DESIGN AND IMPLEMENTATION OF THE R102 – ZULULAND UNIVERSITY TURBO ROUNDABOUT IN KWAZULU-NATAL, SOUTH AFRICA

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Abstract

Roundabouts are increasingly been utilised as a flexible, efficient, safe and desirable form of intersection control in South Africa. However a first for South Africa is the development of the R102 Zululand University Turbo Roundabout, aimed at improving safety and enhancing the capacity of the intersection.

The Turbo Roundabout is a relatively recent concept which emerged in the Netherlands as an alternative to the conventional multi-lane roundabout. The Dutch experience has been confirming the results – mostly in terms of safety relating to the weaving manoeuvres in the entry and negotiating zones. By using physical raised elements in the entrances, ring and exit zones it is possible to define a spiral path which links the entry to the desired exit with high safety levels.

The construction of the R102 Zululand University Turbo Roundabout has recently been completed as a joint venture project between the KwaZulu-Natal Department of Transport and the South African National Roads Agency Limited, and this paper aims to investigate the general design guidelines that were used, and test the applicability of the concept as a South African case study.

1. Introduction

The University of Zululand is a leading tertiary education institution in the country and provides an extremely valuable service to not only the sub-region but to the country at large. The existing approaches to the University were not befitting the prestigious entity that it was.

Conventional roundabouts are excellent solutions for traffic regulation, traffic calming, urban regeneration and landscaping. They lead to good traffic conditions and increased safety. This solution has been disseminated all over the world. To respond to high capacity requirements, the most used solution is the double lane roundabout. In spite of the good performance levels, there are some functional problems in double lane roundabouts. The most common problems are related to the driver behaviour along the entry, circulatory carriageway, and exit zones of the roundabout. This solution introduces the possibility of lane changing on the roundabout disregarding lane marking, cutting the projector curvature and achieving higher speeds. These behaviours raise safety problems and risk of accidents, mostly without serious injuries but affecting the normal traffic flow. The turbo-roundabout concept emerged in the Netherlands in the late 1990's in order to solve problems relating with the weaving manoeuvres in the multiple lane roundabout circulatory carriageways at the entry and exist zones.

The University of Zululand Project involved the investigation and upgrading of the two intersections, namely the intersection at the entrance to the University and the more major intersection of the R102 (Main Road 2) and the University access road.

Figure1: Conceptual diagram of the R102 / P535 Turbo Roundabout

The most appropriate solution for the University entrance intersection was a median diameter single lane roundabout with pedestrian facilities. The proposal solution for the R102 intersection was a large diameter two-lane turbo roundabout also incorporating pedestrian facilities.

Currently, we in South Africa don't have any guidelines or authority which would be able to determine with certainty which of the foreign guidelines regarding Turbo Roundabouts, would be appropriate for South Africa. Because of this, we have to initiate some basic guidelines for planning this type of roundabout by implementing a few examples in a real environment, monitoring and determine potential problems and uncertainties.

The construction of the R102 – Zululand University Turbo Roundabout has been undertaken, and this Paper aims to investigate the general design guidelines that were used and test the applicability of the concept as a South African first case study.

2. Determining the Best Option for the Upgrade of the R102 – Zululand University Intersection

Road safety is a major concern. Fundamentally in a sustainable safe traffic and transport system smart and safe design of infrastructure limits the chance of an accident to a minimum, and in cases where accidents still occur, since humans are by definition liable to error, circumstances are such that the chance of serious injury is minimised.

Intersections are potential danger points in the road network. Safety measures at intersections are often more cost effective than safety measures on road sections. Intersections also determine to a great extent the quality of traffic flow. Average speed along a road depends on the number and type of intersections.

The most important criteria that always need to be considered to determine the appropriate type of intersection are:-

- road category (road function) within the road network
- needed capacity, considering the forecasted traffic volumes
- desired level of road safety
- policy and traffic management
- spatial possibilities or limitations
- capital and maintenance costs

2.1 Road Category

In a sustainable safe traffic system, road users know, based on the road's category, what traffic behaviour is expected of them, and what to expect from other road users.

The type of intersection contributes to the recognisability of a road's category. The R102 – Zululand University Intersection consists of the R102 (Class 2 Provincial Road) being the alternative route of the N2 between Durban and Richards Bay and the P535/P743 roads as the primary link routes between the N2 and the Zululand University, through the settlement of eSikhawini.

Collector/Mobility roads are always priority roads, both in rural and urban areas. The choice of intersection type is in principle a signalised intersection or roundabout.

2.2 Intersection Capacity

The desired quality of the traffic flow is determined by the capacity of the intersection and the delay of traffic on the minor road. The capacity of a priority intersection increases with a greater number of lanes, but with an increasing number of lanes, road safety deteriorates sustainability. When the capacity requires more than one lane per direction of the major road, the intersection should be changed to a single or multi-lane roundabout or to a signalised intersection. The application of traffic signals can be considered when the average delay of left turning road users is more than 30 seconds.

The following table provides an overview of the capacities of different types of roundabouts and intersections:-

Table 2-1 : Practical and theoretical capacity of different types of junctions

Type of roundabout / intersection	Capacity in peak hour (± 10% of AADT), all entries combined		Conflict load (pcu/h)
	Practice	Theoretical	
Single lane roundabout	2,000	2,700	1,350 to 1,500
Multi-lane roundabout with single entry and exit lane	2,200	3,600	1,500 to 1,800
Multi-lane roundabout with two entry lanes and single exit lane	3,000	3,600	1,800 to 2,000
Multi-lane roundabout with two entry and exist lanes	3,500	4,000	2,100 to 2,400
Turbo roundabout with two entry and exit lanes (basic design)	3,500	3,800	1,900 to 2,100
Spiral roundabout	4,000	4,300	2,000 to 2,300

Type of roundabout / intersection	Capacity in peak hour (± 10% of AADT), all entries combined		Conflict load (pcu/h)
	Practice	Theoretical	
Rotor roundabout (three entry lanes and two exit lanes)	4,500	5,000	2,500 to 2,800
Signalised roundabout (3*2 entry lanes)	8,500	11,000	4,200
Priority intersection with left turning lane	1,500	1,800	1,100
Four leg intersection with traffic signals (entries 3*1 travel lanes)	3,500	4,000	3,800
Four leg intersection with traffic signals (entries 3*2 travel lanes)	7,500	8,000	3,800

A traffic analysis was undertaken for the R102 Zululand University Intersection based on the background growth rates as evidenced by historical data, horizon Year 2030 and by using the well-known computer programme "SIDRA Intersection".

The table below tabulates the analysis for future traffic (Year 2030) – AM Peak:-

Table 2-2 : Intersection Analysis for Future Traffic (Year 2030) – AM Peak

R102 / P743 / P535 Intersection / Movement		Performance Indicator			
		Volume	LOS	V/C	Q (m)
R102 (South Approach)	Left Turn	36	A	0.19	7
	Straight	202	A	0.19	7
	Right Turn	153	B	0.15	4
P535 (East Approach)	Left Turn	56	A	0.07	5
	Straight	103	A	0.17	5
	Right Turn	111	B	0.17	5
R102 (North Approach)	Left Turn	55	A	0.18	7
	Straight	145	A	0.18	7
	Right Turn	124	B	0.13	5
P743 (West Approach)	Left Turn	139	A	0.15	2
	Straight	149	B	0.16	5
	Right Turn	43	B	0.16	5
OVERALL		**1316**	**A**		**7**

Whilst the warrant has not been met with regarding the capacity requirements the choice of either a signalised intersection or roundabout is considered an option given the mix of vehicle types, pedestrians and variable traffic speeds.

2.3 Desired Level of Road Safety

The majority of accidents at priority intersections are associated with left turns, and straight through crossings of the major road. These types of accidents are eliminated by a roundabout. The roundabout is the safest at-grade intersection, in particular the single lane roundabouts. Dual lane roundabouts are less safe, not only the consequence of higher levels of traffic, but also because of the inter-weaving paths and cutting off paths at exits. Roundabouts both promote the fluid flow of traffic and have an important speed reducing effect.

Turbo roundabouts do not yield as good a safety record as single lane roundabouts however they can handle greater levels of traffic.

Research in Germany has also found that roundabouts are safer than signalised intersections. The number of potential conflict points for two roundabout options are indicated in the figure below:-

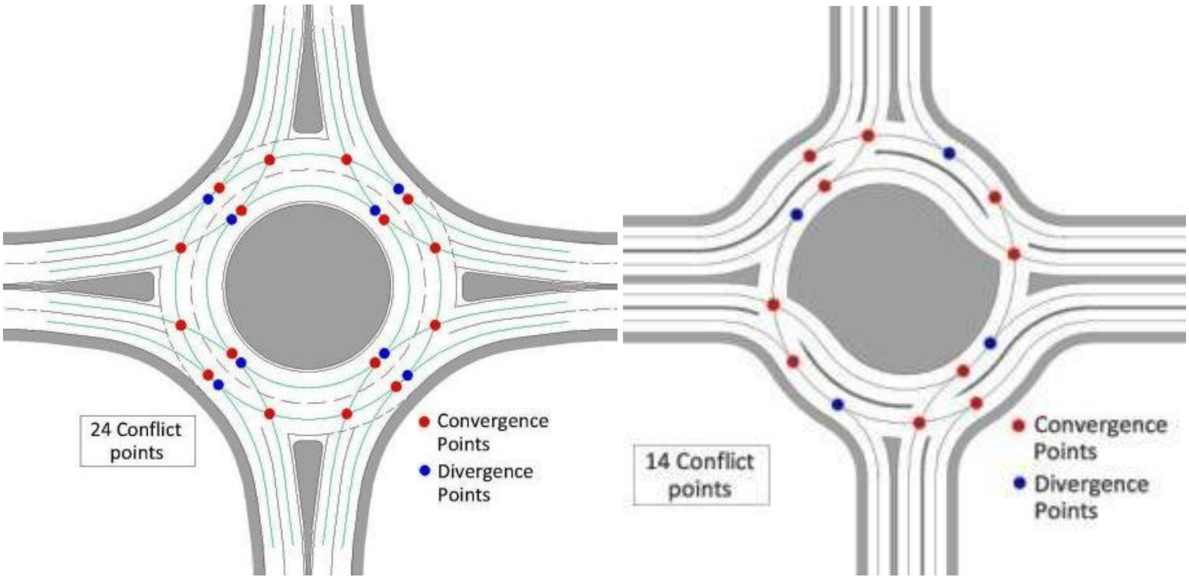

Figure 2-1 : Conflict points in standard 2 lane roundabout vs. Turbo Roundabout.

The safety aspects of the existing R102 – Zululand University Intersection had deteriorated to such an extent, that speed control humps had been installed on all the approaches. This resulted in vehicles moving very slowly through the intersection. The high number of pedestrians as well as the longer delays for traffic on the minor roads made this an area that was highly susceptible to vehicle hijacking. Reportedly there is very little traffic law enforcement available in this area, which raised concern that the option of the traffic signals might not have the necessary adherence without enforcement.

2.4 Policy of Traffic Management

Although roundabouts are known as excellent solutions for traffic regulation, traffic calming, urban regeneration and landscaping from international experience, some local transport authorities are still not fully convinced that roundabouts are a good option, as the road user can often be confused by the operations of multi-lane roundabouts.

Roundabouts may not also be appropriate for use of intelligent traffic systems, integrated traffic management, or other circumstances where access control is required, such as co-ordinated traffic signals. The traffic management was not an issue for the R102 – Zululand University Intersection due to the rural nature of the intersection and the low traffic volumes. However, although the project was a joint venture between the KwaZulu-Natal Department of Transport and the South African National

Roads Agency SOC Limited, the approving authority was the KZN Department of Transport who had various reservations regarding roundabouts in general.

2.5 Special Limitations and Costs

Roundabouts usually require more space than the traditional intersection. At the R102 Intersection the site was quite restricted, that would result in the intersecting legs not intersecting at the desired 90˚ angle.

Compared to signalised intersections, a roundabout does not have traffic signal equipment that requires constant power and maintenance. Roundabouts have very low maintenance costs. The issue of cable theft is also a serious concern with the R102 Intersection.

3. The General Turbo Roundabout Design Guidelines

3.1 Geometric Elements

Turbo roundabouts, which are multi lane roundabouts with special road marking and separated circulating lanes, perform much better in capacity and safety, while they do not need any additional space.

In the turbo roundabout the drivers are forced to follow a specific path according to their intended destination. In the Netherlands where the first turbo roundabouts were installed in 2000, multi lane roundabouts are no longer built, and existing multi lane roundabouts are being reconstructed into turbo roundabouts.

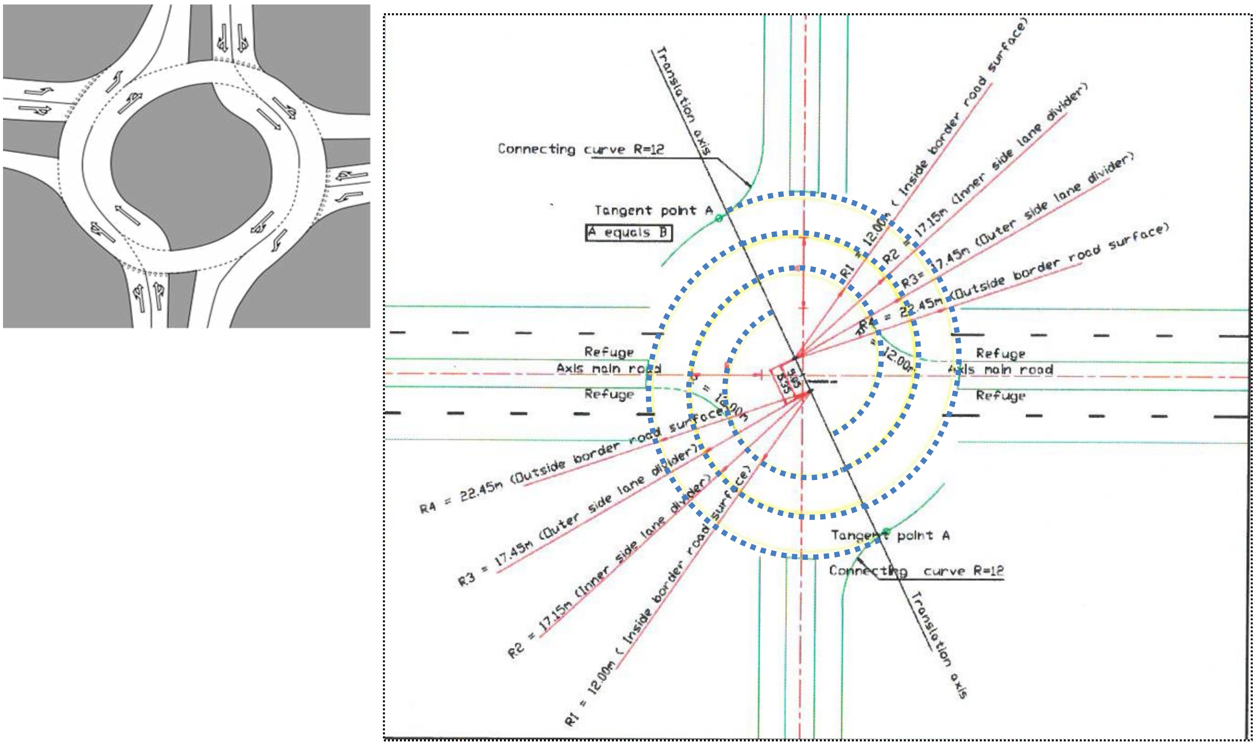

Figure 3-1 : Schematic concept diagram and Geometric details of a turbo roundabout.

The turbo roundabouts consist of spirals. These spirals are composed of segments of circular arcs, often semi-circles with each arc having a larger radius than the previous arc.

In an idealised geometry, the basic turbo roundabout consists of two nested spirals, which represent lane boundaries. Each spiral consists of three semi-circles with successively larger radii. The semi-circles meet at a line called the translation axis. The arcs on the one side of the translation axis have a centre that is above the overall centre of the roundabout, and the arcs on the other side of the translation axis have a centre that is below the overall centre. The distance between the centres of the arc segments is called the shift along the translation axis. Ideally, the shift is one roadway width, because the spiral moves out by one roadway width every 180 degrees.

Table 3-1 : Design Elements of Turbo Roundabout

Feature	Radius and Measurement (m)			
Radius of inside roadway	10,5	12	15	20*
Radius of outside roadway	21,15	22,45	25,2	29,90*
Width of roadway	5,0	5,0*	4.9	4.7
Shift along translation axis	5,05	5,05*	4.95	4.75
Average Diameter	42,60	45,18	50,64	60,00*
Width overrun (22m to 27m vehicles)	5,0	5,0	5,0	5,0*
Speed, passenger car (km/h)	37-41	37-39	38-39	40*

* *Elements used for the R102 Turbo Roundabout*

3.2 Road Marking, Signposting and Lighting

For the right use of a turbo roundabout it is important that road users are clearly informed before reaching the roundabout about the lane they have to choose in order to proceed in the desired direction. On turbo roundabouts driving a full circle to correct a wrong choice for the direction is not possible.

Figure 3-2 : Typical Arrows Used in the Netherlands

Unfortunately in South Africa, these markings are not approved and accepted within the South African Road Traffic Signs Manual (SARTSM), and therefore could not be used on the R102 Zululand University Intersection.

Road users on turbo roundabouts have to receive and interpret much information, and therefore it is important that the road markings and signage are carefully designed, in order not to overload the road user with information. The road users need to be clearly informed in plenty of time using a minimum of signs.

The visibility of the intersection and the alignment of the lanes have to be assured at night time, especially for turbo roundabouts. Lighting is therefore critical.

Figure 3-3 : Signposting on the R102 Intersection

4. Overview of the Project and Conclusion

The turbo roundabout is a recent concept which emerged in The Netherlands as an alternative to the conventional multi-lane roundabouts. The Dutch experience has been confirming the expected results, mostly in terms of safety.

The design and implementation of the R102 Zululand University Turbo Roundabout has been a challenge to the planners, designers, contractors and also the road users. The road authority needed to firstly be convinced that a turbo roundabout could be the best option at the R102 Intersection, and the concept was submitted as an innovation project, which was well received by the KZN Department of Transport. Despite this, there were still reservations from the road authority that the road users in the area might not be able to adapt to the new intersection concept.

To ensure the turbo roundabout concept was given the best chance to succeed, an education drive was undertaken through meetings with the community and local taxi industry. Flyers were distributed to local users, including the university staff and taxi drivers and an article was published in the local newspapers. The existing traffic volumes are very much less than the designed turbo roundabout capacity and this has also assisted for the new form of traffic technology to be accepted.

The R102 Intersection site allowed sufficient space to construct the turbo roundabout, however the existing angle of the intersecting roads were very oblique and even though there were the realignments to improve the intersecting angles of two of the legs, the four legged turbo roundabout did not achieve the desired 90° angle of intersection roads, causing the geometry to effect the safety and flow capacity of the roundabout.

As maintenance was to be kept to a minimum for the R102 turbo roundabout, a concrete pavement as well as concrete lined islands and circle centre was decided as the best option. The concrete panelling proved to be challenging in terms of the jointing design and in casting the panels which required the shuttering to be constructed in different radii.

Figure 4-1: Completed R102 –Zululand University Turbo Roundabout

The applicability of the turbo roundabout concept at the R102 Intersection is currently being monitored and the information will be compared to data recorded prior to the turbo roundabout being constructed. Initial observations have indicated that generally the road users are travelling cautiously through the roundabout and there have been some instances were traffic is weaving between the lane dividers within the circle. This could be as a result of the road user not being properly informed of the correct lane choice required before entering the turbo roundabout. To improve the situation there could also have been a two lane exit on the main R102 route, north and south bound, where the inner lane would be a more natural decision the road user would use to proceed straight through the intersection. This situation will be monitored and rectified if required. As a requirement of the South

African National Roads Agency SOC Limited a Road Safety Audit was undertaken for the R102 turbo roundabout intersection.

South Africa is experiencing unprecedented traffic growth and innovative solutions are needed to improve the efficiency of the transportation networks. Turbo Roundabouts could offer the solution for improved intersections.

Although road users would have to get used to the new roundabout design, there does not seem to be any serious obstacle to the introduction of the turbo roundabout in the South African situation. Initial investment requirements may be compensated for by lower maintenance costs, energy consumption and road accident costs.

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