ROUNDABOUTS

Some remarks on the safety and capacity of roundabouts and roundabout priority systems

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1. INTRODUCTION

The flow of traffic on a road network is determined to a large extent by the capacity of the intersections. These are also an important factor in road safety: over 30% of victims are involved in accidents at intersections - in built-up areas almost 40%. Intersections have consequently received a good deal of attention, and attemps have been made to solve the problems as far as possible by means of design, priority systems and traffic lights. Although a great deal has already been achieved, e.g. with advanced traffic light systems, by no means all the problems have been solved. The frequent use of traffic lights, for instance, irritates road users, especially if they have to wait "unnecessarily" for the lights to change. Ignoring red lights is on the increase and in the case of slow vehicles in particular (cycles and mopeds) this is no longer uncommon. In line with the trend towards deregulation is the idea that there should be more scope for road users to use their own initiative. In this case, however, they should also be placed in a position to act in a suitable way at intersections. If this is to be achieved, simple, clear and recognizable arrangements are needed which will not cause insoluble problems to less experienced or elderly road users. This is important to safety, but so are other requirements such as a suitable speed. To achieve this, devices such as sleeping policeman and road narrowing are often used. Another, perhaps less hostile, way of reducing speeds is the use of roundabouts, an approach which is found on a large scale in England, for example. In various other countries as well, however, including the Netherlands, the problem of roundabouts is - once again - topical.

In this report we consider what contribution roundabouts and roundabout priority systems can make to the safety and capacity of intersections. The data presented here in concise form derive from a study carried out by the Institute for Road Safety Research SWOV; a more detailed report will be produced in due course.

The topics dealt with are: the roundabout concept (section 2), the classification of the problems (section 3), experience and research in the Netherlands and elsewhere (section 4 and Appendix), followed by a discussion (section 5) and some conclusions (section 6).

2. WHAT IS A ROUNDABOUT?

In the present report any more or less circular junction where the traffic travels anticlockwise* around a central island is referred to as a "roundabout". Another condition is that a roundabout must serve at least three roads: this does not therefore include turning loops. The purpose of a roundabout can be defined as to split up the complex situation at an intersection with a large number of conflict points into a number of simpler situations with a small number of conflict points.

Roundabouts are found in a wide variety of sizes and types. Outside built-up areas a roundabout can be so large that it is more in the nature of a curving road with T-junctions; the size is designed to enable traffic to negotiate the roundabout at sufficient speed and/or to make the weaving areas sufficiently long. In built-up areas there is often a distinction between the normal roundabout with a large central island and the mini-roundabout. In many cases a mini-roundabout is no more than an intersection with a small island in the centre. All these types are covered by the term "roundabout" as long as traffic turning left is also obliged to circumnavigate the island.

* Where the report refers to "left turn", "anticlockwise" and "giving way to traffic from the right" this relates to the situation in countries (such as the Netherlands) where traffic travels on the right. Where traffic travels on the left these references should be read as "right turn" etc.

3. WHAT ARE THE PROBLEMS?

What are the situations where roundabouts are suitable as intersections?
How should they be designed?
What is the most suitable priority system?
Are roundabouts as safe as is often claimed?

These are a few of the main questions raised when considering the question of roundabouts, and being interconnected they cannot be considered in isolation. To deal with the fairly complex problems systematically it is useful to start by introducing some kind of classification.

First of all we should distinguish between facets, conditions and criteria. The many facets of the question of roundabouts can be divided roughly into three groups:

1. The use of roundabouts
Where, and in what situations, is a roundabout suitable? This question arises both in new situations, where new roads and districts are being constructed, and in existing situations, where intersections are being converted.
2. Design
Important elements here are: the size, numbers and widths of lanes on the roundabout and the sections of road served, tangential or radial approaches, radius of curvature, banking of curves and provisions for slow vehicles.
3. Traffic control
Priority to traffic from the right, i.e. to traffic entering the roundabout, or priority to traffic on the roundabout. Also included here are traffic light systems and special arrangements for slow vehicles.

The more or less fixed date referred to here as conditions relate to such things as the number and nature of the roads served, the amount of traffic to be handled and the traffic mix, speeds on the approaches, the space available and the type of environment.

Lastly, the criteria: these can be classified as relating to:
a. capacity; this includes the maximum traffic flows that can be han-

dled, waiting times, and - particularly for heavy vehicles - negotiability;

b. safety; numbers of accidents and victims in absolute and relative (risk) terms;

c. environment; obviously such things as air pollution and noise, but also visual aspects relating to the area of pavement and amount of street furniture;

d. cost; including investment, maintenance and running costs; also the cost aspect of road accidents and fuel consumption.

4. EXPERIENCE AND RESULTS OF RESEARCH

The greatest experience of the use of roundabouts is that of road users, but this has not been systematically recorded and is therefore of little practical use. There is also the experience of the highways authorities and there are results form a large number of surveys of a theoretical, experimental or empirical nature. Some of the most important results and experience are briefly dealt with below.

4.1. The Netherlands

Experience in the Netherlands has not been entirely favourable; numbers of roundabouts haven been replaced with other types of intersection in the past. The unfavourable experience has related mainly to capacity. The standard priority system in this country, whereby drivers must give way to traffic from the right (and slow traffic also to fast traffic from the left) generally has a reducing effect on capacity, especially at roundabouts. As the traffic flows increase the waiting times become too long and the roundabout no longer serves its purpose. The installation of traffic lights improves the situation, but then the roundabout loses its proper function, and it is not uncommon for the intersection to be converted in such cases.

There are a few roundabouts in the Netherlands where traffic on the roundabout has priority, indicated by the customary Give Way and Stop signs. Little experience has been gained with this system at roundabouts. Insofar as problems have been noted with this type of roundabout they relate to the conflict between slow and fast traffic and the fact that this is not a normal arrangement in this country.

Now that the interest in roundabouts is again growing and new ones are being constructed, priority for traffic on the roundabout is again being applied, as in the municipalities of Maastricht (St. Annadal Square) and Losser. One of the reasons for the increased interest in roundabouts is the growing interest in speed-restricting devices. The roundabout has for instance been put forward as a "gateway construction" for residential areas.

The safety of roundabouts has received a good deal of attention in the Netherlands but to date has not really been studied systematically. According to information from highways authotities, unfavourable indications usually relate to numbers of accidents; the numbers of accident victims are generally low.

To gain a better understanding of the safety problems at roundabouts the accident data from three types of intersection for the period 1978-1983 were collected and studied. The results relate to all intersections of the particular type, including those controlled by traffic lights; it is not possible, therefore, to draw conclusions on specific types. A discussion of the results is included in the Appendix.

The impression gained from local experience, which is that if roundabouts do not yield fewer accidents at least they yield fewer serious ones, is confirmed by the results.

4.2. Results from other countries

In England, where roundabouts have been used on a large scale for some considerable time now, a good deal of research has been carried out. It has been established on several occasions that roundabouts with priority for traffic on the roundabout have a large capacity and are among the safest types of intersection. Even light-controlled intersections usually score lower on both points. It has however been found that the mini-roundabout is somewhat less safe than the conventional roundabout; this is presumably due to the fact that traffic travelling straight ahead is able to pass through without any great reduction in speed. Concentric lane-markings around the small central island produced little improvement.

In Australia too traffic on the roundabout has priority, and the experience is predominantly favourable. Roundabouts are used at intersections which often handle considerably more than 30,000 vehicles a day. Research has shown that a combination of a two-lane approach and a two-lane roundabout can cope with some 2,400 cars an hour, provided the difference between the flow on the roundabout and that on the approach is not too large.

Research has also produced the following recommendations:
- roundabouts should be designed on the basis of gap acceptance rather than weaving;
- islands should not be too high so that they do not obstruct vision;
- the radius of curvature on approaches should be smaller than on exits;
- proper banking of the carriageway is important so that the situation can be surveyed rapidly.

An example is the United States is Seattle, where a lot of roundabouts (and mini-roundabouts) have been constructed fairly recently. A "before-and-after" study showed that the numbers of accidents at these intersections dropped by an average of about 75%. A reduction in the numbers of accidents on the approaches was also noted (about 40%) as well as a drop in speeds on these sections.

French experience derives mainly from the survey in Quimper. This town has a relatively large number of roundabouts with daily flows ranging from 12,000 to 33,000 vehicles. A "difficult" intersection displayed a 68% drop in road accidents after being converted into a roundabout; shorter waiting times were also observed. Calculations indicated that the use of roundabouts in the town produced considerable fuel savings.
In the cases where traffic on the roundabout has priority it is recommended that radial approaches be used and the priority situation clearly indicated by road signs and markings. This last recommendation is obvious in view of the opinion of various experts that a situation like that in France, where the two priority systems are found alongside each other, should be avoided.

Lastly, a study from West Germany. Calculations based on gap acceptance data showed that a small simple roundabout could handle a maximum of about 2,500 vehicles an hour. This was a situation with a one-lane roundabout and one lane for each approach section, and traffic on the roundabout had priority. The waiting times here were shorter than on a comparable light-controlled intersection. A priority intersection of simular size would be able to handle about 1,600 vehicles an hour with equal traffic flows all directions. A larger roundabout with two lanes, also on the approaches, was compared with a light-controlled intersection with a

total of 12 waiting lanes. Here again the comparison came out in favour of the roundabout, which would have been able to handle 4,000 to 4,500 vehicles an hour according to the calculations.
Advantages of roundabouts mentioned were:

a. shorter waiting times, especially with lower traffic flows;
b. they can often be fitted within the existing intersection area, and require less pavement area;
c. apparently good effect on fuel consumption;
d. ultimately cheaper than a light-controlled intersection.

Here, then, we have the results of the research. The conclusions are favourable as to capacity and safety, and they are remarkably consistent. There are a few positive voices on fuel consumption, but little research has yet been done into the environmental aspects. The information available from the studies mentioned was not always sufficient to enable us to establish how reliable and valid the results were.

It should also be remembered that the results relate almost without exception to situations where slow traffic plays a subordinate role if any. Consequently they cannot be applied directly to the situation in the Netherlands, where slow traffic cannot be ignored, especially in built-up areas.

5. DISCUSSION

To begin with we shall confine our remarks to situations with almost entirely fast traffic.

Use of roundabouts

In many situations the roundabout emerges as a suitable option, with large capacity and short waiting times, provided traffic on the roundabout has priority. Safety is also good, in particular owing to the low speeds and possibly also because of the uncomplicated system of priority. At intersections with low traffic flows a roundabout can sometimes be a practical way of reducing speeds. A roundabout is often a welcome feature to the road user as well, owing to the short waiting times and the absence of unnecessary waiting as can happen at traffic lights. The above is true of roundabouts in built-up areas; outside, and particularly on roads carrying high-speed traffic, caution is called for. An abrupt, drastic reduction in speed owing to the unexpected materialization of a roundabout can cause problems.

Design

The idea that there must be adequate weaving space on a roundabout is increasingly being abandoned. Where traffic on the roundabout has priority, weaving plays little or no part; gap acceptance determines the capacity. Since very low speeds can reduce capacity, however, the radius of curvature should not be too small, and this is also important of the roundabout is to be negotiable by heavy vehicles. From the safety angle it is important that approach speeds be reduced adequately and in plenty of time; the roundabout must therefore be noticeable, even at night. Radial approaches encourage speed reduction and have a good effect on noticeability; they are also more compatible with giving way to traffic on the roundabout.

A mini-roundabout is also a practical option provided the central island is large enough to make it impossible to drive straight through. Where space is limited, a small island, possible enlarged visually with different paving so that heavy vehicles can still negotiate it, may be suitable.

Priority

Priority for traffic on the roundabout is the ideal system, certainly for the busier roundabouts. For the sake of uniformity it would be advisable in this case to apply this system to all roundabouts, thus reducing the risk of drivers making mistakes by not giving way. There is no indication to date that giving way to traffic on the roundabout has an adverse effect on safety; combined with radial approaches and the resulting lower speeds a favourable effect is much more likely. Lower speeds cause an increase in decision-making time, thus reducing the risk of wrong decisions or leaving enough time to correct them. In the event of an accident nevertheless taking place, the consequences at the lower speeds are usually less serious.

Not enough is known as yet about the environmental and cost criteria, although a certain amount can be deduced from the information available. Shorter waiting times, for instance, are likely to result in fuel savings and less air pollution: an idling engine is by no means ideal in this respect. It is not yet known whether vehicles stop more or less at roundabouts. The speeds are to some extent lower than at other types of intersection, but since noise is often caused by acceleration it is not possible to draw a conclusion on this point. The cost of constructing a new intersection is lower in the case of a roundabout than a light-controlled intersection, mainly because of the smaller area of pavement and lower running costs. Converting an existing intersection into a roundabout will often require a larger investment than installing traffic lights; this is counterbalanced, however, by the lower maintenance and running costs.

Let us now take a look at the situation in the Netherlands, with its relatively large amount of slow traffic (cycles and mopeds). Here the capacity of a roundabout for fast traffic will be somewhat lower, and the applications consequently somewhat more limited. Nevertheless a large number of smaller and larger intersections, including light-controlled ones, could be replaced with roundabouts. Their safety will presumably be different owing to the presence of two-wheeled traffic, but this also applies to other types of intersection. The lower speeds on roundabouts remain a plus point, also for two-wheeled traffic. Special consideration does need to be given to the position of slow vehicles: outside the roundabout on separate cycle tracks, or on the roundabout, with or without cycle lanes. The low speed of the motorized traffic, the simpler construction and the more equal treatment of two-wheeled vehicles* would suggest that the latter should use the roundabout. In built-up areas in particular this is an attractive option which makes special facilities and separate priority arrangements unnecessary. The problem of fast traffic not always giving way to slow traffic remains; this also occurs on priority roads and intersections.

Clearly more research is needed before sound decisions can be reached on the position of and priority arrangements for slow vehicles. The opportunities for carrying out such research in the Netherlands are growing now that new roundabouts are again being constructed and priority is on occasion being given to traffic on the roundabout. It would be advisable, incidentally, not to postpone a final decision on the priority system too long; a complex situation where various systems are in force alongside one another is essentially underisable and should not therefore be allowed to persist any longer than is absolutely necessary.

* In the Netherlands, at intersections without signs regulating priority, slow traffic is also required to give way to fast traffic from the left.

6. CONCLUSIONS

The following conclusions can be drawn from this report:

1. The use of roundabouts merits greater consideration, both as an alternative to traffic lights at busy intersections and as a means of reducing speeds at quieter junctions. Careful consideration should be given to the use of roundabouts on roads carrying fast traffic outside built-up areas.
2. The capacity range of roundabouts is very large, up to some 4,000 vehicles an hour provided traffic on the roundabout has priority.
3. The priority system for roundabouts should be standardized, not only nationally but also internationally. The system where traffic on the roundabout has priority would seem to be the best choice at the moment. Roundabouts should be designed with this in mind, e.g. with radial approaches and a suitable radius of curvature.
4. Research should be carried out into the desirability of roundabouts in situations with a lot of slow traffic and the position of slow vehicles on roundabouts; in built-up areas there would seem to be some advantage at the moment in having cycles and mopeds use the roundabout. There is no indication that roundabouts are less safe for slow vehicles than other types of intersection.

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APPENDIX

The table shows recorded numbers of accident victims. It is noticeable that the numbers on roundabouts are low, little more than 1% of all victims at intersections. This does not tell us very much, however, since the numbers of each type of intersection are inadequate and the traffic flows entirely unknown. The table does nevertheless indicate that accidents on roundabouts are generally less serious. The small number of deaths on roundabouts outside built-up areas is particularly striking (two over a period of six years).

Analysis of accidents on roundabouts in comparison with the other types of intersection revealed the following points:

1. A relatively large number of victims on roundabouts among occupants of lorries, buses (except outside built-up areas) and motorcyclists; relatively few among motorcyclists outside built-up areas.
2. In terms of age groups, relatively few victims under 15 and a relatively large number in the 20-29 and 30-44 age group (built-up areas only).
3. A relatively large number of deaths at night, mainly fast traffic.
4. Weather conditions (rain) and wet roads make no significant difference.
5. Single accidents (one-sided and against fixed object) occur relatively frequently on roundabouts; the same is true of T-junctions, but to a lesser extent.
6. Collisions involving injuries on roundabouts:

(a) between fast vehicles are less common;

(b) between a fast vehicle and a cycle or moped are less common in built-up areas and rather more common outside built-up areas;

(c) between fast vehicles and pedestrians, no significant difference exists.

NUMBERS OF ACCIDENT VICTIMS AND SERIOUSNESS BY TYPE OF INTERSECTION AND ENVIRONMENT, 1978-1983

Location	Deaths				Hospital cases			
	+	T/Y	R	Total	+	T/Y	R	Total
BUA	1311	714	19	2044	20794	12480	282	33556
%	64.1	34.9	0.9	100.0	62.0	37.2	0.8	100.0
OBUA	1204	557	2	1763	8088	4655	59	12802
%	68.3	31.6	0.1	100.0	63.2	36.4	0.5	100.0
Total	2515	1271	21	3807	28882	17135	341	46358
%	66.1	33.4	0.6	100.0	62.3	37.0	0.7	100.0

	Other injuries			
	+	T/Y	R	Total
BUA	55033	32285	1037	88355
%	62.3	36.5	1.2	100.0
OBUA	11074	7420	200	18694
%	59.2	39.7	1.1	100.0
Total	66107	39705	1237	107049
%	61.8	37.1	1.2	100.0

	Seriousness					
	S1			S2		
	+	T/Y	R	+	T/Y	R
BUA	5.9	5.4	6.5	28.7	29.0	22.0
OBUA	13.0	10.7	3.3	45.6	41.3	23.4
Total	8.0	6.9	5.8	32.2	31.7	22.6

Key

+ = intersection with four or more arms
T/Y = T-junction or fork
R = roundabout
BUA = in built-up areas
OBUA = outside built-up areas
S1 = number of deaths as percentage of number of deaths + hospital cases
S2 = number of deaths + hospital cases as percentage of total victims