

# DESIGN AND IMPLEMENTATION OF A TURBO ROUNDABOUT

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## ABSTRACT

A first for South Africa, the KwaZulu-Natal Department of Transport (DoT) has partnered with the South African National Roads Agency (SANRAL SOC LTD) to upgrade the R102 / P535 / P743 intersection (west of the eSikhawini off-ramp off the N2 between Mtunzini and Empangeni) into a Turbo Roundabout traffic circle. Royal HaskoningDHV was appointed for the design of the turbo roundabout.

The benefits include:

- improved driver safety
- reduced delays and congestion at the intersection; and
- improved pedestrian safety and crossing opportunities

When compared with a normal traffic circle, the crossing over of lanes when exiting the circle has now been eliminated with the design of the Turbo Roundabout, resulting in less side swipe accidents.

This paper will discuss the planning, design and benefits of the Turbo Roundabout.



Figure1: Conceptual diagram of the R102 / P535 Turbo Roundabout

## 1. INTRODUCTION

The intersection of the R102, P535 and P743 is the intersection between the secondary route from Durban to Richard's bay and the route from the township of eSikhawini to the University of Zululand. The R102 is a class 2 provincial road that services the University, the timber haulage routes, a quarry as well as being an alternative to the toll-route between Mtunzini and Empangeni. The P535 / P743 route is the primary link between eSikhawini and the University of Zululand. As such there was a significant amount of public transport between these node points and a pedestrian pick up point at the intersection in question. There was therefore a conflict point of heavy and light vehicles as well as being an area that was particularly dangerous to pedestrians at the intersection.

The high number of pedestrians as well as the frequency of static traffic made this an area that is highly susceptible to vehicle hijacking.

The original layout of the intersection is shown in Figure 2 below:



**Figure2: R102 / P535 intersection before upgrades**

The heavy vehicle activity was a mix of small, medium and large vehicles, the large vehicles mainly consist of cane and timber haulers. These haulers are long, heavy and when fully laden, move slowly up gradients. The intersection is situated in a sag curve and therefore there is a down gradient on both sides of the R102. This, coupled with the need to slow almost to a stop at the speed humps on all sides of the intersection, results in these vehicles moving very slowly through the intersection.

The Kwa-Zulu Natal Department of Transport (KZN-DOT) identified this intersection as requiring an upgrade. Initially the proposal was made for a standard signalised intersection to be implemented as this would be suitable for the mix of vehicle types, pedestrians and variable traffic speeds. However, there was concern that there was very little traffic law enforcement available and that without enforcement there would be little adherence to additional controls like traffic signals.

A traffic analysis was carried out and it was concluded that there was a strong right turn movement from Empangeni towards the university in the morning peak times and a corresponding left turn movement from the university towards Empangeni in the afternoon peak. As such the upgrade to the intersection would need to cater for a split priority between through flow on the R102 and the flow in and out of the University. This could be in the form of a signalised intersection with turning arrows, but this should not interfere with the ease of traffic flow along the R102. It was noted in the traffic analysis that the predicted traffic flows were low enough

ugh that if the layout of the intersection were improved to the standard specifications required for a signalised intersection (road marking, lane delineation, kerbed and painted islands etc) but without the traffic lights themselves, the intersection would be adequate.

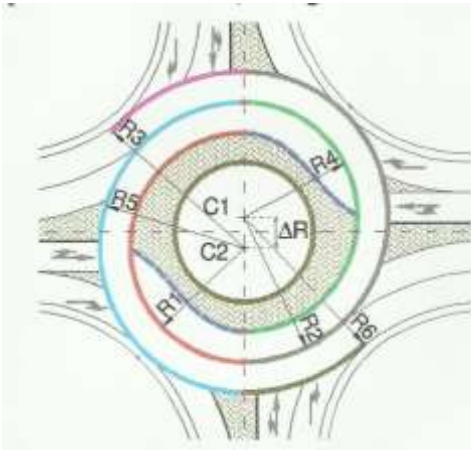
Due to particular features of this intersection such as the hijacking hotspot that would be encouraged through forced stoppages in a signalised intersection, as well as the dependence upon an electricity supply that was susceptible to outages due to cable theft, the KZN-DOT requested a solution to the upgrade that would not be susceptible to the local problems mentioned.

Prior to this investigation Royal HaskoningDHV had presented the concept of a Turbo Roundabout to the KZN-DOT as an innovative alternative to standard roundabouts. Turbo roundabouts have been used very effectively in the Netherlands and Belgium as a means of increasing the capacity of a roundabout and of removing the dependency on traffic signals. Furthermore, the use of two lane circles has been shown to cause confusion among drivers to the extent that two lane circles are no longer used in Germany or the Netherlands. The proposal was very well received and was approved for testing on South African roads.

After considering the intersection in question, it was agreed that this would be an ideal situation to test the concept of a turbo roundabout in a South African context.

## 2. WHAT IS A TURBO ROUNDABOUT

A turbo roundabout works on the concept of spiral lane dividers with mountable kerbs between lanes. This has the effect of reducing the number of conflict points in the intersection. The spiral effect can be generated through an Archimedean spiral or by taking a standard roundabout and splitting the centre points of the arcs by the distance of one lane width as per the following description quoted from Giuffrè, Guerrieri and Granà 2009:



The characteristic shape of the central island (see Figure 3) is designed through arcs of circumferences with different centre and radius. The geometric design follows subsequent steps:

1. single out the center of the intersection (or the intersection point among crossing roads);
2. select the width of the lane and the semi-width of the safety island among lanes (curb and shoulder), which sum corresponds to the distance between C1 and C2:  $C C = DR 1 2$
3. position C1 and C2 centers symmetrically as to the intersection point among the road axis;
4. fix the value of the first radius and put  $R_1 = R_4$ ; the other radius values are defined by the

relation:  $R_i = R_{i-1} + \Delta R$ . In particular, it results

$$R_3 = R_2 + \Delta R.$$

$$R_6 = R_5 + \Delta R.$$

$$R_2 = R_1 + \Delta R.$$

$$R_5 = R_4 + \Delta R.$$

(see Figure 3):

(Giuffrè , Guerrieri and Granà,2009, P4)

### Figure 3: Geometric design of the turbo roundabout

The Archimedean spiral is a more complex method of achieving a similar end. It does have the advantage of a gradual shift in radius as compared to the split circle type but for the low speeds of the R102 Turbo Roundabout, this was deemed as insignificant when compared to the added complexity of design, analysis and construction.

In order to build a turbo roundabout scheme with a continuous variation of curvature of circulating lanes, in some cases a spiral can be applied by turns. Considering that the width of circulating lanes has to be kept constant along its development, it follows that the curve has to be marked by a constant step equal to the transversal spacing between the lanes. The last characteristic belongs to the Archimedean spiral (see Figure 4), which equation is the following:

$$R = a \cdot \theta$$

where  $R$  is the radial distance from the origin,  $a$  is the parameter of the curve and  $\theta$  is the polar angle (i.e. the angle corresponding to the point with curvature  $1/R$ ).

The Archimedean spiral represents the trajectory of a point  $P$  moving with a constant speed along a half-line pivoting with constant speed on the point  $O$ . Any half-line originating from the point  $O$  (i.e. the origin of a system of Cartesian axes) intercepts equal segments on the Archimedean spiral:

$$\overline{OA} = \overline{AB} = \overline{BC} = \dots$$

The well-known parametrical equations of the spiral are as follows:

$$x = R \cdot \cos\theta = a \cdot \theta \cdot \cos\theta$$

$$y = R \cdot \sin\theta = a \cdot \theta \cdot \sin\theta$$

In order to determine the step of the spiral  $K$ , denoting with  $n$  a natural number ( $n = 1, 2, 3, \dots$ ), it is required to assume the following conditions:

$$R_n = a \cdot \theta_n$$

$$R_{n+1} = a \cdot \theta_{n+1}$$

$$K = R_{(n+1)} - R_n = a \cdot (\theta_{n+1} - \theta_n) = 2\pi \cdot a$$

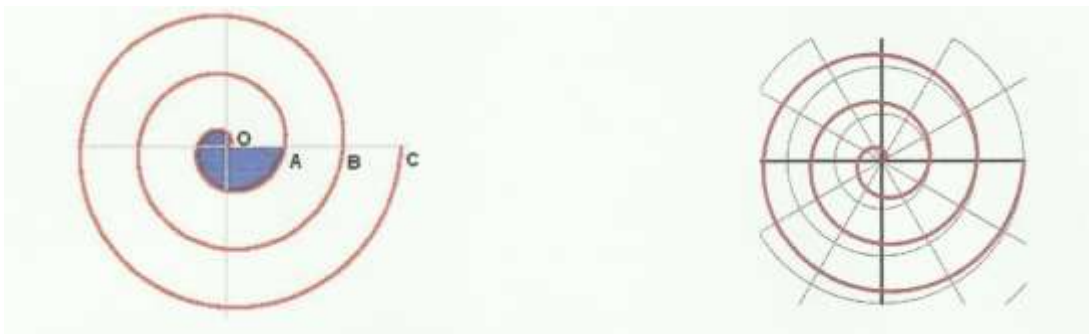
By these relations the value of the  $a$  parameter can be obtained, considering that the step  $K$  of the spiral is known:

$$a = 2\pi / K$$

The length of the spiral can be obtained by the following equation:

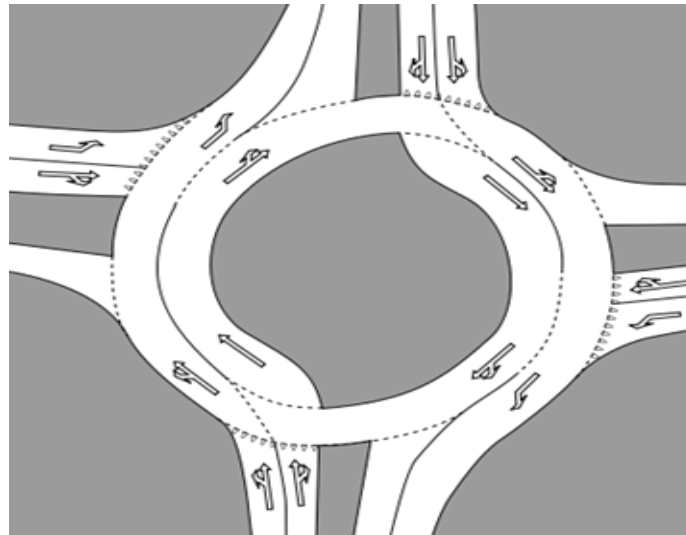
$$L = \frac{1}{2} \cdot a \cdot [\theta \cdot \sqrt{1 + \theta^2} + \ln(\theta + \sqrt{1 + \theta^2})]$$

(Giuffrè , Guerrieri and Granà, 2009, P5)



**Figure 4: The Archimedean spiral**

Despite the difference in appearance of the Turbo Roundabout to a standard roundabout, it does operate on the same principle as a normal two-lane roundabout. The key difference being that it removes the ability for a driver to change lanes and cause conflict within the intersection. As can be seen in Figure 5 below the spiral nature of the intersection reduces conflict points through spatial lane separation as well as physical lane separations like mountable kerbs (represented as solid lines)



**Figure 5 : Schematic concept diagram of a turbo roundabout.**

The reduction of time spent in conflict zones should have an immediate effect on reducing collisions and the physical lane separators would serve as guidance to motorists.

### **3. HISTORY OF TURBO ROUNDABOUTS**

The Turbo Roundabout was developed in The Netherlands by Mr Lambertus Fortuijn, a lecturer at the Delft University of Technology in 1996. His aim was to solve the problems of conventional multilane roundabouts, the most common of which related to drivers performing lane changes in disregard to the lane markings. He formed a solution based on two aspects: 1) no lane changing in the intersection (roundabout) and near the entry and exit; and 2) low speed near and through the intersection due to the raised lane dividers.

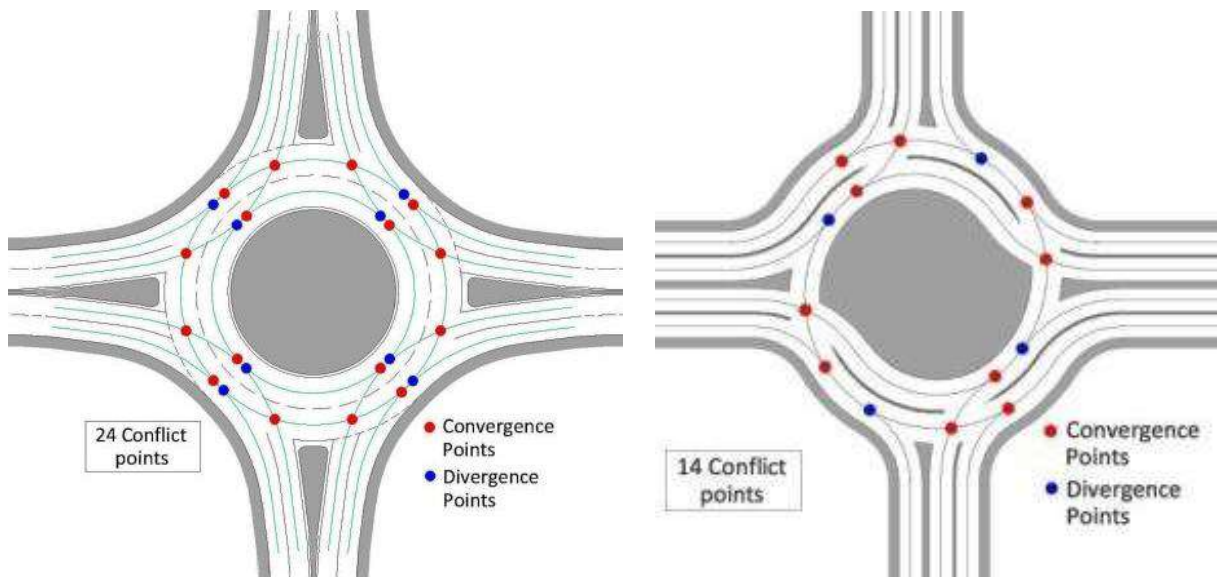
### **4. FACTORS INFLUENCING THE CHOICE OF THIS SOLUTION**

The pilot project of a Turbo Roundabout was one that needed to be tested in a South African context. According to data there should be a significant increase in the capacity of the intersection, approximately 30% higher than a two lane and 75% higher than a one lane roundabout. Although the capacity provided would not be needed, it was advantageous to test the concept where drivers would have more time and space to become accustomed to the new intersection.

The site of the intersection had sufficient space around it to allow the construction of a suitable size roundabout

### **5. THE ADVANTAGES OF THE TURBO ROUNDABOUT**

As previously discussed, the Turbo Roundabout offers a higher capacity than traditional 2 lane roundabouts with fewer conflict points and thus lowering the numbers of collisions. Figure 6 illustrates the difference between standard and Turbo Roundabouts as it pertains to collision points. It must be noted that Figure 6 shows traffic driving on the right side of the road.



**Figure 6 : Conflict points in standard 2 lane roundabout vs. Turbo Roundabout.**

Unlike traffic signals, the Turbo Roundabout is less dependent upon electricity and thus functions in power outages, and is not susceptible to vandalism. The physical barriers in the form of the lane dividers and raised centre island further encourage drivers not to follow their own interpretation of traffic rules.

The Turbo Roundabout concept is also able to be manipulated to allow priority flow thus enabling the designer to maintain the order of the road and the network.

## 6. THE DISADVANTAGES OF THE TURBO ROUNDABOUT

Due to the free flowing nature of the Turbo Roundabout, it is imperative that drivers know what they are required to do before they enter the intersection. This is only possible through very visible and unambiguous signage. Road marking should be clearly visible; signage should be informative as well as give the driver sufficient time to pick the lane that they require. It was suggested that the Turbo Roundabout be serviced by the same form of road signage and road marking that is used in similar roundabouts elsewhere in the world as per the examples below.



**Figure 7a : Road signage and marking used elsewhere in the world**



**Figure 7b: Road signage and marking used elsewhere in the world**

The signage that was used in the R102 Turbo Roundabout had to conform to the South African Road Traffic Signs Manual (SARTSM) and thus the more specific signs as seen above were not available. The applicability of the circle specific signs and markings is being tested elsewhere in the country and should the tests be found to be beneficial, then they should be implemented here.

As with any pilot project, an education drive was necessary. This was undertaken through meetings with the local taxi industry where the Turbo Roundabout was explained and shown through PowerPoint presentations and 3D simulations. Flyers were distributed to local users such as the University staff and taxi drivers, a copy of which is shown in Appendix A, and an article was published in the local newspapers.

The problem would be exacerbated if the roundabout was expected to flow anywhere near capacity in its initial stages, in this case however it is not expected and thus serves as an ideal learning platform for a new form of traffic technology.



## 7. SPECIFIC CHALLENGES TO THIS SITUATION

The Turbo Roundabout is ideally suited for an urban type of environment where the roads intersect at right angles and there is enough space for a suitable roundabout (70m diameter).

On the R102, there was sufficient space to construct the roundabout, but the intersecting roads were far from right angles and as such re-alignments of two of the legs was required to try to get the roads to intersect at a more favourable angle.

The roundabout was constructed while the roads were open to traffic. This created a challenge of traffic accommodation for the contractor who was required to construct deviations around the roundabout area.

A further challenge was set to discourage drivers parking on the safety apron of the circle to pick up passengers as well as to stop them trying to overtake by cutting over the safety apron. It was advised to use a roughened surface like cobble stones in the safety apron, there was however a very real risk of cobble stones being ripped out of the concrete bed in the situation of a trucks wheel path tracking over them. An innovative solution of using back-to-back mountable kerbs in a starburst pattern is being tested. The kerbs go from being almost completely submerged in the concrete on the outer perimeter, to being completely exposed on the inside edge. This would serve to remind the uninformed driver that the safety apron is to increase visibility, allow the rear wheels of a truck's trailer to track over, but is definitely not for driving over.

Pedestrian safety was also a concern as this intersection serves as a drop off point for many of the University students. Because of this, walkways were added to the intersection as well as pedestrian crossings and refuge islands.

Initially, the Turbo Roundabout was intended to have an asphalt surface and a grassed centre that could be cultivated to be a very aesthetically pleasing garden. The client was concerned that this would require significant maintenance and thus opted for a concrete road surface as well as a concrete centre.

The concrete panelling proved to be challenging in terms of the jointing design and in the construction. Casting the panels in concrete required the shuttering to be constructed in different radii while the tining of radial panels was another challenge to the developing contractor.

## 8. CONCLUSION



**Figure 8: Aerial photograph of the completed Turbo Roundabout on the R102**

Although the location of the intersection was not ideal for a Turbo Roundabout, the primary aim is to test all aspects of it in South Africa. The design and construction of this intersection did prove to be challenging as many of the concepts were new to all parties, but as can be seen from the aerial photograph above, the project was completed as per design. The continued use of the intersection will be monitored and the information gathered will be compared to data recorded prior to the construction of the Turbo Roundabout. This will then be compared to records from Turbo Roundabouts in Europe to see whether the same benefits exist in South Africa and whether they are a viable solution to some of South Africa's problem intersections.

## REFERENCES

Silva, AB; Santos ,S & Gaspar M, 2013, *Turbo-roundabout use and design*, University of Coimbra

Giuffrè ,O; Guerrieri, M. & A. Granà, A., 2009, *Turbo-Roundabout general design criteria and functional principles*: Palermo University

Engelsman JC & Uken M, *Turbo Roundabouts as an alternative to two lane roundabouts*.