Chapter 40

Traffic rotaries

40.1 Overview

Rotary intersections or round abouts are special form of at-grade intersections laid out for the movement of traffic in one direction around a central traffic island. Essentially all the major conflicts at an intersection namely the collision between through and right-turn movements are converted into milder conflicts namely merging and diverging. The vehicles entering the rotary are gently forced to move in a clockwise direction in orderly fashion. They then weave out of the rotary to the desired direction. The benefits, design principles, capacity of rotary etc. will be discussed in this chapter.

40.2 Advantages and disadvantages of rotary

The key advantages of a rotary intersection are listed below:

1. Traffic flow is regulated to only one direction of movement, thus eliminating severe conflicts between crossing movements.
2. All the vehicles entering the rotary are gently forced to reduce the speed and continue to move at slower speed. Thus, none of the vehicles need to be stopped,unlike in a signalized intersection.
3. Because of lower speed of negotiation and elimination of severe conflicts, accidents and their severity are much less in rotaries.
4. Rotaries are self governing and do not need practically any control by police or traffic signals.
5. They are ideally suited for moderate traffic, especially with irregular geometry, or intersections with more than three or four approaches.

Although rotaries offer some distinct advantages, there are few specific limitations for rotaries which are listed below.

1. All the vehicles are forced to slow down and negotiate the intersection. Therefore, the cumulative delay will be much higher than channelized intersection.
2. Even when there is relatively low traffic, the vehicles are forced to reduce their speed.
3. Rotaries require large area of relatively flat land making them costly at urban areas.
4. The vehicles do not usually stop at a rotary. They accelerate and exit the rotary at relatively high speed. Therefore, they are not suitable when there is high pedestrian movements.

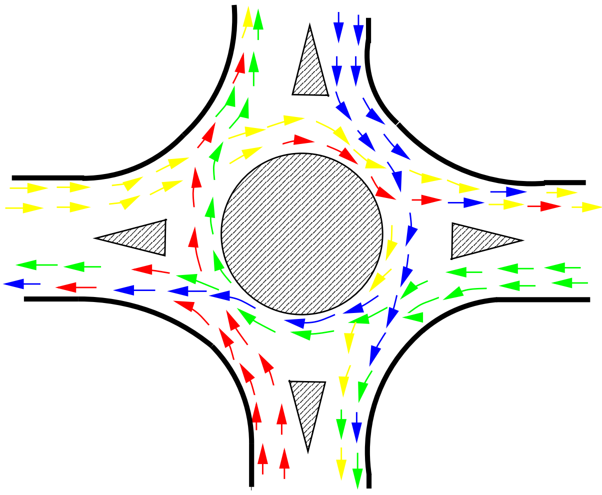

Figure 40:1: Traffic operations in a rotary

40.3 Guidelines for the selection of rotaries

Because of the above limitation, rotaries are not suitable for every location. There are few guidelines that help in deciding the suitability of a rotary. They are listed below.

1. Rotaries are suitable when the traffic entering from all the four approaches are relatively equal.
2. A total volume of about 3000 vehicles per hour can be considered as the upper limiting case and a volume of 500 vehicles per hour is the lower limit.
3. A rotary is very beneficial when the proportion of the right-turn traffic is very high; typically if it is more than 30 percent.
4. Rotaries are suitable when there are more than four approaches or if there is no separate lanes available for right-turn traffic. Rotaries are ideally suited if the intersection geometry is complex.

40.4 Traffic operations in a rotary

As noted earlier, the traffic operations at a rotary are three; diverging, merging and weaving. All the other conflicts are converted into these three less severe conflicts.

1. **Diverging**: It is a traffic operation when the vehicles moving in one direction is separated into different streams according to their destinations.
2. **Merging**: Merging is the opposite of diverging. Merging is referred to as the process of joining the traffic coming from different approaches and going to a common destination into a single stream.
3. **Weaving**: Weaving is the combined movement of both merging and diverging movements in the same direction.

These movements are shown in figure 40:1. It can be observed that movements from each direction split into three; left, straight, and right turn.

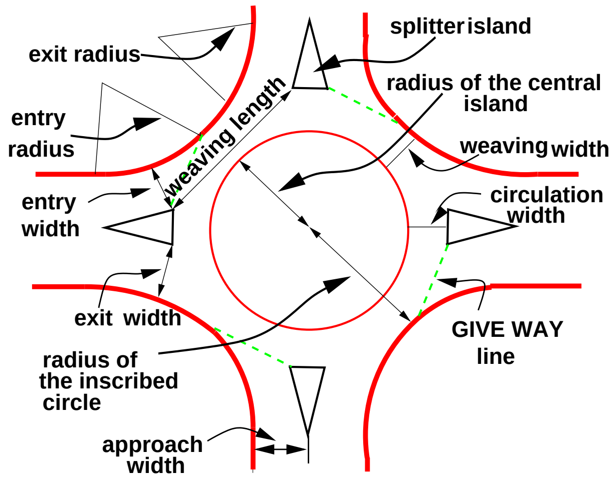

Figure 40:2: Design of a rotary

40.4.1 Design elements

The design elements include design speed, radius at entry, exit and the central island, weaving length and width, entry and exit widths. In addition the capacity of the rotary can also be determined by using some empirical formula. A typical rotary and the important design elements are shown in figure 40:2

40.4.2 Design speed

All the vehicles are required to reduce their speed at a rotary. Therefore, the design speed of a rotary will be much lower than the roads leading to it. Although it is possible to design roundabout without much speed reduction, the geometry may lead to very large size incurring huge cost of construction. The normal practice is to keep the design speed as 30 and 40 kmph for urban and rural areas respectively.

40.4.3 Entry, exit and island radius

The radius at the entry depends on various factors like design speed, super-elevation, and coefficient of friction. The entry to the rotary is not straight, but a small curvature is introduced. This will force the driver to reduce the speed. The entry radius of about 20 and 25 metres is ideal for an urban and rural design respectively.

The exit radius should be higher than the entry radius and the radius of the rotary island so that the vehicles will discharge from the rotary at a higher rate. A general practice is to keep the exit radius as 1.5 to 2 times the entry radius. However, if pedestrian movement is higher at the exit approach, then the exit radius could be set as same as that of the entry radius.

The radius of the central island is governed by the design speed, and the radius of the entry curve. The radius of the central island, in practice, is given a slightly higher radius so that the movement of the traffic already in the rotary will have priority. The radius of the central island which is about 1.3 times that of the entry curve is adequate for all practical purposes.

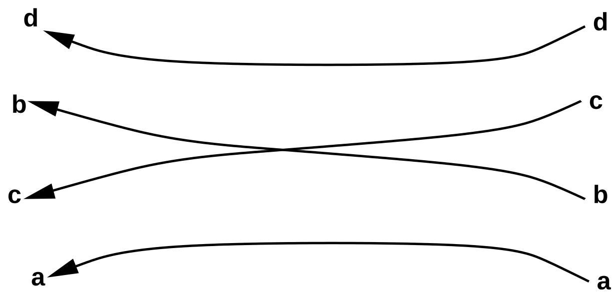

Figure 40:3: Weaving operation in a rotary

40.4.4 Width of the rotary

The entry width and exit width of the rotary is governed by the traffic entering and leaving the intersection and the width of the approaching road. The width of the carriageway at entry and exit will be lower than the width of the carriageway at the approaches to enable reduction of speed. IRC suggests that a two lane road of 7 m width should be kept as 7 m for urban roads and 6.5 m for rural roads. Further, a three lane road of 10.5 m is to be reduced to 7 m and 7.5 m respectively for urban and rural roads.

The width of the weaving section should be higher than the width at entry and exit. Normally this will be one lane more than the average entry and exit width. Thus weaving width is given as,

$$\mathrm{w_{weaving}} = \left(\frac{\mathrm{e_1 + e_2}}{2}\right) + 3.5\mathrm{m} \tag{40.1}$$

where e_1 is the width of the carriageway at the entry and e_2 is the carriageway width at exit.

Weaving length determines how smoothly the traffic can merge and diverge. It is decided based on many factors such as weaving width, proportion of weaving traffic to the non-weaving traffic etc. This can be best achieved by making the ratio of weaving length to the weaving width very high. A ratio of 4 is the minimum value suggested by IRC. Very large weaving length is also dangerous, as it may encourage over-speeding.

40.5 Capacity

The capacity of rotary is determined by the capacity of each weaving section. Transportation road research lab (TRL) proposed the following empirical formula to find the capacity of the weaving section.

$$Q_w = \frac{280w[1 + \frac{e}{w}][1 - \frac{p}{3}]}{1 + \frac{w}{l}} \tag{40.2}$$

where e is the average entry and exit width, i.e, $\frac{(e_1+e_2)}{2}$, w is the weaving width, l is the length of weaving, and p is the proportion of weaving traffic to the non-weaving traffic. Figure 40:3 shows four types of movements at a weaving section, a and d are the non-weaving traffic and b and c are the weaving traffic. Therefore,

$$p = \frac{b + c}{a + b + c + d} \tag{40.3}$$

This capacity formula is valid only if the following conditions are satisfied.

1. Weaving width at the rotary is in between 6 and 18 metres.

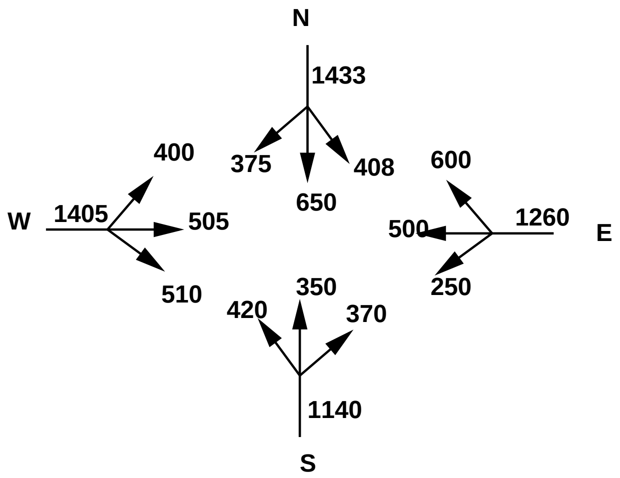

Figure 40:4: Traffic approaching the rotary

2. The ratio of average width of the carriage way at entry and exit to the weaving width is in the range of 0.4 to 1.
3. The ratio of weaving width to weaving length of the roundabout is in between 0.12 and 0.4.
4. The proportion of weaving traffic to non-weaving traffic in the rotary is in the range of 0.4 and 1.
5. The weaving length available at the intersection is in between 18 and 90 m.

Example

The width of a carriage way approaching an intersection is given as 15 m. The entry and exit width at the rotary is 10 m. The traffic approaching the intersection from the four sides is shown in the figure 40:4 below. Find the capacity of the rotary using the given data.

Solution

- The traffic from the four approaches negotiating through the roundabout is illustrated in figure 40:5.
- Weaving width is calculated as, w = $[\frac{e_1+e_2}{2}] + 3.5 = 13.5$ m
- Weaving length, l is calculated as = 4×w = 54 m
- The proportion of weaving traffic to the non-weaving traffic in all the four approaches is found out first.
- It is clear from equation,that the highest proportion of weaving traffic to non-weaving traffic will give the minimum capacity. Let the proportion of weaving traffic to the non-weaving traffic in West-North direction be denoted as p_{WN}, in North-East direction as p_{NE}, in the East-South direction as p_{ES}, and finally in the South-West direction as p_{SW}.
- The weaving traffic movements in the East-South direction is shown in figure 40:6. Then using equation,p_{ES} $=\frac{510+650+500+600}{510+650+500+600+250+375}=\frac{2260}{2885}=0.783$
  $p_{WN} = \frac{505+510+350+600}{505+510+350+600+400+370}=\frac{1965}{2735}=0.718$

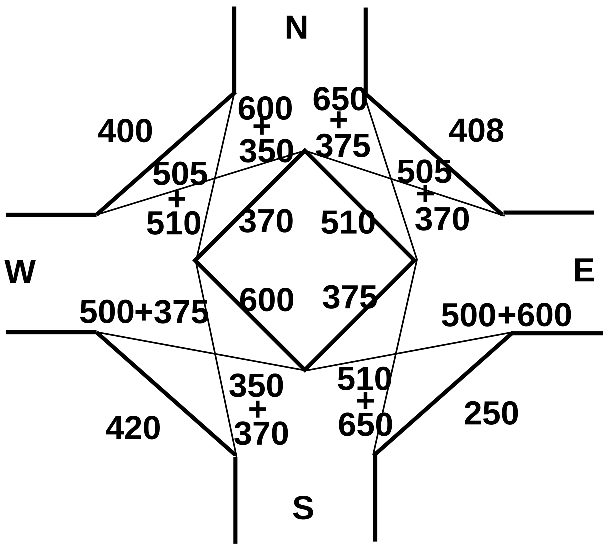

Figure 40:5: Traffic negotiating a rotary

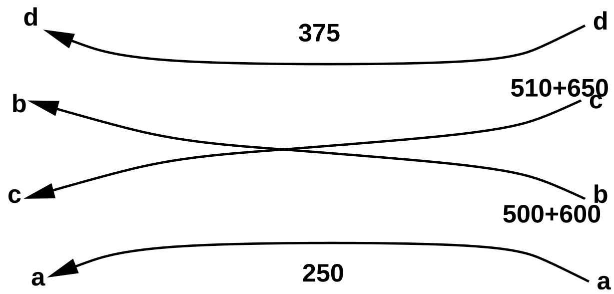

Figure 40:6: Traffic weaving in East-South direction

$$p_{NE} = \frac{650+375+505+370}{650+375+505+370+510+408} = \frac{1900}{2818} = 0.674$$
$$p_{SW} = \frac{350+370+500+375}{350+370+500+375+420+600} = \frac{1595}{2615} = 0.6099$$

- Thus the proportion of weaving traffic to non-weaving traffic is highest in the East-South direction.
- Therefore, the capacity of the rotary will be capacity of this weaving section. From equation,

$$Q_{ES} = \frac{280 \times 13.5[1 + \frac{10}{13.5}][1 - \frac{0.783}{3}]}{1 + \frac{13.5}{54}} = 2161.164 veh/hr. \quad (40.4)$$

40.6 Summary

Traffic rotaries reduce the complexity of crossing traffic by forcing them into weaving operations. The shape and size of the rotary are determined by the traffic volume and share of turning movements. Capacity assessment of a rotary is done by analyzing the section having the greatest proportion of weaving traffic. The analysis is done by using the formula given by TRL.

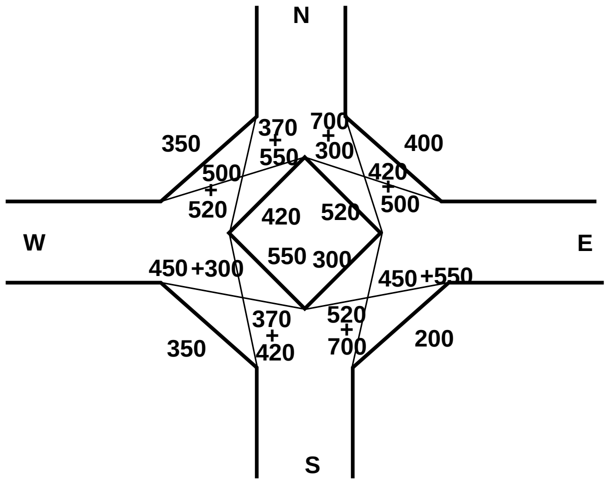

Figure 40:7: Traffic negotiating a rotary

40.7 Problems

1. The width of approaches for a rotary intersection is 12 m. The entry and exit width at the rotary is 10 m. Table below gives the traffic from the four approaches, traversing the intersection. Find the capacity of the rotary.

Approach	Left turn	Straight	Right turn
North	400	700	300
South	350	370	420
East	200	450	550
West	350	500	520

Solution

- The traffic from the four approaches negotiating through the roundabout is illustrated in figure 40:7.
- Weaving width is calculated as, w = $[\frac{e_1+e_2}{2}] + 3.5 = 13.5$ m
- Weaving length can be calculated as, l = 4×w = 54 m
- The proportion of weaving traffic to the non-weaving traffic in all the four approaches is found out first.
- It is clear from equation,that the highest proportion of weaving traffic to non-weaving traffic will give the minimum capacity. Let the proportion of weaving traffic to the non-weaving traffic in West-North direction be denoted as p_{WN}, in North-East direction as p_{NE}, in the East-South direction as p_{ES}, and finally in the South-West direction as p_{SW}. Then using equation,$p_{ES} = \frac{450+550+700+520}{200+450+550+700+520+300} = \frac{2220}{2720} = 0.816$
  $p_{WN} = \frac{370+550+500+520}{350+370+550+500+520+420} = \frac{1740}{2510} = 0.69$
  $p_{NE} = \frac{420+500+700+300}{520+400+420+500+700+300} = \frac{1920}{2840} = 0.676$
  $p_{SW} = \frac{450+300+370+420}{550+450+400+370+420+350} = \frac{1540}{2540} = 0.630$
- Thus the proportion of weaving traffic to non-weaving traffic is highest in the East-South direction.

- Therefore, the capacity of the rotary will be the capacity of this weaving section. From equation, $Q_{ES} = \frac{280\times 13.5[1+\frac{10}{13.5}][1-\frac{0.816}{3}]}{1+\frac{13.5}{54}} = 380.56$veh/hr.