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Traffic Safety at Roundabouts

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Summary

In general, the experience of roundabouts in Sweden is positive (there currently number about 150). In terms of totals, roundabouts give rise to approximately the same number of accidents in relation to the traffic volume as other types of junctions. However, the injury consequences are much lower in roundabouts. This is explained by the fact that the types of accidents with the highest injury consequences in normal junctions are replaced by a corresponding number of accidents with low injury consequences in roundabouts.

This paper presents the results of an inventory comprising all the roundabouts in Sweden done in 1982, reported in Cedersund [1].

Many presently used roundabouts in Sweden originate from the time when Sweden had left-hand traffic. At that time and until the change to right-hand traffic in 1967, circulating traffic had to yield to entering traffic, which often caused traffic jams at peak hours. Many roundabouts were later converted to junctions regulated by traffic signals.

After the change to right-hand traffic, the principle of circulating traffic priority was introduced, which rendered roundabouts renewed popularity as a type of junction with high capacity and with comparatively low costs for building as well as operation.

A roundabout is defined here as a form of traffic regulation giving priority to circulating traffic, i.e. each approach is marked by yield lines and possibly also by a road sign.

Figure 1a A typical roundabout in Sweden with yield lines and road signs.

By international comparison, Sweden has very large central islands. Particularly in Denmark and England, central islands frequently have a diameter of less than 20 metres. In Sweden, however, central islands have an average diameter of 50 metres. Half of the circular central islands have a diameter of exactly 20, 30, 40 metres and so on up to 80 metres. The largest circular central island is 108 meters in diameter and the smallest 15 metres. Roundabouts designed for 70 km/h as maximum permitted speed are larger than those for 50 km/h. Roundabouts for 70 km/h and 4 approaches have the largest average size.

21 roundabouts have a central island which is oval in form. Most of these, however, are almost circular and the degree of ovality is not plainly evident. But there are also central islands which are almost rectangular, the ovality being clearly visible to road users.

This type contains the largest roundabout with a diameter of 200/160 metres. (200 indicates the length and 160 the width of the "rectangle").

Roundabouts have high capacity. Many municipalities therefore choose to build roundabouts where their urban motorways meet major national roads. The average roundabout has an AADT of 16,000 arriving vehicles, although the variation is considerable.

Number of roundabouts in each flow interval (AADT)

0 - 10,000	29
10,000 - 15,000	27
15,000 - 20,000	12
20,000 - 25,000	18
25,000 -	16
Total roundabouts with known total flow	102

If "primary roads" are defined as the two approaches with the largest traffic flows, the remaining approaches are regarded as "secondary roads".

Since a common method is to connect two major roads at a roundabout, this means that the proportion of traffic on the secondary roads is sometimes large.

This is shown in the following table:

0 - 20 %	8
20 - 30 %	24
30 - 40 %	31
40 - 50 %	17
Total roundabouts with known flows in all approaches	80

Figure 1b Different types of accidents in roundabouts.

The investigation period is normally 1975-81. In most cases, the investigation period is shorter because the roundabout was new or because traffic and/or accident data were uncertain for part of the 7-year period. Roundabouts built in 1980 and 1981 are regarded as "new" and are excluded from the data analysed.

2,315 accidents occurred at the 102 roundabouts in the analysis. For 1,904 of these accidents, it is possible to differentiate with regard to accident consequences. Here, 320 accidents resulting in personal injury have occurred and 357 people have been injured or killed.

1,419 of the accidents can be divided up according to injury consequences and accident sequence.

Table 1. Number of accidents according to accident sequence.

1.	Collision with traffic island	96	6.8 %
2.	Run-off outwards	152	10.7 %
3.	Run-off onto central island	75	5.3 %
4.	Rollover	60	4.2 %
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5.	"Squeezing" during circulation	179	12.6 %
6.	Collision in exit	15	1.1 %
7.	Rear-end collision	256	18.0 %
8.	Collision in approach	264	18.6 %
9.	Collision in exit	78	5.5 %
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10.	Bicycle or moped accident	100	7.0 %
11.	Pedestrian accident	32	2.3 %
12.	Other accident sequence	72	5.1 %
13.	Unknown accident sequence	40	2.8 %
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Total		1,419	100.0 %

As the table shows, the accident picture at roundabouts is dominated by single vehicle accidents (1-4) 27.0 %, collisions in approaches (8) 18.6 %, rear-end collisions (7) 18.0 % and "squeezing" accidents (5) 12.6 %.

Tabel 2. Proportions of accidents in various types of junction.

Flow Secondary road proportion	Roundabouts	Large urban junctions [2]	Rural junctions [3]
	Large Very large	Large Large	Small Small
Single vehicle accident	27.0	10.0	15.3
Rear-end collision	18.0	19.1	3.2
Left turn	-	31.6	47.8
Intersecting straight path	-	17.2	7.9
Collision in approach/exit	24.1	-	-
Right turn	-	2.9	4.3
"Squeezing" during circulation	12.6	-	-
Pedestrians	2.3	4.0	0.5
Cyclists	7.0	7.0	5.9
Other accident types	9.0	8.2	15.1

The table shows the very large difference between the accident distributions for roundabouts and those for large urban and rural junctions.

The proportion of accidents with unprotected road users is approximately the same for the three types of junction. However, the proportion reflects more the exposure of unprotected road users than their actual risk. The proportion of rear-end collisions is approximately the same in roundabouts as in large urban junctions.

In typical junctions, accidents in connection with left turns are frequent. Accidents where the vehicles arrive from different approaches and have straight paths, i.e. meeting at right angles to each other, are also common. Neither of these two accident types can occur in roundabouts.

Roundabouts have their own unique accident types - collisions in approaches and exits, which are comparable to right turn accidents at junctions, and accidents in connection with "squeezing" during circulation.

The injury consequences (the number of injured per accident) are remarkably low in the case of roundabouts. In terms of accidents involving unprotected road users, the injury consequences are 0.18.

In an earlier inventory of roundabouts in Sweden [4] an injury consequence of 0.29 has been recorded for roundabouts and in Rural road junctions 0.56 for rural junctions with 3 approaches and 0.77 for rural junctions with 4 approaches. In urban areas [2], an injury consequence of 0.28 - 0.38 has been recorded, depending on the type of junction studied.

The different sources are naturally not fully comparable. For example, the exposure of unprotected road users is unknown. Accidents involving unprotected road users have an injury consequence of almost 1.

Neither earlier traffic safety studies of roundabouts in Sweden nor this survey shows that the number of accidents is significantly lower than in normal junctions with similar flows, number of approaches and speed limit.

The accident rate (number of accidents per million arriving vehicles) at the 102 roundabouts that it was possible to analyse is 0.62.

A comparison between roundabouts and large urban junctions with comparable, if not identical, traffic conditions reveals no notable differences.

Table 3. Accident rate at large urban junctions compared to roundabouts

LARGE URBAN JUNCTIONS [2]			ROUNDBABOUTS [1]	
Three-way junctions	Four-way junctions		Three-way junctions	Four-way junctions
0.30	0.56	50 km/h	0.44	0.63
0.44	0.68	70 km/h	(0.15)	0.65

In the traffic safety studies of urban and rural junctions, relatively clear relations have been found between accident rate and arriving flow.

This is borne out by Figure 2, which includes all roundabouts in the data analysed. The accident rate for the roundabouts with the lowest flows is approximately 0.35 and for roundabouts with the highest flows approximately 0.60 - 0.80.

Arriving flow correlates to several other variables, such as number of approaches and proportion of traffic on the secondary road, which in turn can influence accident rates.

In Figure 3, the roundabouts are divided into those with three approaches and those with four. There are few roundabouts with 3 approaches, but the difference between the curves in the diagram is nevertheless evident. The relation is well-known from other studies of junctions. However, the relation between accident rate and arriving flow is as clear as in Figure 2.

In the traffic safety studies of urban and rural junctions, the proportion of traffic on the secondary road reveals a relation to the accident rate.

In Figure 4, roundabouts with 4 approaches have been divided into those with a low proportion of traffic on the secondary road and those with a high proportion. Here, the relation between accident rate and arriving flow is as plain as in Figures 2 - 4. However, although Figure 4 does not confirm any positive relation between accident rate and proportion of traffic on the secondary road, this does not preclude its possibility.

Figure 2 Roundabouts. The relationship between accident rate and number of oncoming vehicles. (Moving average).

Figure 3 Roundabouts with 3 or 4 approaches. The relationship between accident rate and number of oncoming vehicles. (Moving average).

Figure 4 Roundabouts with 4 approaches and small or large proportion of secondary traffic (> or < 30 %). The relationship between accident rate and number of oncoming vehicles. (Moving average).

Figure 5 Roundabouts with 3 or 4 approaches with oval or circular central island. The relationship between accident rate and number of entering vehicles (Moving average).

Figure 6 Roundabouts with large or small central island (> or < 50 m in diameter). The relationship between accident rate and number of entering vehicles (Moving average).

Finally, Figures 5 -6 show roundabouts divided between shape and size of the central island. The relation between accident rate and arriving flow is evident also here. Furthermore, it may be possible to detect a relation to the size of the central island.

If accidents involving unprotected road users are excluded, single vehicle accidents have the highest accident consequence.

The accident sequences for roundabouts have a low or very low injury consequence.

Table 4. Number of injured persons/number of accidents; injury consequence for different accident sequences and speed limits.

		50 km/h	70 km/h	
1.	Collision with traffic island	8/60 0.13	2/36 0.06	
2.	Run-off outwards	22/115 0.19	14/37 0.38	
3.	Run-off onto central island	13/58 0.22	4/17 0.24	
4.	Rollover	3/39 0.08	4/21 0.19	
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5.	"Squeezing" during circulation	4/153 0.03	1/26 0.04	
6.	Collision in exit	2/14 0.14	2/1 2.00	
7.	Rear-end collision	11/183 0.06	7/73 0.10	
8.	Collision in approach	27/233 0.12	2/31 0.06	
9.	Collision in exit	2/63 0.03	0/15 0.00	
<hr/>				
10.	Bicycle or moped accident	64/80 0.80	18/20 0.90	
11.	Pedestrian accident	25/32 0.78	0/0 -	
12.	Other accident sequence	11/56 0.20	2/16 0.12	
13.	Unknown accident sequence	7/25 0.28	0/15 0.00	
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	Total	199/1,111 0.18	56/308 0.18	

Table 5 Proportions of accidents at different types of junction. (Injury consequence, number of persons injured per accident).

Flow Proportion on secondary road	Roundabouts Large Very large	Large urban junction Large Large [2]		Rural junctions Small Small [3]	
Single vehicle accidents	27.0 (0.18)	10.0 (0.19)		15.3 (0.46)	
Rear-end collisions	18.0 (0.07)	19.1 (0.11)		3.2 (0.38)	
Left turn	-	31.6 (0.27)		47.8 (0.63)	
Intersecting straight paths	-	17.2 (0.40)		7.9 (1.02)	
Collision in approach/exit	24.1 (0.09)	-	-	-	-
Right turn	-	2.9 (0.10)		4.3 (0.40)	
"Squeezing" during circulation	12.6 (0.03)				
Pedestrians	2.3	4.0		0.5	
Cyclists	7.0	7.0		5.9	
Other types of accident	9.0	8.2		15.1	

Comparisons on the basis of the table are difficult because the types of junction have no comparable background data, such as total flow, proportion of traffic on the secondary road, proportion of junctions with 70 km/h, exposure of unprotected road users, different investigation periods etc. Nevertheless, the data provide a good picture of why roundabouts have such a low injury consequence compared to other types of junction.

The types of accident not found in roundabouts (left turn and intersecting straight paths) have the highest injury conse-

quences, while the accident sequences unique to roundabouts have very low injury consequences.

In simple terms, the types of accident with the highest injury consequences in normal junctions are replaced by a corresponding number of accidents with low injury consequences in roundabouts.

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