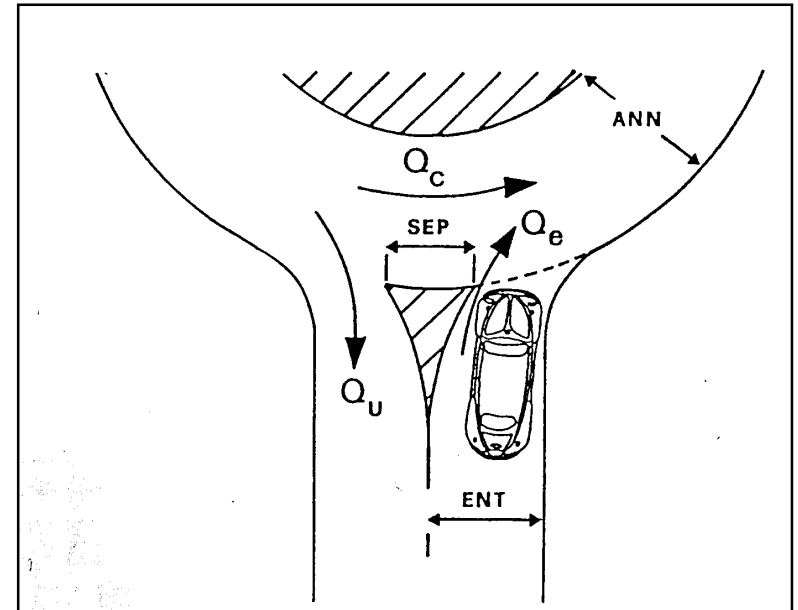
$$(CT\%)_4 = 100 * Q_{e,4} / C_4 = 100 * 152 / 1171 = 12,98 \%$$



# Metodo Francese, SETRA (1)

$$Q_u' = \frac{Q_u \cdot (15 - SEP)}{15}$$

$$Q_u' = 0 \quad \text{per} \quad SEP > 15$$

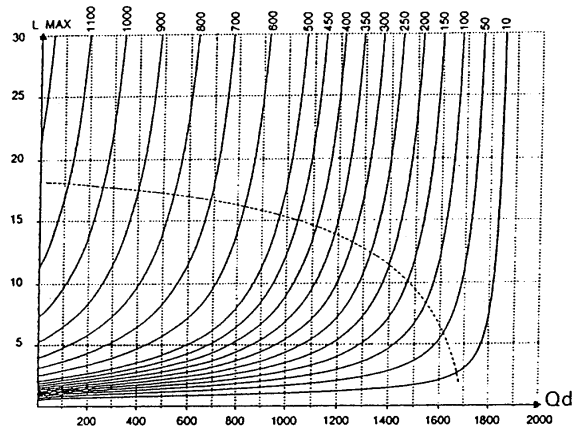


$$Q_d = \left( Q_c + \frac{2}{3} \cdot Q_u' \right) \cdot [1 - 0,085 \cdot (ANN - 8)]$$

$$C_i = (1330 - 0,7 \cdot Q_{d,i}) \cdot [1 + 0,1(ENT_i - 3,5)] \quad C_{p,i} = C_i - 150$$

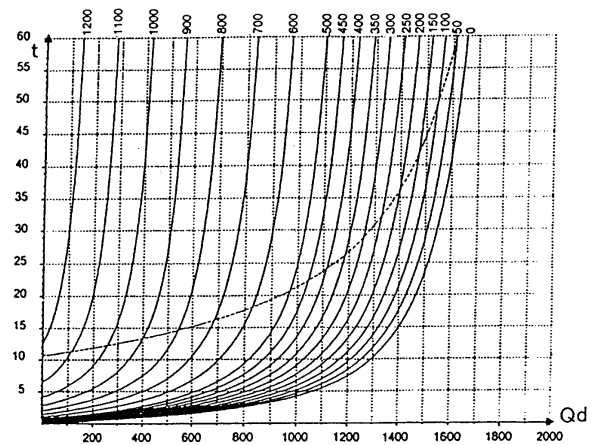
# Metodo Francese, SETRA (2)

Parametro: Q' (traffico in ingresso rapportato ad una entrata di 3,5 m)



La curva punteggiata indica il limite corrispondente alla capacità pratica Qe-150

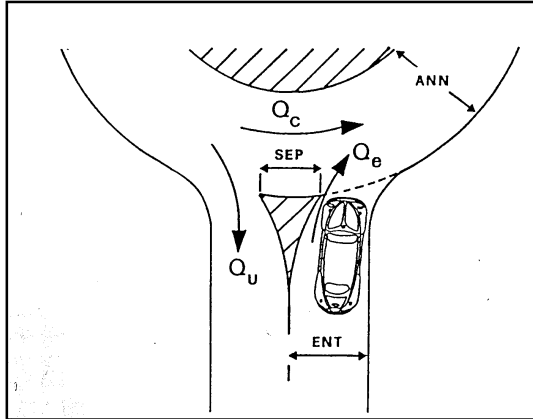
Parametro: Q' (traffico in ingresso rapportato ad una entrata di 3,5 m)



La curva punteggiata indica il limite corrispondente alla capacità pratica Qe-150

$$Q'_e = \frac{Q_e}{1 + 0,1(ENT - 3,5)}$$

# Metodo Francese, SETRA – Esempio (1)



**ANN = 8 m;**

**SEP<sub>1</sub> = SEP<sub>3</sub> = 2,37 m; SEP<sub>2</sub> = SEP<sub>4</sub> = 9,23 m**

**ENT<sub>1</sub> = ENT<sub>3</sub> = 7,00 m; ENT<sub>2</sub> = ENT<sub>4</sub> = 4,00 m**

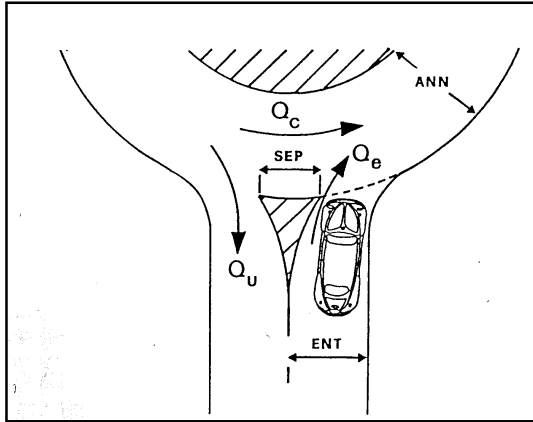
**Q<sub>e,1</sub> = 340 v/h Q<sub>u,1</sub> = 380 v/h Q<sub>c,1</sub> = 190 v/h**

**Q<sub>e,2</sub> = 236 v/h Q<sub>u,2</sub> = 230 v/h Q<sub>c,2</sub> = 300 v/h**

**Q<sub>e,3</sub> = 477 v/h Q<sub>u,3</sub> = 322 v/h Q<sub>c,3</sub> = 214 v/h**

**Q<sub>e,4</sub> = 152 v/h Q<sub>u,4</sub> = 271 v/h Q<sub>c,4</sub> = 418 v/h**

## Metodo Francese, SETRA – Esempio (2)



$$Q'_{u,1} = \frac{Q_{u,1} \cdot (15 - SEP_1)}{15} = \frac{380 \cdot (15 - 2,37)}{15} = 320 \text{ veic./h}$$

$$Q'_{u,2} = \frac{Q_{u,2} \cdot (15 - SEP_2)}{15} = \frac{230 \cdot (15 - 9,23)}{15} = 88 \text{ veic./h}$$

$$Q'_{u,3} = \frac{Q_{u,3} \cdot (15 - SEP_3)}{15} = \frac{322 \cdot (15 - 2,37)}{15} = 271 \text{ veic./h}$$

$$Q'_{u,4} = \frac{Q_{u,4} \cdot (15 - SEP_4)}{15} = \frac{271 \cdot (15 - 9,23)}{15} = 104 \text{ veic./h}$$



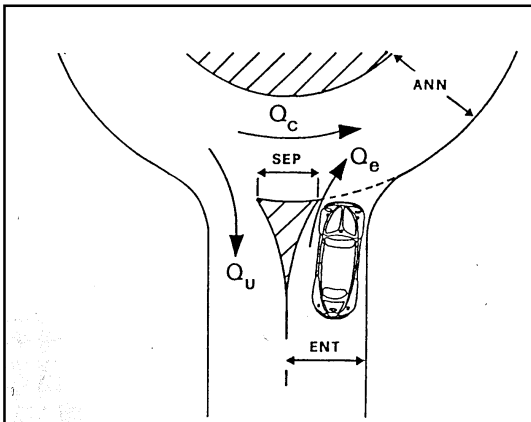
## Metodo Francese, SETRA – Esempio (3)

$$Q_{d,1} = \left( Q_{c,1} + \frac{2}{3} \cdot Q'_{u,1} \right) \cdot [1 - 0,085 \cdot (ANN - 8)] = \left( 190 + \frac{2}{3} \cdot 320 \right) \cdot [1 - 0,085 \cdot (8 - 8)] = 403 \text{ veic./h}$$

$$Q_{d,2} = \left( 300 + \frac{2}{3} \cdot 88 \right) \cdot [1 - 0,085 \cdot (8 - 8)] = 359 \text{ veic./h}$$

$$Q_{d,3} = \left( 214 + \frac{2}{3} \cdot 271 \right) \cdot [1 - 0,085 \cdot (8 - 8)] = 395 \text{ veic./h}$$

$$Q_{d,4} = \left( 418 + \frac{2}{3} \cdot 104 \right) \cdot [1 - 0,085 \cdot (8 - 8)] = 487 \text{ veic./h}$$



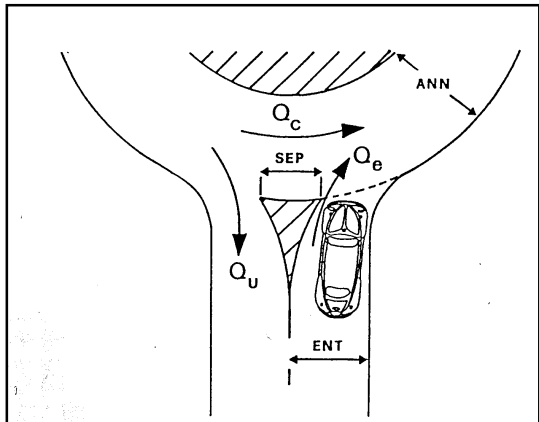
# Metodo Francese, SETRA – Esempio (4)

$$C_1 = (1330 - 0,7 \cdot Q_{d,1}) \cdot [1 + 0,1 \cdot (ENT_1 - 3,5)] = (1330 - 0,7 \cdot 403) \cdot [1 + 0,1 \cdot (7,00 - 3,5)] = 1415 \text{ veic./h}$$

$$C_2 = (1330 - 0,7 \cdot 359) \cdot [1 + 0,1 \cdot (4,00 - 3,5)] = 1133 \text{ veic./h}$$

$$C_3 = (1330 - 0,7 \cdot 395) \cdot [1 + 0,1 \cdot (7,00 - 3,5)] = 1422 \text{ veic./h}$$

$$C_4 = (1330 - 0,7 \cdot 487) \cdot [1 + 0,1 \cdot (4,00 - 3,5)] = 1039 \text{ veic./h}$$



# Metodo Francese, SETRA – Esempio (5)

$$Q'_{e,1} = \frac{Q_{e,1}}{1 + 0,1 \cdot (ENT_1 - 3,5)} = \frac{340}{1 + 0,1 \cdot (7,00 - 3,5)} = 252 \text{ veic/h}$$

$$Q'_{e,2} = \frac{236}{1 + 0,1 \cdot (4,00 - 3,5)} = 225 \text{ veic/h}$$

$$Q'_{e,3} = \frac{477}{1 + 0,1 \cdot (7,00 - 3,5)} = 353 \text{ veic/h}$$

$$Q'_{e,4} = \frac{152}{1 + 0,1 \cdot (4,00 - 3,5)} = 145 \text{ veic/h}$$

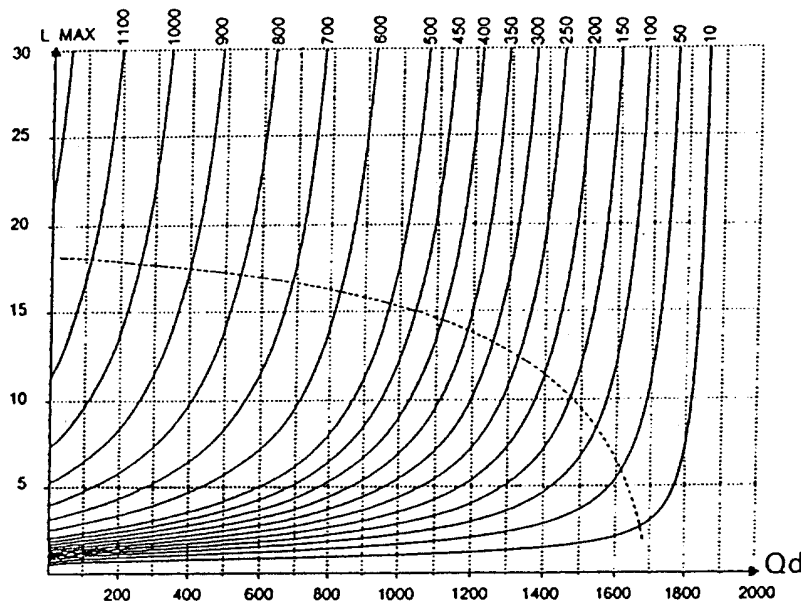
**L1 = 2 veic.**

**L2 = 2 veic.**

**L3 = 3 veic.**

**L4 = 3 veic.**

Parametro: Q' (traffico in ingresso rapportato ad una entrata di 3,5 m)



La curva punteggiata indica il limite corrispondente alla capacità pratica Qe-150

# Metodo Francese, SETRA – Esempio (5)

$$Q'_{e,1} = \frac{Q_{e,1}}{1 + 0,1 \cdot (ENT_1 - 3,5)} = \frac{340}{1 + 0,1 \cdot (7,00 - 3,5)} = 252 \text{ veic/h}$$

$$Q'_{e,2} = \frac{236}{1 + 0,1 \cdot (4,00 - 3,5)} = 225 \text{ veic/h}$$

$$Q'_{e,3} = \frac{477}{1 + 0,1 \cdot (7,00 - 3,5)} = 353 \text{ veic/h}$$

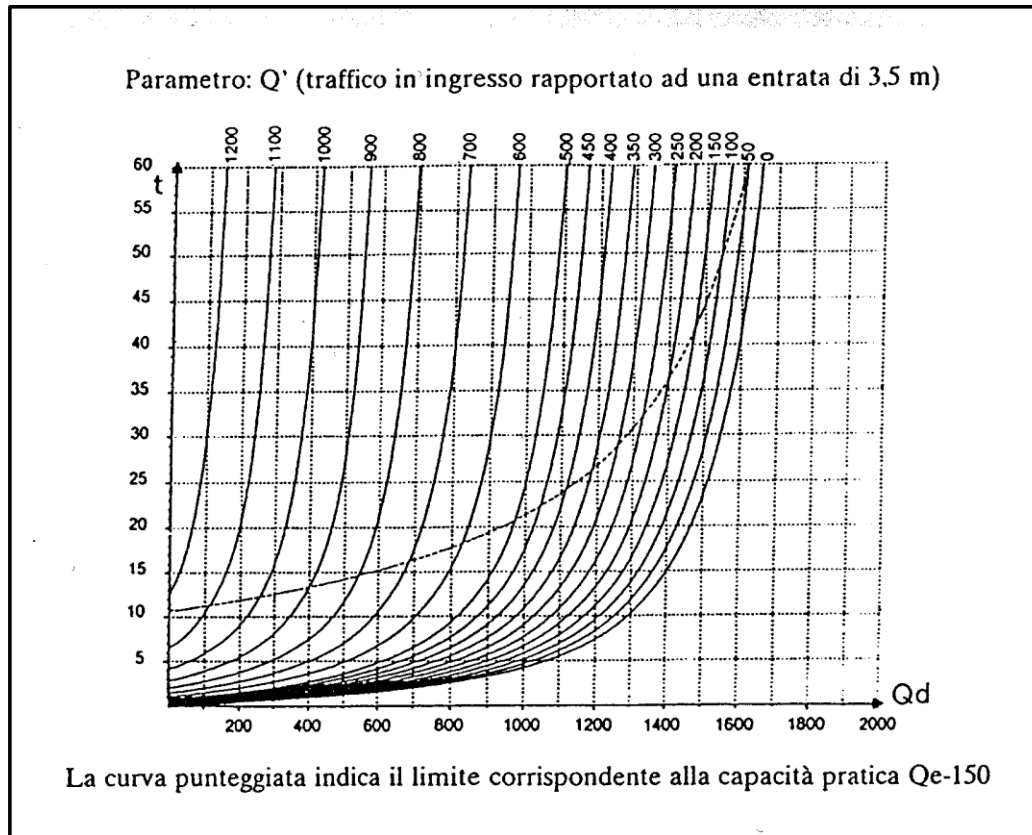
$$Q'_{e,4} = \frac{152}{1 + 0,1 \cdot (4,00 - 3,5)} = 145 \text{ veic/h}$$

$$E1 = 1 \text{ s}$$

$$E2 = 1 \text{ s}$$

$$E3 = 2 \text{ s}$$

$$E4 = 2 \text{ s}$$





## Metodo Francese, SETRA – Esempio (6)

$$C_{p,1} = C_1 - 150 = 1415 - 150 = 1265 \quad \text{veic./h}$$

$$C_{p,2} = C_2 - 150 = 1133 - 150 = 983 \quad \text{veic./h}$$

$$C_{p,3} = C_3 - 150 = 1272 - 150 = 1122 \quad \text{veic./h}$$

$$C_{p,4} = C_4 - 150 = 1039 - 150 = 889 \quad \text{veic./h}$$

$$(RC\%)_1 = \frac{C_{p,1} - Q_{e,1}}{C_{p,1}} \cdot 100 = \frac{1265 - 340}{1265} \cdot 100 = 73,12\% \quad \text{veic./h}$$

$$(RC\%)_2 = \frac{983 - 236}{983} \cdot 100 = 76,00\% \quad \text{veic./h}$$

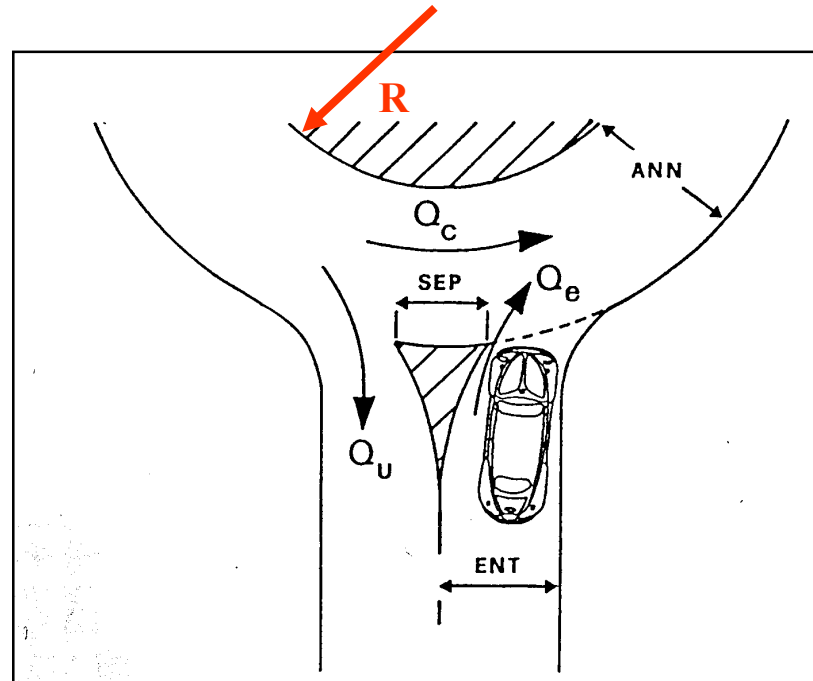
$$(RC\%)_3 = \frac{1272 - 477}{1272} \cdot 100 = 62,50\% \quad \text{veic./h}$$

$$(RC\%)_4 = \frac{889 - 152}{889} \cdot 100 = 82,90\% \quad \text{veic./h}$$

# Metodo Francese, CETUR

$$C = \gamma \cdot \left( 1500 - \frac{5}{6} \cdot Q_d \right)$$

$$Q_d = \beta \cdot Q_c + 0,2 \cdot Q_u$$



$\gamma = 1$  per ingressi con 1 corsia;  $\gamma = 1,5$  per ingressi a due o più corsie

$\beta = 1$  per  $ANN < 8$  m;  $\beta = 0,9$  per  $ANN \geq 8$  m e  $R < 20$  m;  $\beta = 0,7$  per  $ANN \geq 8$  m e  $R \geq 20$  m;

# Metodo Francese, CETUR - Esempio

$$Q_{d,1} = \beta \cdot Q_{c,1} + 0,2 \cdot Q_{u,1} = 0,7 \cdot 190 + 0,2 \cdot 380 = 209 \text{ veic./h}$$

$$Q_{d,2} = 0,7 \cdot 300 + 0,2 \cdot 230 = 256 \text{ veic./h}$$

$$Q_{e,1} = 340 \text{ v/h} \quad Q_{u,1} = 380 \text{ v/h} \quad Q_{c,1} = 190 \text{ v/h}$$

$$Q_{d,3} = 0,7 \cdot 214 + 0,2 \cdot 322 = 214 \text{ veic./h}$$

$$Q_{e,2} = 236 \text{ v/h} \quad Q_{u,2} = 230 \text{ v/h} \quad Q_{c,2} = 300 \text{ v/h}$$

$$Q_{d,4} = 0,7 \cdot 418 + 0,2 \cdot 271 = 346 \text{ veic./h}$$

$$Q_{e,3} = 477 \text{ v/h} \quad Q_{u,3} = 322 \text{ v/h} \quad Q_{c,3} = 214 \text{ v/h}$$

$$Q_{e,4} = 152 \text{ v/h} \quad Q_{u,4} = 271 \text{ v/h} \quad Q_{c,4} = 418 \text{ v/h}$$

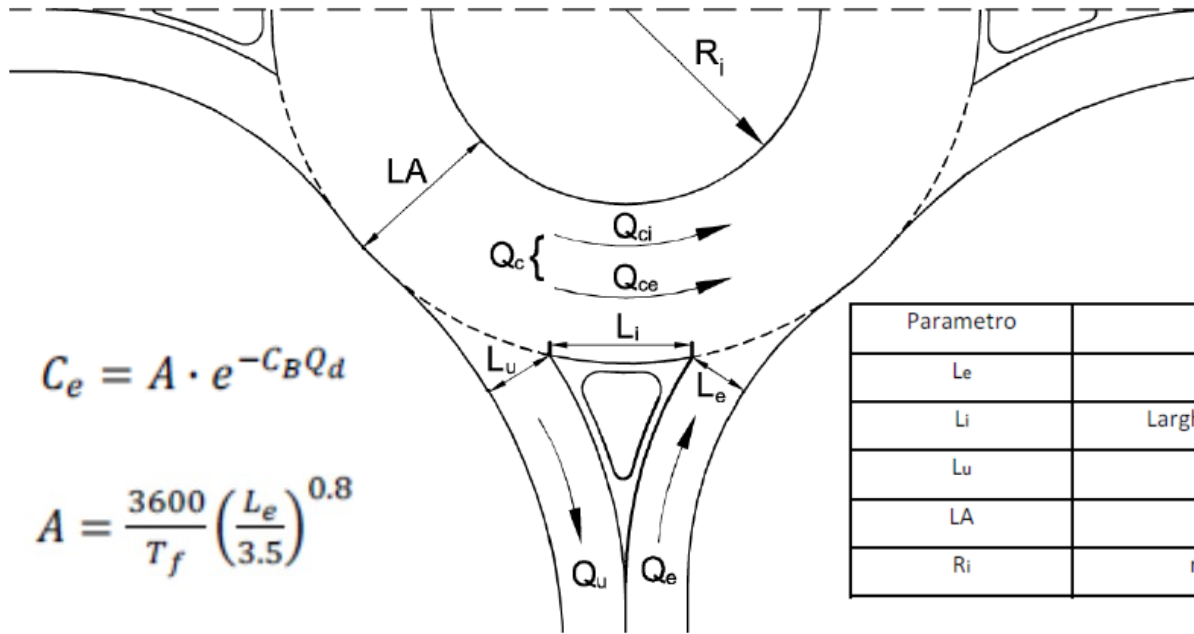
$$C_1 = \gamma \cdot \left( 1500 - \frac{5}{6} \cdot Q_{d,1} \right) = 1,5 \cdot \left( 1500 - \frac{5}{6} \cdot 209 \right) = 1988 \text{ veic./h}$$

$$C_2 = 1,5 \cdot \left( 1500 - \frac{5}{6} \cdot 256 \right) = 1930 \text{ veic./h}$$

$$C_3 = 1,5 \cdot \left( 1500 - \frac{5}{6} \cdot 214 \right) = 1982 \text{ veic./h}$$

$$C_{41} = 1,5 \cdot \left( 1500 - \frac{5}{6} \cdot 346 \right) = 1817 \text{ veic./h}$$

# Metodo Francese, Girabase (1)



$$C_e = A \cdot e^{-C_B Q_d}$$

$$A = \frac{3600}{T_f} \left( \frac{L_e}{3.5} \right)^{0.8}$$

| Parametro | Descrizione                    | Campo di variabilità |
|-----------|--------------------------------|----------------------|
| Le        | larghezza entrata              | 3 ÷ 11 m             |
| Li        | Larghezza isola spartitraffico | 0 ÷ 70 m             |
| Lu        | larghezza uscita               | 3,5 ÷ 10,5 m         |
| LA        | larghezza anello               | 4,5 ÷ 17,5 m         |
| Ri        | raggio isola centrale          | 3,5 ÷ 87,5 m         |

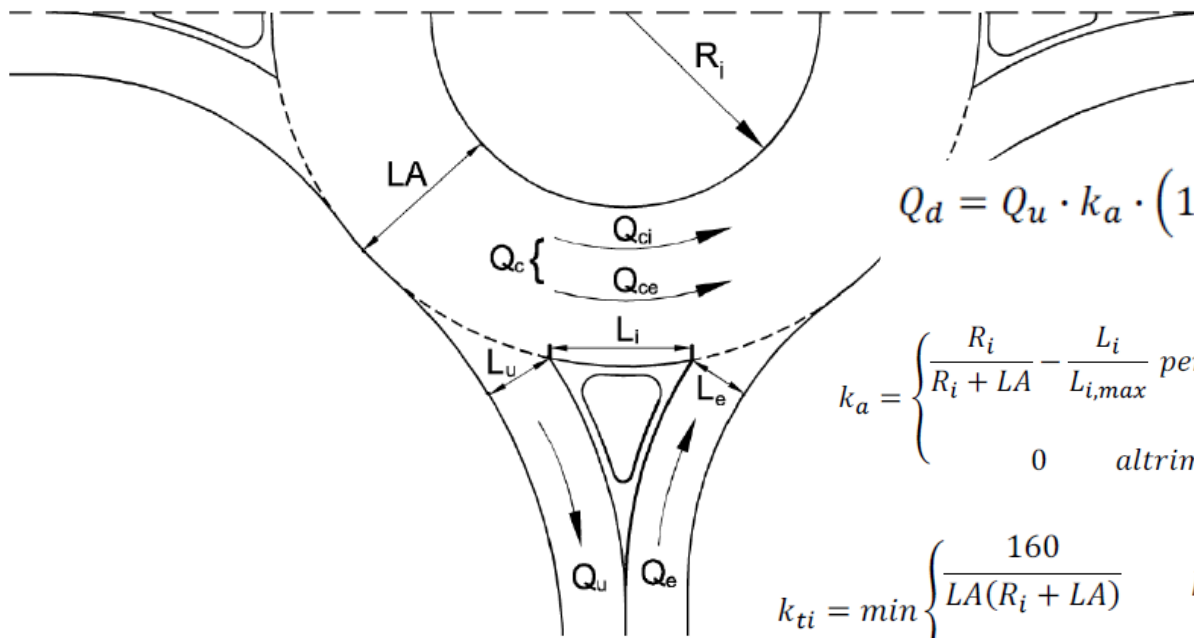
dove:

$T_f$  = tempo di follow-up = 2,05 s

$L_e$  = larghezza dell'entrata in prossimità della rotatoria, misurata perpendicolarmente alla direzione dell'ingresso (m)

$C_B$  = coefficiente che vale 3,525 per aree urbane e 3,625 per aree extraurbane

## Metodo Francese, Girabase (2)



$$Q_d = Q_u \cdot k_a \cdot \left(1 - \frac{Q_u}{Q_c + Q_u}\right) + Q_{ci} \cdot k_{ti} + Q_{ce} \cdot k_{te}$$

$$k_a = \begin{cases} \frac{R_i}{R_i + LA} - \frac{L_i}{L_{i,max}} & \text{per } L_i < L_{i,max} \\ 0 & \text{altrimenti} \end{cases} \quad L_{i,max} = 4,55 \cdot \sqrt{R_i + \frac{LA}{2}}$$

$$k_{ti} = \min \left\{ \frac{160}{LA(R_i + LA)}, 1 \right\} \quad k_{te} = \min \left\{ 1 - \frac{(LA - 8)}{LA} \cdot \left(\frac{R_i}{(R_i + LA)}\right)^2, 1 \right\}$$

$Q_d$ = traffico di disturbo in prossimità dell'ingresso considerato (veh/h)

$Q_u$ = flusso uscente (veh/h)

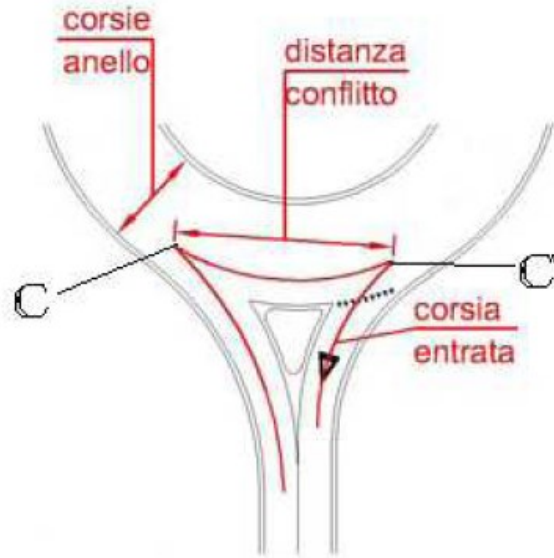
$Q_c = Q_{ci} + Q_{ce}$ = flusso di traffico circolante sull'anello in corrispondenza dell'ingresso considerato (veh/h)

$Q_{ci}$ = aliquota di traffico  $Q_c$  sulla semicarreggiata interna dell'anello (veh/h)

$Q_{ce}$ = aliquota di traffico  $Q_c$  sulla semicarreggiata esterna dell'anello (veh/h)



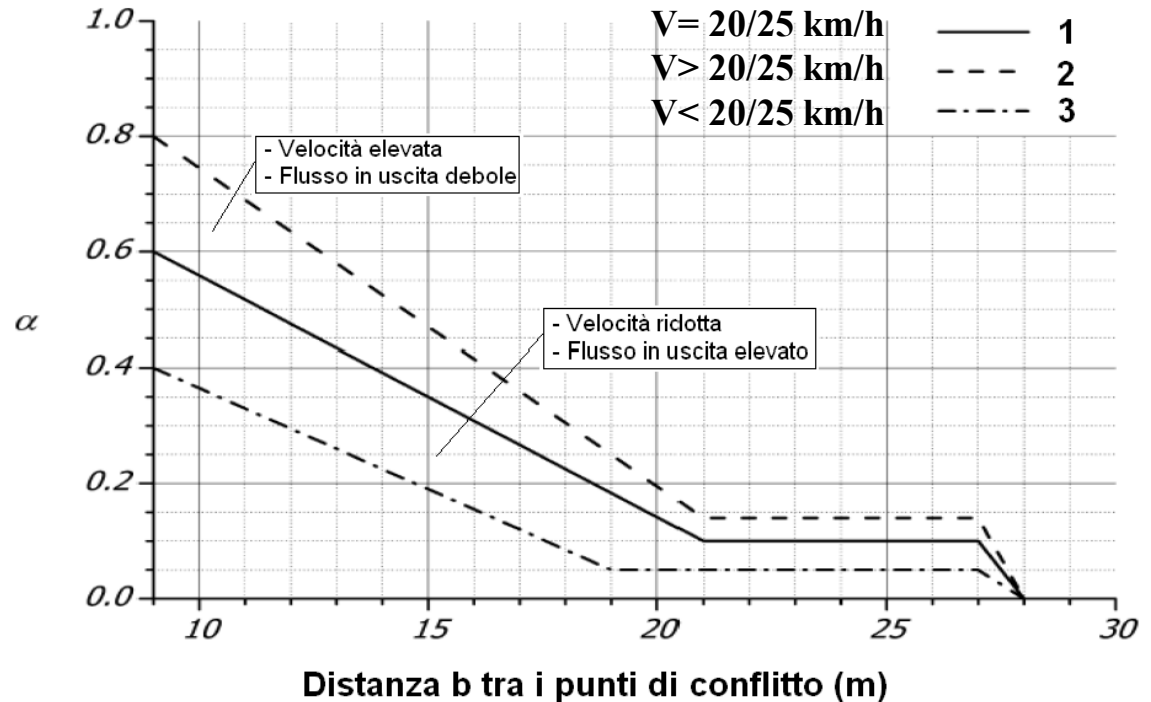
# Metodo Svizzero, Bovy (1)



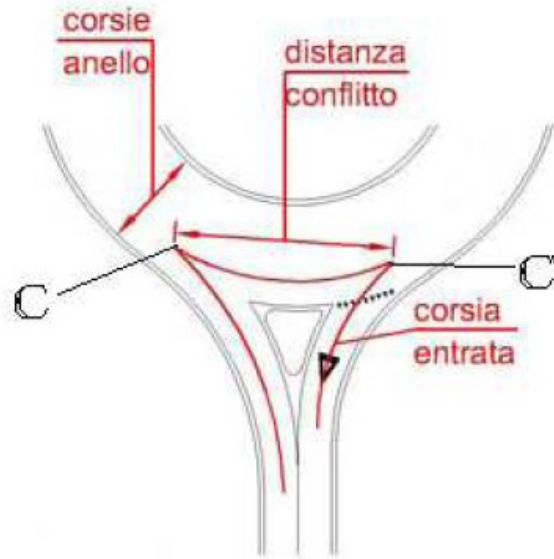
$$C_e = \frac{1}{\gamma} \left( 1500 - \frac{8}{9} Q_d \right) \quad [veh/h]$$

$$Q_d = \alpha Q_u + \beta Q_c \quad [veh/h]$$

| $\gamma$ | n° corsie in ingresso |
|----------|-----------------------|
| 1,0      | 1                     |
| 0,6-0,7  | 2                     |
| 0,5      | 3                     |



# Metodo Svizzero, Bovy (2)



$$C_e = \frac{1}{\gamma} \left( 1500 - \frac{8}{9} Q_d \right) \quad [veh/h]$$

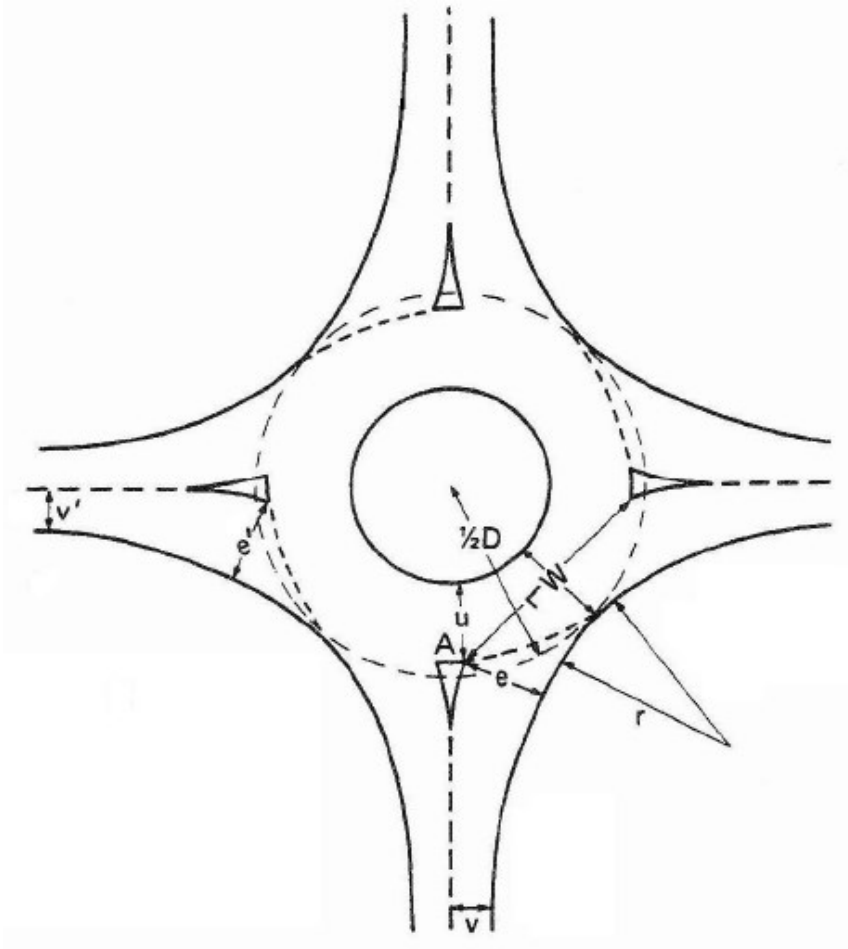
$$Q_d = \alpha Q_u + \beta Q_c \quad [veh/h]$$

| Tipo di veicolo                    | Coefficiente di equivalenza |
|------------------------------------|-----------------------------|
| 1 ciclo o motociclo<br>in ingresso | 0,2 autovetture             |
| 1 ciclo o motociclo<br>sull'anello | 0,8 autovetture             |
| 1 mezzo pesante o<br>autobus       | 2,0 autovetture             |

| $\beta$ | n° corsie sull'anello |
|---------|-----------------------|
| 0,9-1,0 | 1                     |
| 0,6-0,8 | 2                     |
| 0,5-0,6 | 3                     |

# Metodo inglese, Kimber (1)

$$C_e = k(F - f_c Q_c) \quad [veh/h]$$



$$\text{con:} \begin{cases} F = 303x \\ f_c = 0,210t_D(1 + 0,2x) \\ k = 1 - 0,00347(\Phi - 30) - 0,978 \left( \frac{1}{r} - 0,05 \right) \end{cases}$$

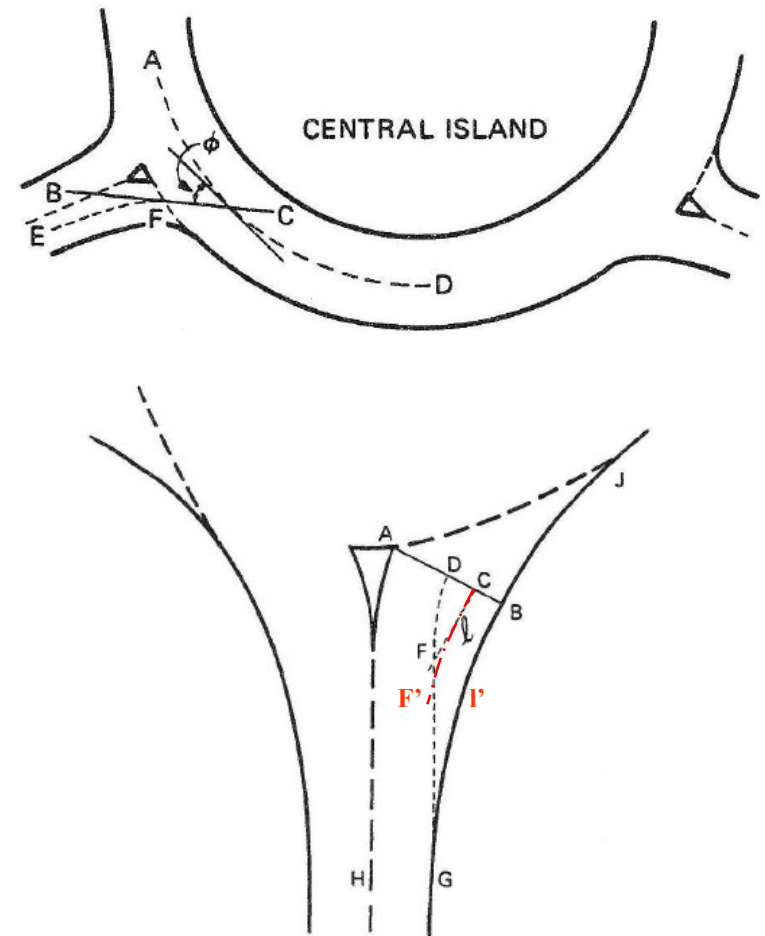
$$t_D = 1 + \frac{1}{2 \left[ 1 + \exp \left( \frac{(D - 60)}{10} \right) \right]}$$

$$x = v + \frac{(e - v)}{(1 + 2S)}$$

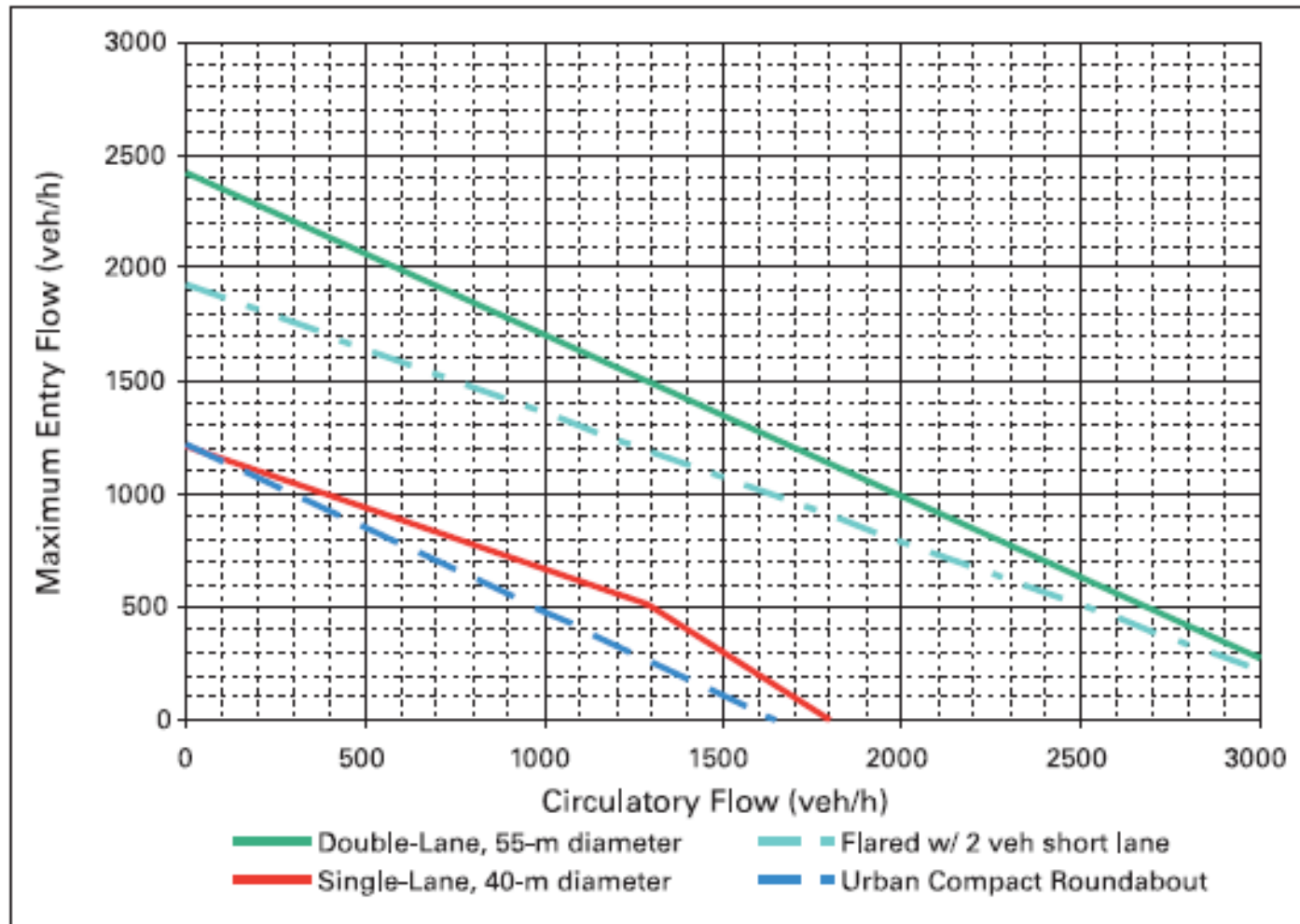
$$S = \frac{1,6(e - v)}{l'} = \frac{(e - v)}{l}$$

# Metodo inglese, Kimber (2)

| Parametro          | Descrizione                  | Campo di variabilità |
|--------------------|------------------------------|----------------------|
| e                  | larghezza entrata            | 3,6 ÷ 16,5 m         |
| v                  | larghezza corsia             | 1,9 ÷ 12,5 m         |
| e'                 | larghezza entrata precedente | 3,6 ÷ 15,0 m         |
| v'                 | larghezza corsia precedente  | 2,9 ÷ 12,5 m         |
| u                  | larghezza anello             | 4,9 ÷ 22,7 m         |
| l, l'              | lunghezza media svasatura    | 1,0 ÷ ∞ m            |
| S                  | acutezza svasatura           | 0 ÷ 2,9 m            |
| r                  | raggio curvatura entrata     | 3,4 ÷ ∞ m            |
| $\Phi$             | angolo d'entrata             | 0° ÷ 77°             |
| D=D <sub>ext</sub> | diametro cerchio inscritto   | 13,5 ÷ 171,6 m       |
| w                  | larghezza tronco di scambio  | 7,0 ÷ 26,0 m         |
| L                  | lunghezza tronco di scambio  | 9,0 ÷ 86,0 m         |



# Metodo FHWA - USA (1)

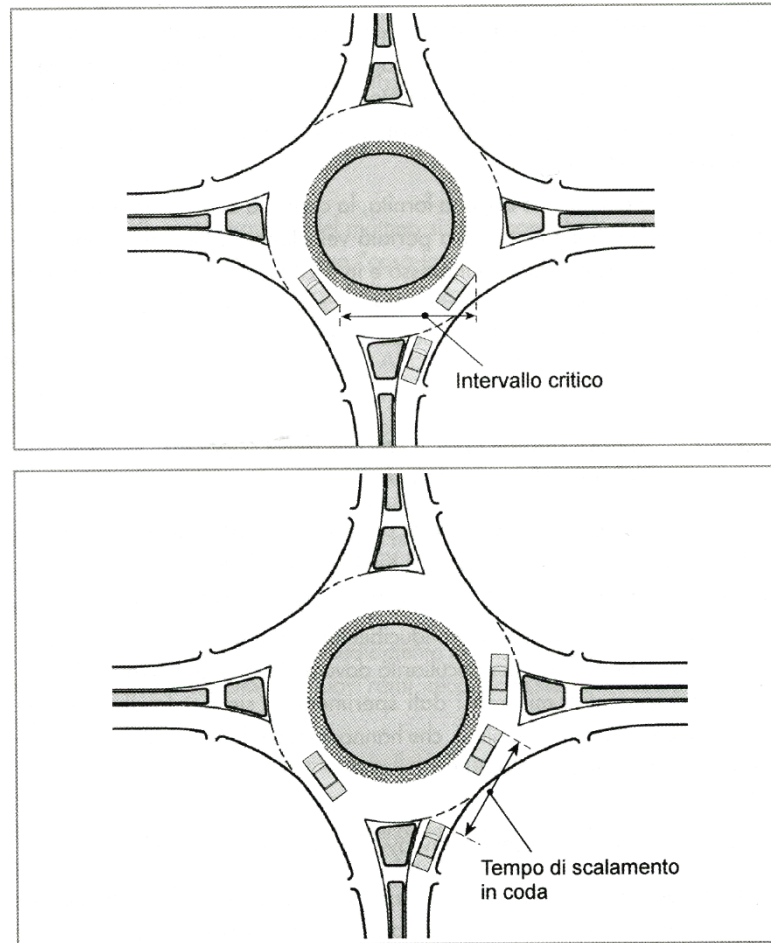




## Metodo FHWA - USA (2)

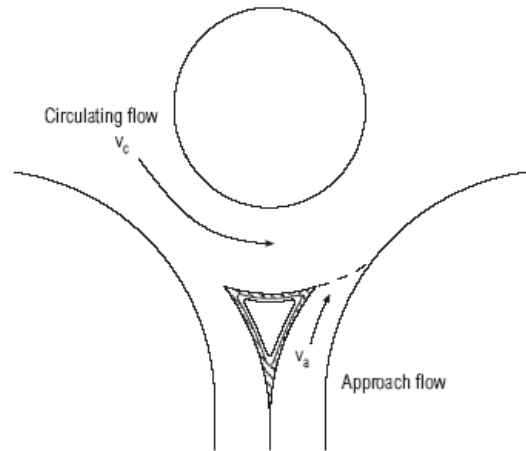
| Parametri geometrici | Rotatorie a singola corsia | Rotatorie a doppia corsia | Rotatorie urbane compatte                     |
|----------------------|----------------------------|---------------------------|---|
| D                    | 40 m                       | 55 m                      | Basato sul metodo di Brilon<br>Equazione 2.14 |
| $r_e$                | 20 m                       | 20 m                      |   |
| $\Phi$               | 30°                        | 30°                       |   |
| v                    | 4 m                        | 8 m                       |   |
| e                    | 4 m                        | 8 m                       |   |
| l'                   | 40 m                       | 40 m                      |   |
| $Q_e$                | 1212-0,5447 $Q_c$          | 2424-0,71 $Q_c$           | 1218-0,74 $Q_c$                               |

# Metodo HCM - USA (1)



# Metodo HCM - USA (2)

EXHIBIT 17-36. ANALYSIS ON ONE ROUNDABOUT LEG



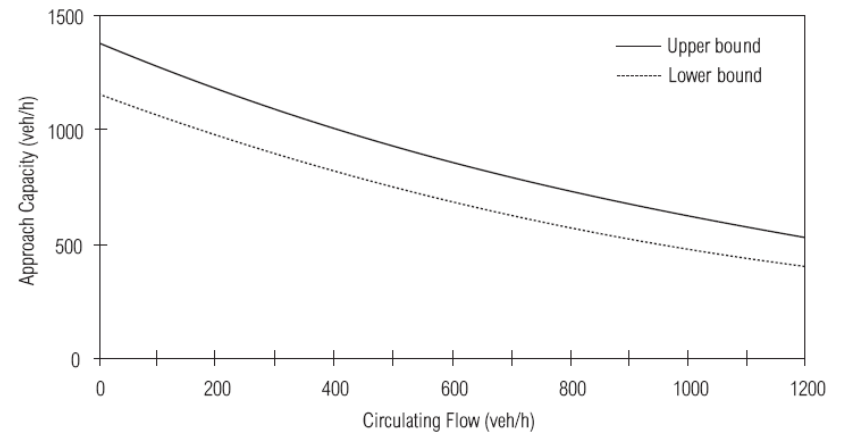
$$c_a = \frac{v_c e^{-v_c t_c / 3600}}{1 - e^{-v_c t_f / 3600}}$$

- $c_a$  = approach capacity (veh/h),
- $v_c$  = conflicting circulating traffic (veh/h),
- $t_c$  = critical gap (s), and
- $t_f$  = follow-up time (s).

EXHIBIT 17-37. CRITICAL GAP AND FOLLOW-UP TIMES FOR ROUNDABOUTS

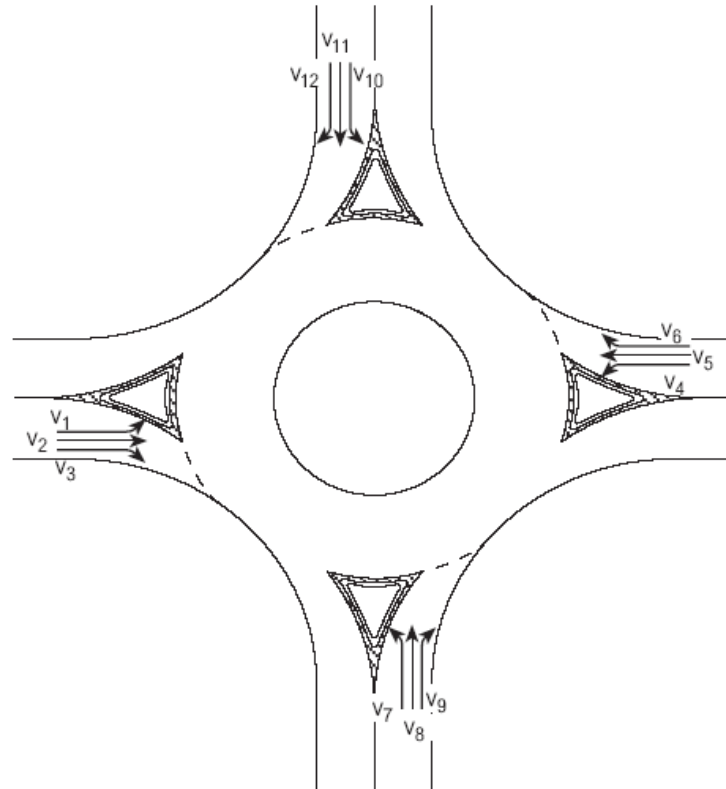
|             | Critical Gap (s) | Follow-Up Time (s) |
|-------------|------------------|--------------------|
| Upper bound | 4.1              | 2.6                |
| Lower bound | 4.6              | 3.1                |

EXHIBIT 17-38. ROUNDABOUT APPROACH CAPACITY



# Metodo HCM - USA (3)

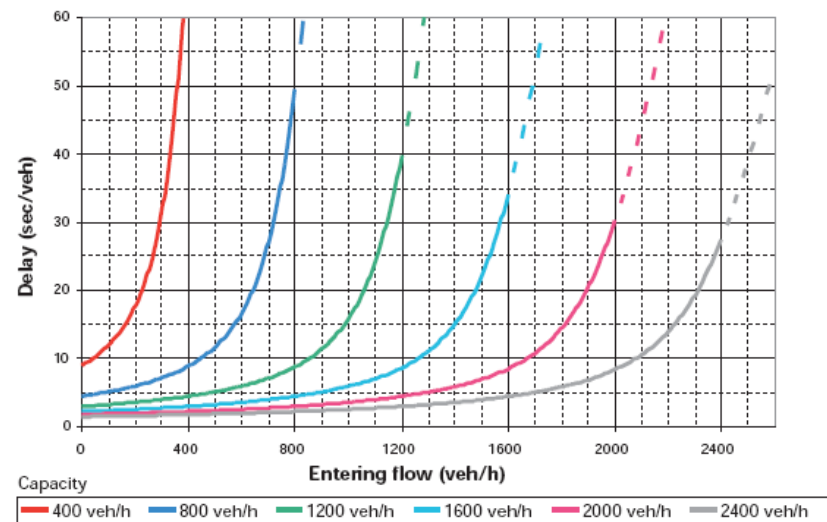
EXHIBIT 17-39. FLOW STREAM DEFINITIONS



# Metodo HMC - USA (4)

$$d = \frac{3600}{C_{m,x}} + 900T \times \left[ \frac{V_x}{C_{m,x}} - 1 + \sqrt{\left( \frac{V_x}{C_{m,x}} - 1 \right)^2 + \frac{\left( \frac{3600}{C_{m,x}} \right) \left( \frac{V_x}{C_{m,x}} \right)}{450T}} \right]$$

where:  $d$  = average control delay, sec/veh;  
 $V_x$  = flow rate for movement x, veh/h;  
 $C_{m,x}$  = capacity of movement x, veh/h; and  
 $T$  = analysis time period, h ( $T = 0.25$  for a 15-minute period).





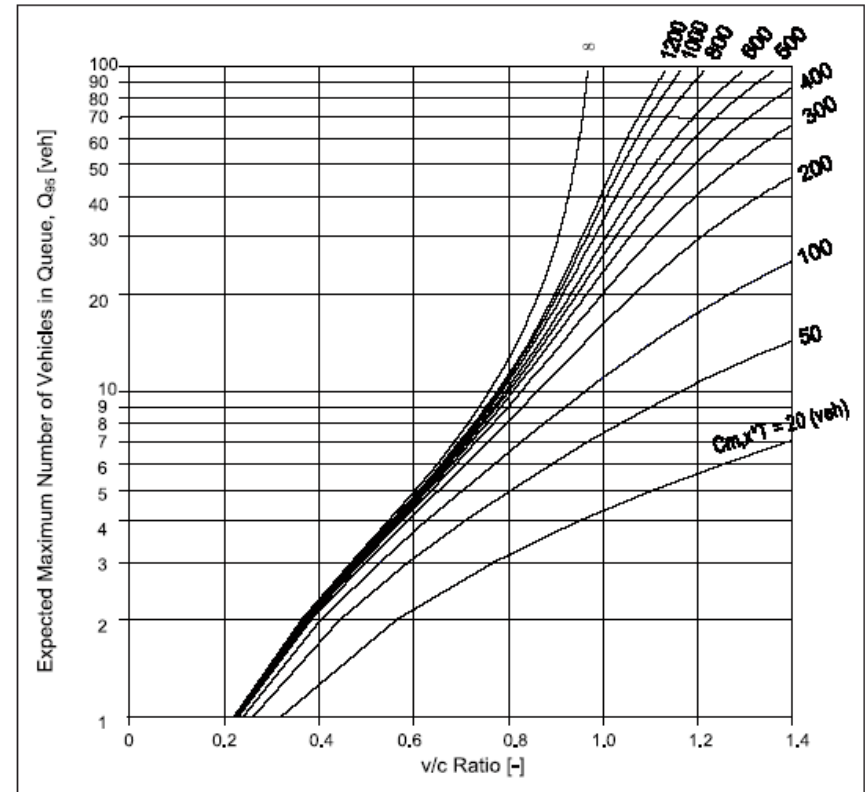
# Metodo HMC - USA (5)

$$L = v \cdot \frac{d}{3600}$$

$$Q_{95} \approx 900T \left[ \frac{v_x}{C_{m,x}} - 1 + \sqrt{\left(1 - \frac{v_x}{C_{m,x}}\right)^2 + \frac{\left(\frac{3600}{C_{m,x}}\right)\left(\frac{v_x}{C_{m,x}}\right)}{150T}} \right] \left(\frac{C_{m,x}}{3600}\right)$$

where:

- $Q_{95}$  = 95th percentile queue, veh,
- $v_x$  = flow rate for movement x, veh/h,
- $C_{m,x}$  = capacity of movement x, veh/h, and
- $T$  = analysis time period, h (0.25 for 15-minute period).



# Metodo USA – Esempio (1)

$$V_{a,1} = 340 \text{ v/h} \quad V_{u,1} = 380 \text{ v/h} \quad V_{c,1} = 190 \text{ v/h}$$

$$V_{a,2} = 236 \text{ v/h} \quad V_{u,2} = 230 \text{ v/h} \quad V_{c,2} = 300 \text{ v/h}$$

$$V_{a,3} = 477 \text{ v/h} \quad V_{u,3} = 322 \text{ v/h} \quad V_{c,3} = 214 \text{ v/h}$$

$$V_{a,4} = 152 \text{ v/h} \quad V_{u,4} = 271 \text{ v/h} \quad V_{c,4} = 418 \text{ v/h}$$

$$C_{a,i} = \frac{V_{c,i} \cdot e^{-V_{c,i} \cdot t_c / 3600}}{1 - e^{-V_{c,i} \cdot t_f / 3600}}$$

EXHIBIT 17-37. CRITICAL GAP AND FOLLOW-UP TIMES FOR ROUNDABOUTS

|             | Critical Gap (s) | Follow-Up Time (s) |
|-------------|------------------|--------------------|
| Upper bound | 4.1              | 2.6                |
| Lower bound | 4.6              | 3.1                |

$$C_{a,1,u} = \frac{V_{c,1} \cdot e^{-V_{c,1} \cdot t_c / 3600}}{1 - e^{-V_{c,1} \cdot t_f / 3600}} = \frac{190 \cdot e^{-1904,1/3600}}{1 - e^{-1902,6/3600}} = 1193 \text{ veic./h}$$

$$C_{a,1,l} = \frac{190 \cdot e^{-1904,6/3600}}{1 - e^{-1903,1/3600}} = 987 \text{ veic./h}$$

$$C_{a,2,u} = \frac{300 \cdot e^{-3004,1/3600}}{1 - e^{-3002,6/3600}} = 1094 \text{ veic./h}$$

$$C_{a,2,l} = \frac{300 \cdot e^{-3004,6/3600}}{1 - e^{-3003,1/3600}} = 898 \text{ veic./h}$$

$$C_{a,3,u} = \frac{214 \cdot e^{-2144,1/3600}}{1 - e^{-2142,6/3600}} = 1171 \text{ veic./h}$$

$$C_{a,3,l} = \frac{214 \cdot e^{-2144,6/3600}}{1 - e^{-2143,1/3600}} = 967 \text{ veic./h}$$

$$C_{a,4,u} = \frac{418 \cdot e^{-4184,1/3600}}{1 - e^{-4182,6/3600}} = 996 \text{ veic./h}$$

$$C_{a,4,l} = \frac{418 \cdot e^{-4184,6/3600}}{1 - e^{-4183,1/3600}} = 810 \text{ veic./h}$$

## Metodo USA – Esempio (2)

$$C_{m,1} = 1090 \text{ v/h}; C_{m,2} = 996 \text{ v/h}; C_{m,3} = 1069 \text{ v/h}; C_{m,4} = 903 \text{ v/h};$$

$$d_1 = \frac{3600}{C_{m,1}} + 900 \cdot T \cdot \left[ \frac{V_1}{C_{m,1}} - 1 + \sqrt{\left( \frac{V_1}{C_{m,1}} - 1 \right)^2 + \frac{3600 \cdot V_1}{C_{m,1} \cdot C_{m,1}}} \right] = \frac{3600}{1090} + 900 \cdot 0,25 \cdot \left[ \frac{340}{1090} - 1 + \sqrt{\left( \frac{340}{1090} - 1 \right)^2 + \frac{3600 \cdot 340}{1090 \cdot 1090}} \right] = 4,793 \text{ [s]}$$

$$L_1 = V_1 \cdot \frac{d_1}{3600} = 340 \cdot \frac{4,793}{3600} = 0,453 \text{ [veic.]}$$

$$Q_{95} = 900 \cdot T \cdot \left[ \frac{V_1}{C_{m,1}} - 1 + \sqrt{\left( \frac{V_1}{C_{m,1}} - 1 \right)^2 + \frac{3600 \cdot V_1}{C_{m,1} \cdot C_{m,1}}} \right] \cdot \frac{C_{m,1}}{3600} = +900 \cdot 0,25 \cdot \left[ \frac{340}{1090} - 1 + \sqrt{\left( \frac{340}{1090} - 1 \right)^2 + \frac{3600 \cdot 340}{1090 \cdot 1090}} \right] \cdot \frac{1090}{3600} = 1,341 \text{ [veic.]}$$

# Confronti e considerazioni

|          | Braccio 1 | Braccio 2 | Braccio 3 | Braccio 4 |
|----------|-----------|-----------|-----------|-----------|
| Germania | 1285      | 1230      | 1273      | 1171      |
| SETRA    | 1415      | 1133      | 1422      | 1039      |
| CETUR    | 1988      | 1930      | 1982      | 1817      |
| USA      | 1090      | 996       | 1069      | 903       |

# Capacità in presenza di flusso pedonale

$$C_{ped} = C_e \cdot M$$

**Metodo di Brilon, Struwe e Drews**

dove M dipende dalla configurazione degli ingressi:

- Entrata ad 1 corsia

$$M = \frac{1119,5 - 0,715Q_c - 0,644Q_{ped} + 0,00073Q_cQ_{ped}}{1069 - 0,65Q_c}$$

- Entrata a 2 corsie

$$M = \frac{1260,6 - 0,381Q_{ped} - 0,329Q_c}{1380 - 0,50Q_c}$$

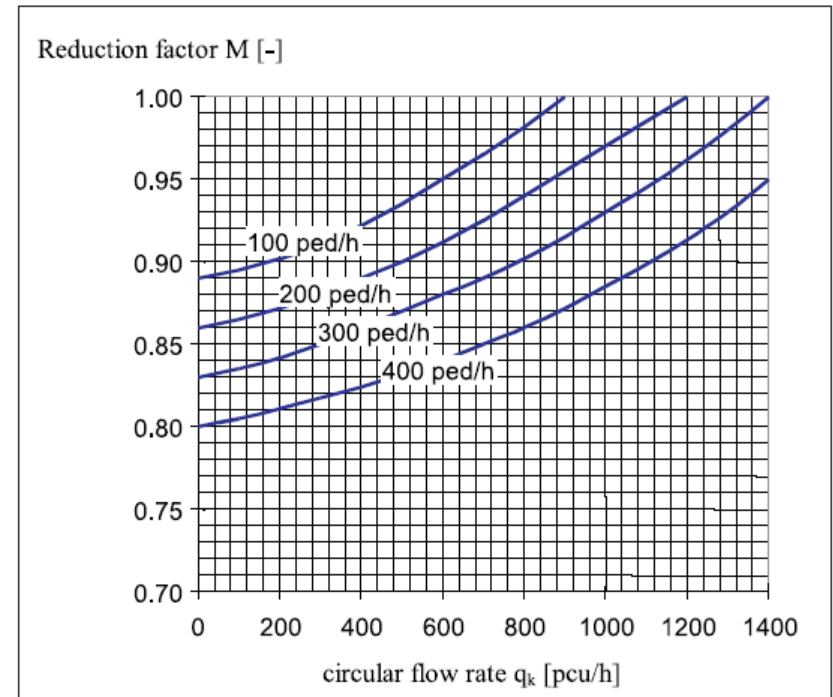
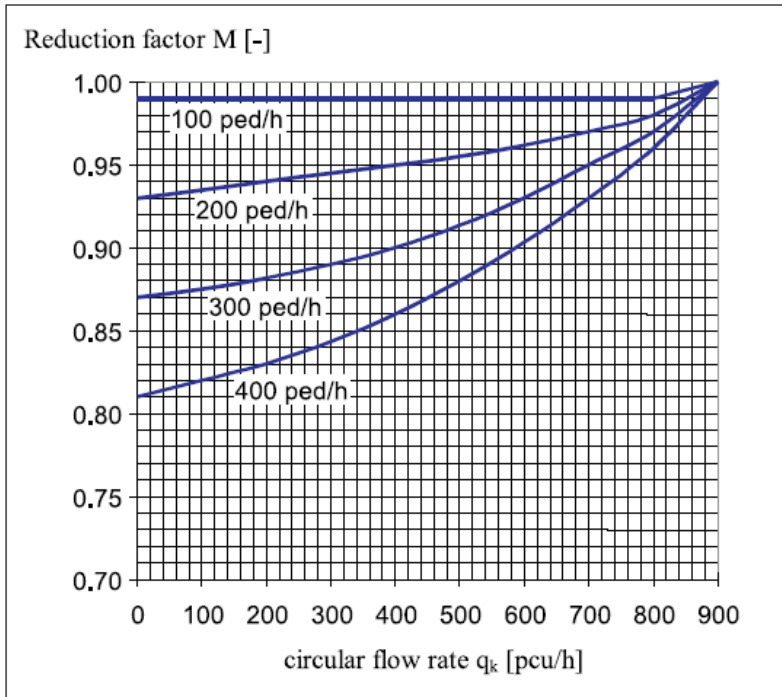
con:

$Q_c$  = flusso circolante all'anello in prossimità dell'ingresso considerato (veh/h)

$Q_{ped}$  = flusso di traffico pedonale in attraversamento del braccio considerato (ped/h)



# Capacità in presenza di flusso pedonale

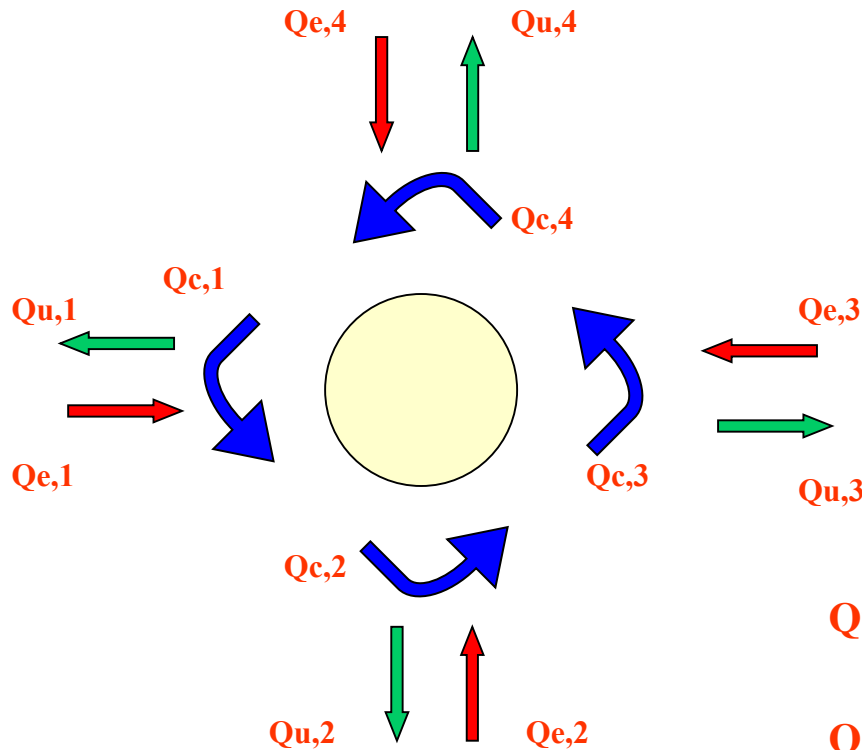


# Capacità delle uscite e dell'anello

Da osservazioni sperimentali per le uscite, si sono ricavati valori del limite di capacità per corsia di 1200÷1400 veh/h.

| Tipo di rotatoria   | Numero di corsie agli ingressi | Capacità dell'anello [veh/h] |
|---|--------------------------------|------------------------------|
| Rotatorie ad 1 corsia all'anello (minirotorie e rotatorie compatte) | 1                              | 1600                         |
| Rotatorie compatte con 2 corsie all'anello                          | 1                              | 1600                         |
|   | 2                              | 1600                         |
| Grandi rotatorie  | 1                              | 2000                         |
|   | 2                              | 2500                         |

# Calcolo flussi



| Uscite<br>Ingressi | 1    | 2    | 3    | 4    |
|--------------------|------|------|------|------|
| 1                  | 0,00 | 0,18 | 0,65 | 0,17 |
| 2                  | 0,20 | 0,00 | 0,21 | 0,59 |
| 3                  | 0,72 | 0,10 | 0,00 | 0,18 |
| 4                  | 0,20 | 0,70 | 0,10 | 0,00 |

$$Qe,1=700; Qe,2=525; Qe,3=310; Qe,4=430$$

$$Qu,1= Qe,2*0,20+Qe,3*0,72+Qe,4*0,20$$

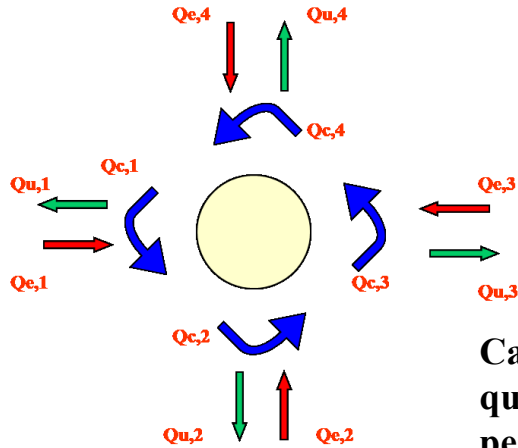
$$Qc,1= Qe,4*0,70+Qe,4*0,10+Qe,3*0,10$$

Flusso  
entrato in  
4 e uscente  
in 2

Flusso  
entrato in  
4 e uscente  
in 3

Flusso  
entrato in  
3 e uscente  
in 2

# Calcolo Capacità Semplice



Modelli per il calcolo capacità degli ingressi:  $C_i = f(Q_{c,i}; Q_{u,i})$  per ogni "i"

Per esempio il metodo tedesco:  $C_i = A - B \cdot Q_{c,i}$

**Capacità semplice:** è la somma dei flussi nei bracci di entrata di una rotatoria quando uno dei bracci abbia raggiunto la sua capacità, cioè determina la presenza permanente di veicoli in attesa.

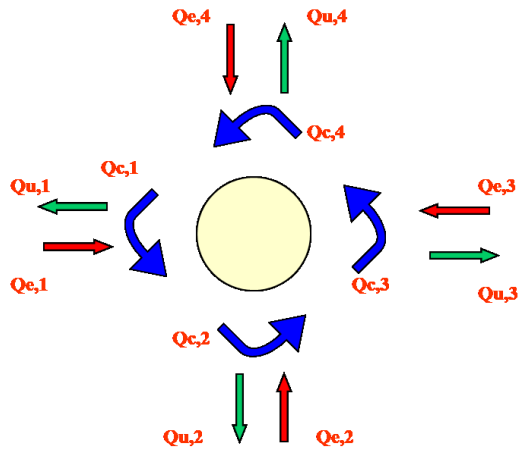
Per individuare la capacità semplice si scrivono un insieme di equazioni del tipo:

$$\delta_i \cdot Q_{e,i} = C_i = f(\delta_i \cdot Q_{c,i}; \delta_i \cdot Q_{u,i}) \quad \text{una per ogni ramo "i"}$$

Da cui si individuano le incognite  $\delta_i$  ed il minimo dei  $\delta_i$ :  $\hat{\delta} = \min\{\delta_i\}$

$$C_{\text{semplice}} = \sum_i (\hat{\delta} \cdot Q_{e,i}) \quad \text{quando in un ramo "i" } \hat{\delta} \cdot Q_{e,i} = C_i = f(\hat{\delta} \cdot Q_{c,i}; \hat{\delta} \cdot Q_{u,i})$$

# Calcolo Capacità Totale



La Capacità totale rappresenta una misura sintetica delle condizioni limite della rotatoria a smaltire il traffico quando ad ognuno degli accessi «i» sono presenti code.

Capacità totale della rotatoria è la somma dei flussi in ingresso che distribuendosi fra le diverse uscite determinano il raggiungimento contemporaneo della capacità su tutti bracci.

$$C_{\text{Totale}} = \sum_i C_i$$

Per individuare la capacità totale va risolto un sistema di equazioni (tante quante sono gli ingressi) con incognite le  $Q_{e,i}$  :

$$Q_{e,i} = C_i = f(Q_{c,i}; Q_{u,i}) \quad \text{una per ogni ramo "i"}$$

Con ciascun  $Q_{c,i}$  e  $Q_{u,i}$  che dipendono dalle incognite  $Q_{e,i}$ , di TUTTI rami



# Zone di scambio (1)

Le zone di scambio. Queste si hanno quando avviene l'attraversamento reciproco di due correnti di traffico aventi medesima direzione e verso, lungo un tronco stradale di lunghezza significativa (FONTE: DM intersezioni).

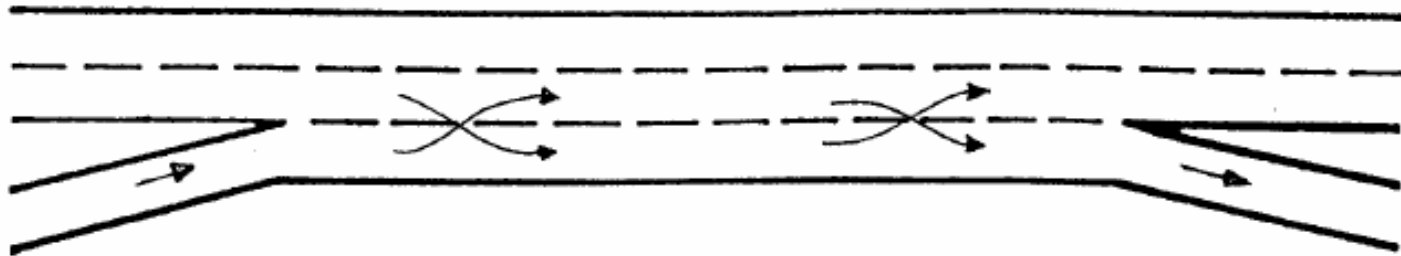
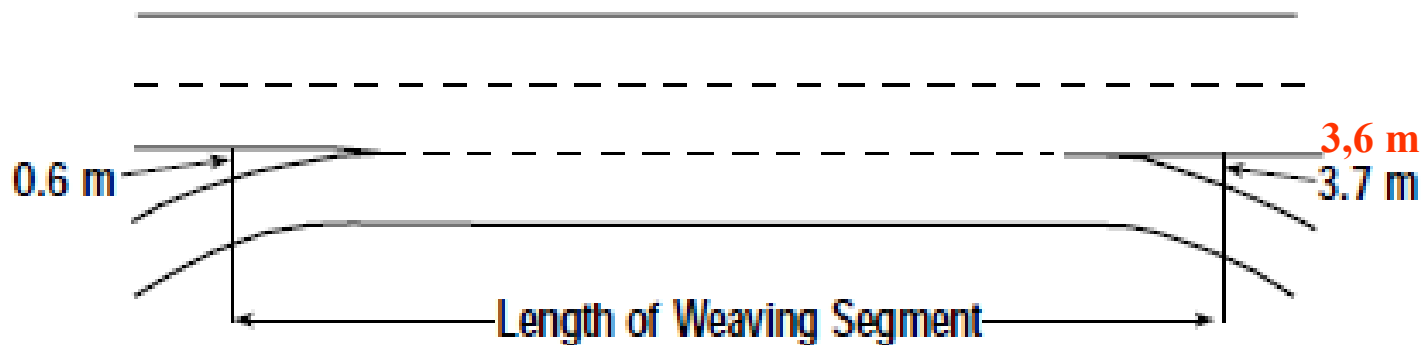


EXHIBIT 13-11. MEASURING THE LENGTH OF A WEAVING SEGMENT



# Zone di scambio (2)

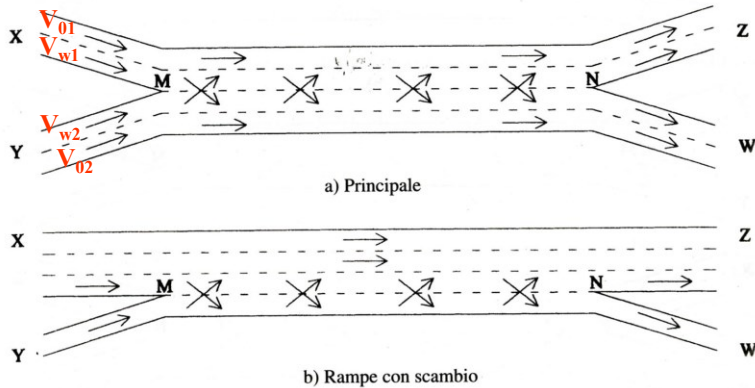


Fig.2 - Zone di scambio di tipo A

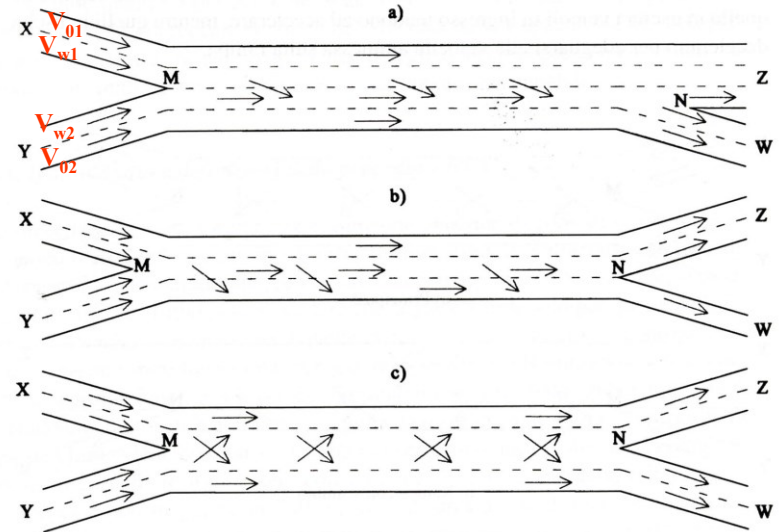


Fig.3 - Zone di scambio di tipo B

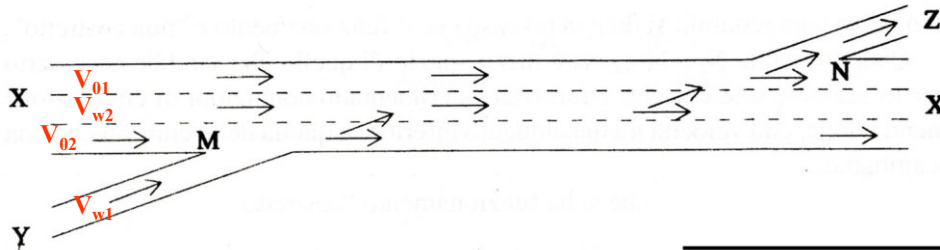


Fig.4 - Zona di scambio di tipo C

EXHIBIT 24-5. DETERMINING CONFIGURATION TYPE

| Number of Lane Changes Required by Movement $v_{w1}$ | Number of Lane Changes Required by Movement $v_{w2}$ |        |          |
|--|--|--------|----------|
|  | 0  | 1      | $\geq 2$ |
| 0  | Type B   | Type B | Type C   |
| 1  | Type B   | Type A | N/A      |
| $\geq 2$   | Type C   | N/A    | N/A      |

Note:  
N/A = not applicable; configuration is not feasible.

# Zone di scambio (3)

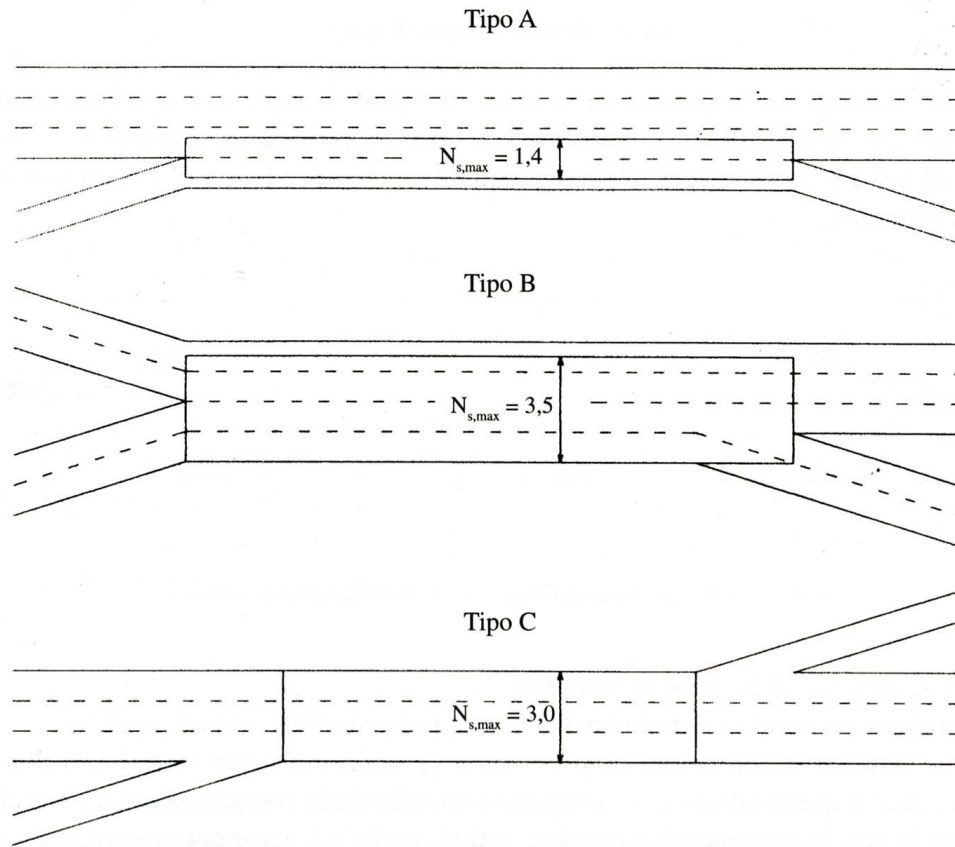


Fig.6 – Massimo numero di corsie utilizzabili dalle correnti che scambiano

# Zone di scambio (4)

EXHIBIT 24-2. LOS CRITERIA FOR WEAVING SEGMENTS

| LOS | Density (pc/km/ln)      |  |
|-----|-------------------------|--|
|     | Freeway Weaving Segment | Multilane and Collector-Distributor Weaving Segments |
| A   | ≤ 6.0                   | ≤ 8.0  |
| B   | > 6.0–12.0              | > 8.0–15.0   |
| C   | > 12.0–17.0             | > 15.0–20.0  |
| D   | > 17.0–22.0             | > 20.0–23.0  |
| E   | > 22.0–27.0             | > 23.0–25.0  |
| F   | > 27.0                  | > 25.0   |

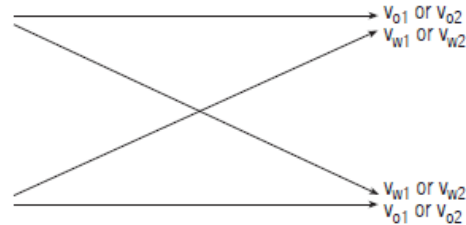
EXHIBIT 13-13. EXAMPLE SERVICE VOLUMES FOR FREEWAY WEAVING SEGMENTS  
(SEE FOOTNOTE FOR ASSUMED VALUES)

| Weaving Section<br>Number of Lanes | Service Volumes (veh/h) for LOS |      |      |      |        |
|------------------------------------|---------------------------------|------|------|------|--------|
|                                    | A                               | B    | C    | D    | E      |
| Type A                             |                                 |      |      |      |        |
| 3                                  | 1710                            | 3010 | 3920 | 4740 | 5490   |
| 4                                  | 2280                            | 4010 | 5230 | 6320 | 7330   |
| 5                                  | 2850                            | 5010 | 6540 | 7930 | 9260   |
| Type B                             |                                 |      |      |      |        |
| 3                                  | 1780                            | 3290 | 4430 | 5490 | 6320   |
| 4                                  | 2380                            | 4390 | 5900 | 7320 | 8430   |
| 5                                  | 2970                            | 5490 | 7380 | 9140 | 10,540 |
| Type C                             |                                 |      |      |      |        |
| 3                                  | 1790                            | 3280 | 4380 | 5400 | 6320   |
| 4                                  | 2380                            | 4370 | 5840 | 7200 | 8430   |

Note:  
Assumptions: FFS = 120 km/h, PHF = 0.90, 5 percent trucks, level terrain, volume ratio = 0.20, weaving segment length = 300 m.

# Zone di scambio (5)

EXHIBIT 24-3. PARAMETERS AFFECTING WEAVING SEGMENT OPERATION



| Symbol      | Definition  |
|-------------|---|
| L           | Length of weaving segment (m)   |
| N           | Total number of lanes in the weaving segment  |
| $N_w$       | Number of lanes to be used by weaving vehicles if unconstrained operation is to be achieved               |
| $N_w(\max)$ | Maximum number of lanes that can be used by weaving vehicles for a given configuration                    |
| $N_{nw}$    | Number of lanes used by nonweaving vehicles   |
| v           | Total flow rate in the weaving segment (pc/h)   |
| $v_{o1}$    | Larger of the two outer, or nonweaving, flow rates in the weaving segment (pc/h)                          |
| $v_{o2}$    | Smaller of the two outer, or nonweaving, flow rates in the weaving segment (pc/h)                         |
| $v_{w1}$    | Larger of the two weaving flow rates in the weaving segment (pc/h)  |
| $v_{w2}$    | Smaller of the two weaving flow rates in the weaving segment (pc/h)                                       |
| $v_w$       | Total weaving flow rate in the weaving segment (pc/h) ( $v_w = v_{w1} + v_{w2}$ )                         |
| $v_{nw}$    | Total nonweaving flow rate in the weaving segment (pc/h) ( $v_{nw} = v_{o1} + v_{o2}$ )                   |
| VR          | Volume ratio; the ratio of weaving flow rate to total flow rate in the weaving segment ( $VR = v_w/v$ )   |
| R           | Weaving ratio; the ratio of the smaller weaving flow rate to total weaving flow rate ( $R = v_{w2}/v_w$ ) |
| $S_w$       | Speed of weaving vehicles in the weaving segment (km/h)   |
| $S_{nw}$    | Speed of nonweaving vehicles in the weaving segment (km/h)  |
| S           | Speed of all vehicles in the weaving segment (km/h)   |
| D           | Density of all vehicles in the weaving segment (pc/km/ln)   |
| $W_w$       | Weaving intensity factor for prediction of weaving speed  |
| $W_{nw}$    | Weaving intensity factor for prediction of nonweaving speed   |



## Zone di scambio (6)

$$S_i = S_{\min} + \frac{S_{\max} - S_{\min}}{1 + W_i} \quad (24-2)$$

where

- $S_i$  = average speed of weaving ( $i = w$ ) or nonweaving ( $i = nw$ ) vehicles (km/h),
- $S_{\min}$  = minimum speed expected in a weaving segment (km/h),
- $S_{\max}$  = maximum speed expected in a weaving segment (km/h), and
- $W_i$  = weaving intensity factor for weaving ( $i = w$ ) and nonweaving ( $i = nw$ ) flows.

$$S_i = 24 + \frac{S_{FF} - 16}{1 + W_i} \quad (24-3)$$

where  $S_{FF}$  is the average free-flow speed of the freeway segments entering and leaving the weaving segment (km/h).

# Zone di scambio (7)

EXHIBIT 24-6. CONSTANTS FOR COMPUTATION OF WEAVING INTENSITY FACTORS

General Form

$$W = \frac{a(1+VR)^b \left(\frac{v}{N}\right)^c}{(3.28L)^d}$$

|                      | Constants for Weaving Speed, $S_w$ |     |      |      | Constants for Nonweaving Speed, $S_{nw}$ |     |     |      |
|----------------------|------------------------------------|-----|------|------|--|-----|-----|------|
|                      | a                                  | b   | c    | d    | a  | b   | c   | d    |
| Type A Configuration |                                    |     |      |      |  |     |     |      |
| Unconstrained        | 0.15                               | 2.2 | 0.97 | 0.80 | 0.0035                                   | 4.0 | 1.3 | 0.75 |
| Constrained          | 0.35                               | 2.2 | 0.97 | 0.80 | 0.0020                                   | 4.0 | 1.3 | 0.75 |
| Type B Configuration |                                    |     |      |      |  |     |     |      |
| Unconstrained        | 0.08                               | 2.2 | 0.70 | 0.50 | 0.0020                                   | 6.0 | 1.0 | 0.50 |
| Constrained          | 0.15                               | 2.2 | 0.70 | 0.50 | 0.0010                                   | 6.0 | 1.0 | 0.50 |
| Type C Configuration |                                    |     |      |      |  |     |     |      |
| Unconstrained        | 0.08                               | 2.3 | 0.80 | 0.60 | 0.0020                                   | 6.0 | 1.1 | 0.60 |
| Constrained          | 0.14                               | 2.3 | 0.80 | 0.60 | 0.0010                                   | 6.0 | 1.1 | 0.60 |

where

- $W_i$  = weaving intensity factors for weaving ( $i = w$ ) and nonweaving ( $i = nw$ ) flows;
- $VR$  = volume ratio;
- $v$  = total flow rate in the weaving segment (pc/h);
- $N$  = total number of lanes in the weaving segment;
- $L$  = length of the weaving segment (m); and
- $a, b, c, d$  = constants of calibration.

# Zone di scambio (8)

EXHIBIT 24-7. CRITERIA FOR UNCONSTRAINED VERSUS CONSTRAINED OPERATION OF WEAVING SEGMENTS

| Configuration | Number of Lanes Required for Unconstrained Operation, $N_w$ | $N_w(\max)$      |
|---------------|---|------------------|
| Type A        | $1.21(N) VR^{0.571} L^{0.234} / S_w^{0.438}$                | 1.4              |
| Type B        | $N[0.085 + 0.703VR + (71.57/L) - 0.0112(S_{nw} - S_w)]$     | 3.5              |
| Type C        | $N[0.761 + 0.047VR - 0.00036L - 0.0031(S_{nw} - S_w)]$      | 3.0 <sup>a</sup> |

Note:

a. For two-sided weaving segments, all freeway lanes may be used by weaving vehicles.

# Zone di scambio (9)

$$S = \frac{v}{\left(\frac{v_w}{S_w}\right) + \left(\frac{v_{nw}}{S_{nw}}\right)} \quad (24-5)$$

where

- $S$  = space mean speed of all vehicles in the weaving segment (km/h),
- $S_w$  = space mean speed of weaving vehicles in the weaving segment (km/h),
- $S_{nw}$  = space mean speed of nonweaving vehicles in the weaving segment (km/h),
- $v$  = total flow rate in the weaving segment (pc/h),
- $v_w$  = weaving flow rate in the weaving segment (pc/h), and
- $v_{nw}$  = nonweaving flow rate in the weaving segment (pc/h).

$$D = \frac{\left(\frac{v}{N}\right)}{S} \quad (24-6)$$

where  $D$  is the average density for all vehicles in the weaving segment (pc/km/ln).

# Zone di scambio (10)

EXHIBIT 24-8. CAPACITY FOR VARIOUS WEAVING SEGMENTS

| (A) Type A Weaving Segments—120-km/h Free-Flow Speed |                               |                     |                     |                     |                     |
|--|-------------------------------|---------------------|---------------------|---------------------|---------------------|
| Volume Ratio, VR                                     | Length of Weaving Segment (m) |                     |                     |                     |                     |
|  | 150                           | 300                 | 450                 | 600                 | 750 <sup>a</sup>    |
| Three-Lane Segments                                  |                               |                     |                     |                     |                     |
| 0.10   | 6050                          | 6820                | 7200 <sup>b</sup>   | 7200 <sup>b</sup>   | 7200 <sup>b</sup>   |
| 0.20   | 5490                          | 6260                | 6720                | 7050                | 7200 <sup>b</sup>   |
| 0.30   | 5040                          | 5780                | 6240                | 6570                | 6830                |
| 0.40   | 4660                          | 5380                | 5530                | 5800 <sup>c</sup>   | 6050 <sup>c</sup>   |
| 0.45 <sup>d</sup>                                    | 4430                          | 5000 <sup>c</sup>   | 5270 <sup>c</sup>   | 5550 <sup>c</sup>   | 5800 <sup>c</sup>   |
| Four-Lane Segments                                   |                               |                     |                     |                     |                     |
| 0.10   | 8060                          | 9010                | 9600 <sup>b</sup>   | 9600 <sup>b</sup>   | 9600 <sup>b</sup>   |
| 0.20   | 7320                          | 8340                | 8960                | 9400                | 9600 <sup>b</sup>   |
| 0.30   | 6710                          | 7520 <sup>c</sup>   | 8090 <sup>c</sup>   | 8510 <sup>c</sup>   | 8840                |
| 0.35 <sup>e</sup>                                    | 6370 <sup>c</sup>             | 7160 <sup>c</sup>   | 7700 <sup>c</sup>   | 8000 <sup>f</sup>   | 8000 <sup>f</sup>   |
| Five-Lane Segments                                   |                               |                     |                     |                     |                     |
| 0.10   | 10,080                        | 11,380              | 12,000 <sup>b</sup> | 12,000 <sup>b</sup> | 12,000 <sup>b</sup> |
| 0.20 <sup>g</sup>                                    | 9150                          | 10,540 <sup>c</sup> | 11,270 <sup>c</sup> | 11,790 <sup>c</sup> | 12,000 <sup>b</sup> |
| (B) Type A Weaving Segments—110-km/h Free-Flow Speed |                               |                     |                     |                     |                     |
| Volume Ratio, VR                                     | Length of Weaving Segment (m) |                     |                     |                     |                     |
|  | 150                           | 300                 | 450                 | 600                 | 750 <sup>a</sup>    |
| Three-Lane Segments                                  |                               |                     |                     |                     |                     |
| 0.10   | 5770                          | 6470                | 6880                | 7050 <sup>b</sup>   | 7050 <sup>b</sup>   |
| 0.20   | 5250                          | 5960                | 6280                | 6680                | 6900                |
| 0.30   | 4830                          | 5520                | 5940                | 6240                | 6480                |
| 0.40   | 4480                          | 5150                | 5250 <sup>c</sup>   | 5530 <sup>c</sup>   | 5760 <sup>c</sup>   |
| 0.45 <sup>d</sup>                                    | 4190                          | 4790 <sup>c</sup>   | 5020 <sup>c</sup>   | 5310 <sup>c</sup>   | 5530 <sup>c</sup>   |
| Four-Lane Segments                                   |                               |                     |                     |                     |                     |
| 0.10   | 7690                          | 8630                | 9180                | 9400 <sup>b</sup>   | 9400 <sup>b</sup>   |
| 0.20   | 7000                          | 7940                | 8500                | 8900                | 9200                |
| 0.30   | 6440                          | 7180 <sup>c</sup>   | 7710 <sup>c</sup>   | 8090 <sup>c</sup>   | 8390 <sup>c</sup>   |
| 0.35 <sup>e</sup>                                    | 6080 <sup>c</sup>             | 6830 <sup>c</sup>   | 7360 <sup>c</sup>   | 7730 <sup>c</sup>   | 8030 <sup>c</sup>   |
| Five-Lane Segments                                   |                               |                     |                     |                     |                     |
| 0.10   | 9610                          | 10,790              | 11,470              | 11,750 <sup>b</sup> | 11,750 <sup>b</sup> |
| 0.20 <sup>g</sup>                                    | 8750                          | 10,030 <sup>c</sup> | 10,690 <sup>c</sup> | 11,160 <sup>c</sup> | 11,520 <sup>c</sup> |

Notes:  
Refer to the last page of Exhibit 24-8.

EXHIBIT 24-8 (CONTINUED). CAPACITY FOR VARIOUS WEAVING SEGMENTS

| (C) Type A Weaving Segments—100-km/h Free-Flow Speed |                               |                   |                     |                     |                     |
|--|-------------------------------|-------------------|---------------------|---------------------|---------------------|
| Volume Ratio, VR                                     | Length of Weaving Segment (m) |                   |                     |                     |                     |
|  | 150                           | 300               | 450                 | 600                 | 750 <sup>a</sup>    |
| Three-Lane Segments                                  |                               |                   |                     |                     |                     |
| 0.10   | 5470                          | 6110              | 6480                | 6730                | 6910                |
| 0.20   | 5000                          | 5640              | 6020                | 6290                | 6490                |
| 0.30   | 4610                          | 5240              | 5620                | 5900                | 6110                |
| 0.40   | 4290                          | 4900              | 4990 <sup>c</sup>   | 5250 <sup>c</sup>   | 5460 <sup>c</sup>   |
| 0.45 <sup>d</sup>                                    | 4000                          | 4520 <sup>c</sup> | 4790 <sup>c</sup>   | 5040 <sup>c</sup>   | 5200 <sup>c</sup>   |
| Four-Lane Segments                                   |                               |                   |                     |                     |                     |
| 0.10   | 7300                          | 8150              | 8630                | 8970                | 9220                |
| 0.20   | 6660                          | 7520              | 8030                | 8380                | 8650                |
| 0.30   | 6080 <sup>c</sup>             | 6830 <sup>c</sup> | 7310 <sup>c</sup>   | 7650 <sup>c</sup>   | 7920 <sup>c</sup>   |
| 0.35 <sup>e</sup>                                    | 5780 <sup>c</sup>             | 6520 <sup>c</sup> | 6990 <sup>c</sup>   | 7330 <sup>c</sup>   | 7600 <sup>c</sup>   |
| Five-Lane Segments                                   |                               |                   |                     |                     |                     |
| 0.10   | 9120                          | 10,180            | 10,790              | 11,210              | 11,500 <sup>b</sup> |
| 0.20 <sup>g</sup>                                    | 8330                          | 9500 <sup>c</sup> | 10,080 <sup>c</sup> | 10,510 <sup>c</sup> | 10,830 <sup>c</sup> |
| (D) Type A Weaving Segments—90-km/h Free-Flow Speed  |                               |                   |                     |                     |                     |
| Volume Ratio, VR                                     | Length of Weaving Segment (m) |                   |                     |                     |                     |
|  | 150                           | 300               | 450                 | 600                 | 750 <sup>a</sup>    |
| Three-Lane Segments                                  |                               |                   |                     |                     |                     |
| 0.10   | 5160                          | 5730              | 6050                | 6270                | 6430                |
| 0.20   | 4730                          | 5310              | 5650                | 5880                | 6060                |
| 0.30   | 4380                          | 4850              | 5290                | 5540                | 5720                |
| 0.40   | 4090                          | 4420 <sup>c</sup> | 4730 <sup>c</sup>   | 4960 <sup>c</sup>   | 5140 <sup>c</sup>   |
| 0.45 <sup>d</sup>                                    | 3850                          | 4240 <sup>c</sup> | 4470 <sup>c</sup>   | 4780 <sup>c</sup>   | 4950 <sup>c</sup>   |
| Four-Lane Segments                                   |                               |                   |                     |                     |                     |
| 0.10   | 6880                          | 7460              | 8070                | 8350                | 8570                |
| 0.20   | 6310                          | 7080              | 7530                | 7840                | 8080                |
| 0.30   | 5790 <sup>c</sup>             | 6360 <sup>c</sup> | 6890 <sup>c</sup>   | 7190 <sup>c</sup>   | 7430 <sup>c</sup>   |
| 0.35 <sup>e</sup>                                    | 5520 <sup>c</sup>             | 6180 <sup>c</sup> | 6590 <sup>c</sup>   | 6910 <sup>c</sup>   | 7140 <sup>c</sup>   |
| Five-Lane Segments                                   |                               |                   |                     |                     |                     |
| 0.10   | 8600                          | 9550              | 10,080              | 10,440              | 10,710              |
| 0.20 <sup>g</sup>                                    | 8060 <sup>c</sup>             | 8930 <sup>c</sup> | 9460 <sup>c</sup>   | 9820 <sup>c</sup>   | 10,100 <sup>c</sup> |

Notes:  
Refer to the last page of Exhibit 24-8.

# Zone di scambio (11)

EXHIBIT 24-8 (CONTINUED). CAPACITY FOR VARIOUS WEAVING SEGMENTS

| (E) Type B Weaving Segments—120-km/h Free-Flow Speed |                               |                     |                     |                     |                     |
|--|-------------------------------|---------------------|---------------------|---------------------|---------------------|
| Volume Ratio, VR                                     | Length of Weaving Segment (m) |                     |                     |                     |                     |
|  | 150                           | 300                 | 450                 | 600                 | 750 <sup>a</sup>    |
| Three-Lane Segments                                  |                               |                     |                     |                     |                     |
| 0.10   | 7200 <sup>b</sup>             | 7200 <sup>b</sup>   | 7200 <sup>b</sup>   | 7200 <sup>b</sup>   | 7200 <sup>b</sup>   |
| 0.20   | 6830                          | 7200 <sup>b</sup>   | 7200 <sup>b</sup>   | 7200 <sup>b</sup>   | 7200 <sup>b</sup>   |
| 0.30   | 6120                          | 6690                | 7010                | 7200 <sup>b</sup>   | 7200 <sup>b</sup>   |
| 0.40   | 5550                          | 6100                | 6430                | 6670                | 6850                |
| 0.50   | 5100                          | 5630                | 5950                | 6180                | 6370                |
| 0.60   | 4750                          | 5260                | 5570                | 5800                | 5980                |
| 0.70   | 4180                          | 4990                | 5290                | 5520                | 5690                |
| 0.80 <sup>h</sup>                                    | 3900                          | 4820                | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   |
| Four-Lane Segments                                   |                               |                     |                     |                     |                     |
| 0.10   | 9600 <sup>b</sup>             | 9600 <sup>b</sup>   | 9600 <sup>b</sup>   | 9600 <sup>b</sup>   | 9600 <sup>b</sup>   |
| 0.20   | 9110                          | 9600 <sup>b</sup>   | 9600 <sup>b</sup>   | 9600 <sup>b</sup>   | 9600 <sup>b</sup>   |
| 0.30   | 8170                          | 8910                | 9350                | 9600 <sup>b</sup>   | 9600 <sup>b</sup>   |
| 0.40   | 7400                          | 8140                | 8570                | 8890                | 9130                |
| 0.50   | 6670 <sup>c</sup>             | 7500                | 7930                | 8000 <sup>f</sup>   | 8000 <sup>f</sup>   |
| 0.60   | 6070 <sup>c</sup>             | 6670 <sup>f</sup>   | 6670 <sup>f</sup>   | 6670 <sup>f</sup>   | 6670 <sup>f</sup>   |
| 0.70   | 5580 <sup>c</sup>             | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   |
| 0.80 <sup>h</sup>                                    | 5000 <sup>f</sup>             | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   |
| Five-Lane Segments                                   |                               |                     |                     |                     |                     |
| 0.10   | 12,000 <sup>b</sup>           | 12,000 <sup>b</sup> | 12,000 <sup>b</sup> | 12,000 <sup>b</sup> | 12,000 <sup>b</sup> |
| 0.20   | 11,390                        | 12,000 <sup>b</sup> | 12,000 <sup>b</sup> | 12,000 <sup>b</sup> | 12,000 <sup>b</sup> |
| 0.30   | 10,210                        | 11,140              | 11,690              | 12,000 <sup>b</sup> | 12,000 <sup>b</sup> |
| 0.40   | 9270 <sup>c</sup>             | 10,000 <sup>f</sup> | 10,000 <sup>f</sup> | 10,000 <sup>f</sup> | 10,000 <sup>f</sup> |
| 0.50   | 8000 <sup>f</sup>             | 8000 <sup>f</sup>   | 8000 <sup>f</sup>   | 8000 <sup>f</sup>   | 8000 <sup>f</sup>   |
| 0.60   | 6670 <sup>f</sup>             | 6670 <sup>f</sup>   | 6670 <sup>f</sup>   | 6670 <sup>f</sup>   | 6670 <sup>f</sup>   |
| 0.70   | 5760 <sup>f</sup>             | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   |
| 0.80 <sup>h</sup>                                    | 5000 <sup>f</sup>             | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   |

Notes:  
Refer to the last page of Exhibit 24-8.

EXHIBIT 24-8 (CONTINUED). CAPACITY FOR VARIOUS WEAVING SEGMENTS

| (F) Type B Weaving Segments—110-km/h Free-Flow Speed |                               |                     |                     |                     |                     |
|--|-------------------------------|---------------------|---------------------|---------------------|---------------------|
| Volume Ratio, VR                                     | Length of Weaving Segment (m) |                     |                     |                     |                     |
|  | 150                           | 300                 | 450                 | 600                 | 750 <sup>a</sup>    |
| Three-Lane Segments                                  |                               |                     |                     |                     |                     |
| 0.10   | 7050 <sup>b</sup>             | 7050 <sup>b</sup>   | 7050 <sup>b</sup>   | 7050 <sup>b</sup>   | 7050 <sup>b</sup>   |
| 0.20   | 6460                          | 6950                | 7050 <sup>b</sup>   | 7050 <sup>b</sup>   | 7050 <sup>b</sup>   |
| 0.30   | 5810                          | 6320                | 6620                | 6830                | 6980                |
| 0.40   | 5280                          | 5790                | 6090                | 6300                | 6470                |
| 0.50   | 4860                          | 5350                | 5650                | 5860                | 6030                |
| 0.60   | 4550                          | 5010                | 5300                | 5510                | 5680                |
| 0.70   | 4320                          | 4770                | 5050                | 5250                | 5410                |
| 0.80 <sup>h</sup>                                    | 3650                          | 4600                | 4880                | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   |
| Four-Lane Segments                                   |                               |                     |                     |                     |                     |
| 0.10   | 9400 <sup>b</sup>             | 9400 <sup>b</sup>   | 9400 <sup>b</sup>   | 9400 <sup>b</sup>   | 9400 <sup>b</sup>   |
| 0.20   | 8610                          | 9270                | 9400 <sup>b</sup>   | 9400 <sup>b</sup>   | 9400 <sup>b</sup>   |
| 0.30   | 7750                          | 8430                | 8820                | 9100                | 9310                |
| 0.40   | 7040                          | 7720                | 8120                | 8400                | 8620                |
| 0.50   | 6370 <sup>c</sup>             | 7140                | 7530                | 7820                | 8000 <sup>f</sup>   |
| 0.60   | 5810 <sup>c</sup>             | 6670 <sup>f</sup>   | 6670 <sup>f</sup>   | 6670 <sup>f</sup>   | 6670 <sup>f</sup>   |
| 0.70   | 5350 <sup>c</sup>             | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   |
| 0.80 <sup>h</sup>                                    | 5000 <sup>f</sup>             | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   |
| Five-Lane Segments                                   |                               |                     |                     |                     |                     |
| 0.10   | 11,750 <sup>b</sup>           | 11,750 <sup>b</sup> | 11,750 <sup>b</sup> | 11,750 <sup>b</sup> | 11,750 <sup>b</sup> |
| 0.20   | 10,760                        | 11,590              | 11,750 <sup>b</sup> | 11,750 <sup>b</sup> | 11,750 <sup>b</sup> |
| 0.30   | 9690                          | 10,540              | 11,030              | 11,370              | 11,640              |
| 0.40   | 8830 <sup>c</sup>             | 9650                | 10,000 <sup>f</sup> | 10,000 <sup>f</sup> | 10,000 <sup>f</sup> |
| 0.50   | 7960 <sup>c</sup>             | 8000 <sup>f</sup>   | 8000 <sup>f</sup>   | 8000 <sup>f</sup>   | 8000 <sup>f</sup>   |
| 0.60   | 6670 <sup>f</sup>             | 6670 <sup>f</sup>   | 6670 <sup>f</sup>   | 6670 <sup>f</sup>   | 6670 <sup>f</sup>   |
| 0.70   | 5760 <sup>f</sup>             | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   |
| 0.80 <sup>h</sup>                                    | 5000 <sup>f</sup>             | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   |

Notes:  
Refer to the last page of Exhibit 24-8.



# Zone di scambio (12)

EXHIBIT 24-8 (CONTINUED). CAPACITY FOR VARIOUS WEAVING SEGMENTS

| (G) Type B Weaving Segments—100-km/h Free-Flow Speed |                               |                     |                     |                     |                     |
|--|-------------------------------|---------------------|---------------------|---------------------|---------------------|
| Volume Ratio, VR                                     | Length of Weaving Segment (m) |                     |                     |                     |                     |
|  | 150                           | 300                 | 450                 | 600                 | 750 <sup>a</sup>    |
| Three-Lane Segments                                  |                               |                     |                     |                     |                     |
| 0.10   | 6750                          | 6900 <sup>b</sup>   | 6900 <sup>b</sup>   | 6900 <sup>b</sup>   | 6900 <sup>b</sup>   |
| 0.20   | 6070                          | 6510                | 6750                | 6900 <sup>b</sup>   | 6900 <sup>b</sup>   |
| 0.30   | 5490                          | 5950                | 6210                | 6400                | 6540                |
| 0.40   | 5010                          | 5470                | 5740                | 5930                | 6070                |
| 0.50   | 4620                          | 5070                | 5340                | 5530                | 5680                |
| 0.60   | 4330                          | 4760                | 5020                | 5220                | 5360                |
| 0.70   | 4120                          | 4530                | 4790                | 4970                | 5120                |
| 0.80 <sup>h</sup>                                    | 3600                          | 4380                | 4630                | 4820                | 4960                |
| Four-Lane Segments                                   |                               |                     |                     |                     |                     |
| 0.10   | 9000                          | 9200 <sup>b</sup>   | 9200 <sup>b</sup>   | 9200 <sup>b</sup>   | 9200 <sup>b</sup>   |
| 0.20   | 8100                          | 8680                | 9010                | 9200 <sup>b</sup>   | 9200 <sup>b</sup>   |
| 0.30   | 7320                          | 7930                | 8280                | 8530                | 8710                |
| 0.40   | 6680                          | 7290                | 7650                | 7900                | 8100                |
| 0.50   | 6060 <sup>c</sup>             | 6760                | 7120                | 7370                | 7580                |
| 0.60   | 5540 <sup>c</sup>             | 6340                | 6670 <sup>f</sup>   | 6670 <sup>f</sup>   | 6670 <sup>f</sup>   |
| 0.70   | 5130 <sup>c</sup>             | 5640 <sup>b</sup>   | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   |
| 0.80 <sup>h</sup>                                    | 4800 <sup>c</sup>             | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   |
| Five-Lane Segments                                   |                               |                     |                     |                     |                     |
| 0.10   | 11,250                        | 11,500 <sup>b</sup> | 11,500 <sup>b</sup> | 11,500 <sup>b</sup> | 11,500 <sup>b</sup> |
| 0.20   | 10,120                        | 10,850              | 11,260              | 11,500 <sup>b</sup> | 11,500 <sup>b</sup> |
| 0.30   | 9150                          | 9910                | 10,350              | 10,660              | 10,890              |
| 0.40   | 8370 <sup>c</sup>             | 9110                | 9560                | 9880                | 10,000 <sup>f</sup> |
| 0.50   | 7570 <sup>c</sup>             | 8000 <sup>f</sup>   | 8000 <sup>f</sup>   | 8000 <sup>f</sup>   | 8000 <sup>f</sup>   |
| 0.60   | 6670 <sup>f</sup>             | 6670 <sup>f</sup>   | 6670 <sup>f</sup>   | 6670 <sup>f</sup>   | 6670 <sup>f</sup>   |
| 0.70   | 5760 <sup>f</sup>             | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   |
| 0.80 <sup>h</sup>                                    | 5000 <sup>f</sup>             | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   |

Notes:  
Refer to the last page of Exhibit 24-8.

EXHIBIT 24-8 (CONTINUED). CAPACITY FOR VARIOUS WEAVING SEGMENTS

| (H) Type B Weaving Segments—90-km/h Free-Flow Speed |                               |                   |                     |                     |                     |
|---|-------------------------------|-------------------|---------------------|---------------------|---------------------|
| Volume Ratio, VR                                    | Length of Weaving Segment (m) |                   |                     |                     |                     |
|   | 150                           | 300               | 450                 | 600                 | 750 <sup>a</sup>    |
| Three-Lane Segments                                 |                               |                   |                     |                     |                     |
| 0.10  | 6270                          | 6600              | 6750 <sup>b</sup>   | 6750 <sup>b</sup>   | 6750 <sup>b</sup>   |
| 0.20  | 5670                          | 6050              | 6270                | 6410                | 6520                |
| 0.30  | 5150                          | 5560              | 5790                | 5950                | 6070                |
| 0.40  | 4720                          | 5130              | 5370                | 5540                | 5670                |
| 0.50  | 4370                          | 4770              | 5010                | 5190                | 5320                |
| 0.60  | 4110                          | 4500              | 4730                | 4900                | 5030                |
| 0.70  | 3910                          | 4290              | 4520                | 4690                | 4820                |
| 0.80 <sup>h</sup>                                   | 3440                          | 4150              | 4380                | 4540                | 4670                |
| Four-Lane Segments                                  |                               |                   |                     |                     |                     |
| 0.10  | 8350                          | 8800              | 9000 <sup>b</sup>   | 9000 <sup>b</sup>   | 9000 <sup>b</sup>   |
| 0.20  | 7560                          | 8070              | 8360                | 8550                | 8690                |
| 0.30  | 6870                          | 7410              | 7720                | 7940                | 8100                |
| 0.40  | 6290                          | 6840              | 7160                | 7390                | 7560                |
| 0.50  | 5740 <sup>c</sup>             | 6360              | 6680                | 6920                | 7090                |
| 0.60  | 5270 <sup>c</sup>             | 5990              | 6310                | 6530                | 6670 <sup>f</sup>   |
| 0.70  | 4890 <sup>c</sup>             | 5350 <sup>c</sup> | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   |
| 0.80 <sup>h</sup>                                   | 4590 <sup>c</sup>             | 5000 <sup>f</sup> | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   |
| Five-Lane Segments                                  |                               |                   |                     |                     |                     |
| 0.10  | 10,440                        | 10,990            | 11,250 <sup>b</sup> | 11,250 <sup>b</sup> | 11,250 <sup>b</sup> |
| 0.20  | 9450                          | 10,090            | 10,440              | 10,680              | 10,860              |
| 0.30  | 8580                          | 9260              | 9650                | 9920                | 10,120              |
| 0.40  | 7890 <sup>c</sup>             | 8550              | 8950                | 9230                | 9450                |
| 0.50  | 7170 <sup>c</sup>             | 7960              | 8000 <sup>f</sup>   | 8000 <sup>f</sup>   | 8000 <sup>f</sup>   |
| 0.60  | 6580 <sup>c</sup>             | 6670 <sup>f</sup> | 6670 <sup>f</sup>   | 6670 <sup>f</sup>   | 6670 <sup>f</sup>   |
| 0.70  | 5760 <sup>f</sup>             | 5760 <sup>f</sup> | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   | 5760 <sup>f</sup>   |
| 0.80 <sup>h</sup>                                   | 5000 <sup>f</sup>             | 5000 <sup>f</sup> | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   | 5000 <sup>f</sup>   |

Notes:  
Refer to the last page of Exhibit 24-8.

# Zone di scambio (13)

EXHIBIT 24-8 (CONTINUED). CAPACITY FOR VARIOUS WEAVING SEGMENTS

| (I) Type C Weaving Segments—120-km/h Free-Flow Speed |                               |                     |                     |                     |                     |
|--|-------------------------------|---------------------|---------------------|---------------------|---------------------|
| Volume Ratio, VR                                     | Length of Weaving Segment (m) |                     |                     |                     |                     |
|  | 150                           | 300                 | 450                 | 600                 | 750 <sup>a</sup>    |
| Three-Lane Segments                                  |                               |                     |                     |                     |                     |
| 0.10   | 7200 <sup>b</sup>             | 7200 <sup>b</sup>   | 7200 <sup>b</sup>   | 7200 <sup>b</sup>   | 7200 <sup>b</sup>   |
| 0.20   | 6590                          | 7200 <sup>b</sup>   | 7200 <sup>b</sup>   | 7200 <sup>b</sup>   | 7200 <sup>b</sup>   |
| 0.30   | 5890                          | 6540                | 6930                | 7200                | 7200 <sup>b</sup>   |
| 0.40   | 5530                          | 5960                | 6350                | 6620                | 6840                |
| 0.50 <sup>i</sup>                                    | 4890                          | 5500                | 5870                | 6140                | 6360                |
| Four-Lane Segments                                   |                               |                     |                     |                     |                     |
| 0.10   | 9600 <sup>b</sup>             | 9600 <sup>b</sup>   | 9600 <sup>b</sup>   | 9600 <sup>b</sup>   | 9600 <sup>b</sup>   |
| 0.20   | 8780                          | 9600 <sup>b</sup>   | 9600 <sup>b</sup>   | 9600 <sup>b</sup>   | 9600 <sup>b</sup>   |
| 0.30   | 7850                          | 8720                | 9230                | 9590                | 9600 <sup>b</sup>   |
| 0.40   | 7110                          | 7950                | 8470                | 8750 <sup>f</sup>   | 8750 <sup>f</sup>   |
| 0.50 <sup>i</sup>                                    | 6520                          | 7000 <sup>f</sup>   | 7000 <sup>f</sup>   | 7000 <sup>f</sup>   | 7000 <sup>f</sup>   |
| Five-Lane Segments                                   |                               |                     |                     |                     |                     |
| 0.10   | 12,000 <sup>b</sup>           | 12,000 <sup>b</sup> | 12,000 <sup>b</sup> | 12,000 <sup>b</sup> | 12,000 <sup>b</sup> |
| 0.20   | 11,520 <sup>e</sup>           | 12,000 <sup>b</sup> | 12,000 <sup>b</sup> | 12,000 <sup>b</sup> | 12,000 <sup>b</sup> |
| 0.30   | 10,140 <sup>e</sup>           | 11,170 <sup>c</sup> | 11,670 <sup>f</sup> | 11,670 <sup>f</sup> | 11,670 <sup>f</sup> |
| 0.40   | 8750 <sup>f</sup>             | 8750 <sup>f</sup>   | 8750 <sup>f</sup>   | 8750 <sup>f</sup>   | 8750 <sup>f</sup>   |
| 0.50 <sup>i</sup>                                    | 7000 <sup>f</sup>             | 7000 <sup>f</sup>   | 7000 <sup>f</sup>   | 7000 <sup>f</sup>   | 7000 <sup>f</sup>   |
| (J) Type C Weaving Segments—110-km/h Free-Flow Speed |                               |                     |                     |                     |                     |
| Volume Ratio, VR                                     | Length of Weaving Segment (m) |                     |                     |                     |                     |
|  | 150                           | 300                 | 450                 | 600                 | 750 <sup>a</sup>    |
| Three-Lane Segments                                  |                               |                     |                     |                     |                     |
| 0.10   | 7010                          | 7050 <sup>b</sup>   | 7050 <sup>b</sup>   | 7050 <sup>b</sup>   | 7050 <sup>b</sup>   |
| 0.20   | 6240                          | 6830                | 7050 <sup>b</sup>   | 7050 <sup>b</sup>   | 7050 <sup>b</sup>   |
| 0.30   | 5610                          | 6200                | 6550                | 6790                | 6980                |
| 0.40   | 5090                          | 5670                | 6020                | 6270                | 6470                |
| 0.50 <sup>i</sup>                                    | 4680                          | 5240                | 5590                | 5840                | 6030                |
| Four-Lane Segments                                   |                               |                     |                     |                     |                     |
| 0.10   | 9350                          | 9400 <sup>b</sup>   | 9400 <sup>b</sup>   | 9400 <sup>b</sup>   | 9400 <sup>b</sup>   |
| 0.20   | 8320                          | 9100                | 9400 <sup>b</sup>   | 9400 <sup>b</sup>   | 9400 <sup>b</sup>   |
| 0.30   | 7470                          | 8270                | 8730                | 9060                | 9300                |
| 0.40   | 6240                          | 7560                | 8030                | 8360                | 8620                |
| 0.50 <sup>i</sup>                                    | 5830                          | 6990                | 7000 <sup>f</sup>   | 7000 <sup>f</sup>   | 7000 <sup>f</sup>   |
| Five-Lane Segments                                   |                               |                     |                     |                     |                     |
| 0.10   | 11,750 <sup>b</sup>           | 11,750 <sup>b</sup> | 11,750 <sup>b</sup> | 11,750 <sup>b</sup> | 11,750 <sup>b</sup> |
| 0.20   | 10,900 <sup>e</sup>           | 11,750 <sup>b</sup> | 11,750 <sup>b</sup> | 11,750 <sup>b</sup> | 11,750 <sup>b</sup> |
| 0.30   | 9630 <sup>e</sup>             | 10,570 <sup>c</sup> | 10,910              | 11,320              | 11,630              |
| 0.40   | 8590 <sup>e</sup>             | 8750 <sup>f</sup>   | 8750 <sup>f</sup>   | 8750 <sup>f</sup>   | 8750 <sup>f</sup>   |
| 0.50 <sup>i</sup>                                    | 7000 <sup>f</sup>             | 7000 <sup>f</sup>   | 7000 <sup>f</sup>   | 7000 <sup>f</sup>   | 7000 <sup>f</sup>   |

Notes:  
Refer to the last page of Exhibit 24-8.

EXHIBIT 24-8 (CONTINUED). CAPACITY FOR VARIOUS WEAVING SEGMENTS

| (K) Type C Weaving Segments—100-km/h Free-Flow Speed |                               |                     |                     |                     |                     |
|--|-------------------------------|---------------------|---------------------|---------------------|---------------------|
| Volume Ratio, VR                                     | Length of Weaving Segment (m) |                     |                     |                     |                     |
|  | 150                           | 300                 | 450                 | 600                 | 750 <sup>a</sup>    |
| Three-Lane Segments                                  |                               |                     |                     |                     |                     |
| 0.10   | 6570                          | 6900 <sup>b</sup>   | 6900 <sup>b</sup>   | 6900 <sup>b</sup>   | 6900 <sup>b</sup>   |
| 0.20   | 5890                          | 6410                | 6700                | 6900                | 6900 <sup>b</sup>   |
| 0.30   | 5310                          | 5850                | 6160                | 6370                | 6540                |
| 0.40   | 4840                          | 5370                | 5680                | 5910                | 6080                |
| 0.50 <sup>i</sup>                                    | 4460                          | 4970                | 5290                | 5510                | 5690                |
| Four-Lane Segments                                   |                               |                     |                     |                     |                     |
| 0.10   | 8760                          | 9200 <sup>b</sup>   | 9200 <sup>b</sup>   | 9200 <sup>b</sup>   | 9200 <sup>b</sup>   |
| 0.20   | 7850                          | 8540                | 8930                | 9200                | 9200 <sup>b</sup>   |
| 0.30   | 7080                          | 7790                | 8210                | 8500                | 8720                |
| 0.40   | 6450                          | 7150                | 7580                | 7880                | 8110                |
| 0.50 <sup>i</sup>                                    | 5950                          | 6630                | 7000 <sup>f</sup>   | 7000 <sup>f</sup>   | 7000 <sup>f</sup>   |
| Five-Lane Segments                                   |                               |                     |                     |                     |                     |
| 0.10   | 11,500 <sup>b</sup>           | 11,500 <sup>b</sup> | 11,500 <sup>b</sup> | 11,500 <sup>b</sup> | 11,500 <sup>b</sup> |
| 0.20   | 10,250 <sup>c</sup>           | 11,050 <sup>c</sup> | 11,170              | 11,500              | 11,500 <sup>b</sup> |
| 0.30   | 9110 <sup>c</sup>             | 9960 <sup>c</sup>   | 10,260              | 10,620              | 10,900              |
| 0.40   | 8170 <sup>c</sup>             | 8750 <sup>f</sup>   | 8750 <sup>f</sup>   | 8750 <sup>f</sup>   | 8750 <sup>f</sup>   |
| 0.50 <sup>i</sup>                                    | 7000 <sup>f</sup>             | 7000 <sup>f</sup>   | 7000 <sup>f</sup>   | 7000 <sup>f</sup>   | 7000 <sup>f</sup>   |

Notes:  
Refer to the last page of Exhibit 24-8.

# Zone di scambio (14)

EXHIBIT 24-8 (CONTINUED). CAPACITY FOR VARIOUS WEAVING SEGMENTS

| (L) Type C Weaving Segments—90-km/h Free-Flow Speed |                               |                     |                   |                     |                     |
|---|-------------------------------|---------------------|-------------------|---------------------|---------------------|
| Volume Ratio, VR                                    | Length of Weaving Segment (m) |                     |                   |                     |                     |
|   | 150                           | 300                 | 450               | 600                 | 750 <sup>a</sup>    |
| Three-Lane Segments                                 |                               |                     |                   |                     |                     |
| 0.10  | 6120                          | 6520                | 6730              | 6750 <sup>b</sup>   | 6750 <sup>b</sup>   |
| 0.20  | 5510                          | 5970                | 6230              | 6400                | 6520                |
| 0.30  | 5000                          | 5480                | 5750              | 5940                | 6090                |
| 0.40  | 4570                          | 5050                | 5330              | 5530                | 5680                |
| 0.50 <sup>i</sup>                                   | 4230                          | 4700                | 4980              | 5180                | 5330                |
| Four-Lane Segments                                  |                               |                     |                   |                     |                     |
| 0.10  | 8150                          | 8700                | 8980              | 9000 <sup>b</sup>   | 9000 <sup>b</sup>   |
| 0.20  | 7350                          | 7960                | 8300              | 8530                | 8700                |
| 0.30  | 6660                          | 7300                | 7670              | 7920                | 8110                |
| 0.40  | 5640                          | 6730                | 7110              | 7370                | 7580                |
| 0.50 <sup>i</sup>                                   | 5300                          | 6260                | 6640              | 6900                | 7000 <sup>f</sup>   |
| Five-Lane Segments                                  |                               |                     |                   |                     |                     |
| 0.10  | 10,770 <sup>c</sup>           | 11,250 <sup>b</sup> | 11,230            | 11,250 <sup>b</sup> | 11,250 <sup>b</sup> |
| 0.20  | 9580 <sup>c</sup>             | 10,270 <sup>c</sup> | 10,380            | 10,660              | 10,870              |
| 0.30  | 8570 <sup>c</sup>             | 9310 <sup>c</sup>   | 9580              | 9900                | 10,140              |
| 0.40  | 7720 <sup>c</sup>             | 8470 <sup>c</sup>   | 8750 <sup>f</sup> | 8750 <sup>f</sup>   | 8750 <sup>f</sup>   |
| 0.50 <sup>i</sup>                                   | 7000 <sup>f</sup>             | 7000 <sup>f</sup>   | 7000 <sup>f</sup> | 7000 <sup>f</sup>   | 7000 <sup>f</sup>   |

Notes:

- a. Weaving segments longer than 750 m are treated as isolated merge and diverge areas using the procedures of Chapter 25, "Ramps and Ramp Junctions."
- b. Capacity constrained by basic freeway capacity.
- c. Capacity occurs under constrained operating conditions.
- d. Three-lane Type A segments do not operate well at volume ratios greater than 0.45. Poor operations and some local queuing are expected in such cases.
- e. Four-lane Type A segments do not operate well at volume ratios greater than 0.35. Poor operations and some local queuing are expected in such cases.
- f. Capacity constrained by maximum allowable weaving flow rate: 2,800 pc/h (Type A), 4,000 (Type B), 3,500 (Type C).
- g. Five-lane Type A segments do not operate well at volume ratios greater than 0.20. Poor operations and some local queuing are expected in such cases.
- h. Type B weaving segments do not operate well at volume ratios greater than 0.80. Poor operations and some local queuing are expected in such cases.
- i. Type C weaving segments do not operate well at volume ratios greater than 0.50. Poor operations and some local queuing are expected in such cases.

# Approfondimenti e Riflessioni



**Inventas vitam juvat excoluisse per artes.  
Lasciateci migliorare la vita attraverso la  
scienza e l'arte (Virgilio)**

