ROTARY INTERCHANGE ON NATIONAL ROUTE 3

Walden, S. and McGuigan, D.J.

BCP Engineers (Pty) Ltd, PO Box 94, Pietermaritzburg, 3200, South Africa.
Tel: 033 345-3211. Fax: 033 342-6271. E-mail: derekm@bcp.co.za

ABSTRACT

The paper describes the background, modelling, geometric design and performance of the reconfigured Armitage Road/Sanctuary Road interchange on the N3 in Pietermaritzburg. This reconfigured interchange is the first rotary type constructed on a National Route in South Africa.

The development of the node surrounding the original half-diamond interchange (including a regional shopping centre), rendered the existing interchange incapable of handling the projected traffic volumes. The new interchange needed to satisfy both commuting and access requirements. Furthermore, the constrictions imposed by the site and financial constraints dictated that the options in meeting the stated goals were limited. In order to accommodate these divergent functions, innovative proposals were tested in the quest to provide an efficient and effective solution. The modeling and testing was undertaken using a combination of accepted computer programs namely SIDRA and the SimTraffic/Synchro pairing. The adopted rotary interchange was deemed the optimum in complying with the various constraints. This assessment process is described in detail in the paper.

The rotary design parameters are dealt with covering, particularly, the geometry, the constraints and scope, roadmarking and signposting.

The rotary was commissioned one week before the opening of the regional shopping centre that serves the entire KwaZulu-Natal Midlands. Consequently the rotary was subjected to intense testing in a very short period of time by motorists who themselves were undergoing a familiarization process.

The performance in the weeks and months following the commissioning is explained in the paper covering the adjustments and fine-tuning necessary to achieve optimum performance and capacity.

1. INTRODUCTION

National Route 3 (N3) is the major transportation linkage between Africa's busiest port of Durban and Johannesburg, the economic and industrial hub of South Africa. The N3 passes through Pietermaritzburg, the capital city of KwaZulu-Natal, approximately 80 km from Durban. The traffic volumes on the N3 in the vicinity of the interchange (Armitage Road / Sanctuary Road) under review, are in the order of 20 000 vehicles per day.

The development of a 38 000m² regional shopping centre adjacent to the N3 in Pietermaritzburg acted as a catalyst to other major development proposals that have led to the establishment of a commercial node straddling the N3. Access to the N3 at this point is via the Armitage Road / Sanctuary Road Interchange - a dated, sub-standard half diamond configuration with limited traffic capacity. The traffic generation potential of the proposed commercial node required the capacity of

the interchange to be significantly enhanced.

Achieving this goal was influenced by numerous constraints such as physical infrastructure, limited funding, serviceability, existing commuter patterns, traffic accommodation during construction and future traffic expectations.

The selection of a rotary interchange satisfied these criteria more appropriately than any other potential configuration.

This paper describes the research and planning, design issues, construction principles, commission and operational performance of the implemented interchange. The operational performance is based on observations over a short end-of-year period, when there still existed an element of novelty and may not be truly representative of the longer-term traffic patterns. Furthermore, the development node is, in terms of traffic generating potential, at ±70% of its capacity.

2. RESEARCH AND PLANNING

Research for the design entailed firstly an analysis of the traffic performance of the proposed interchange via the use of the Highway Capacity Manual and the computer program SIDRA (Signalising Intersection Design and Research Aid). SIDRA is a useful, tried and tested tool in analysing isolated intersections whether signal, priority or roundabout controlled.

A traffic model was constructed in which the observed existing traffic was superimposed onto the traffic generations that would result from the adjacent and vicinity development.

The construction of the model followed the classic procedure;
- generate traffic
- distribute traffic
- assign traffic
- add existing traffic (+ traffic growth)

Modal split was ignored as it is relatively insignificant at this particular location.

A concept layout was prepared which satisfied the physical constrains and which took cognizance of the traffic patterns and demands of the localised road network.

The procedures of the Highway Capacity Manual were employed for the analysis of the ramp merge and diverges. SIDRA was used to analyse the performance of the interchange crossing road and road/ramp approaches as for a conventional roundabout. Whilst it was recognised that the rotary crossroad did not represent a typical roundabout in terms of shape, size and lane configuration it was nevertheless deemed appropriate in that the principle dynamics of a roundabout whereby incoming traffic creates gap opportunities downstream were likely to be achieved.

Subsequent to the construction and commissioning of the rotary interchange as part of a wider traffic study the opportunity arose to model the interchange using a traffic simulation technique. The Synchro/SimTraffic program pairing was used for this purpose. The simulation program (Synchro/SimTraffic) does not model give-way (yield) intersections very well and consequently queue lengths are longer with this model than that as calculated by SIDRA. Nevertheless the simulation did provide a measure of confidence as to the dynamics of the roundabout operation and the results of this modeling exercise have confirmed the SIDRA analysis.

The existing traffic volume and future volume (essentially the predicted shopper traffic) patterns are depicted on Figure 1, the salient points being the strong commuter movements during the peak hours and the conflicting traffic needs of the shopping centre. The limited road space meant that the

conflicting traffic demands needed to be accommodated as efficiently as possible with minimal delay and/or queuing.

Other configurations were considered but in all cases the difficulty in satisfying crucial issues such as limited space, short ramp lengths, conflicting traffic demands, commuter traffic patterns and most importantly the cost, resulted in the selected option.

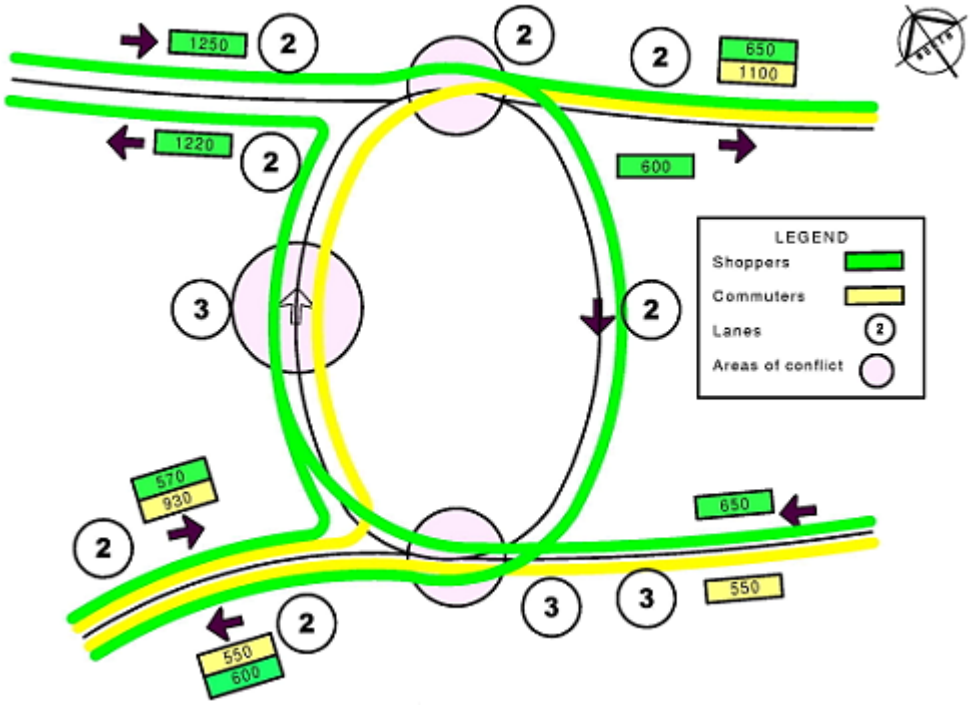

Figure 1. Traffic diagram (PM Peak).

The results of the SIDRA analysis for the afternoon peak period are shown on Table 1 below:

Table 1. SIDRA analysis.

APPROACH	Traffic Volume	V/C Ratio	Ave Queue (m)	Ave Delay (sec)	LOS
Ramp A	1200	0.35	15	2	A
Ramp B	one-way exit ramp				
Armitage Road (from CBD)	1500	0.61	35	3	A
Sanctuary Road	1250	0.77	64	11	C

3. DESIGN

The layout plan is depicted on Figure 2 with the principle design criteria being summarised as follows:

- retain existing infrastructure where possible – both ramps were retained and widened and the crossing road converted to one-way;
- optimise vehicle speed (fast enough to maximise capacity but slow enough to maximise road safety);

- all intersections to be 'free flowing' – yield/free control was selected in accordance with the principles of roundabout operation;
- the rotary crossroad lane balance had to accommodate merging and weaving over relatively short distances. It should be noted that merging and weaving is minimal as traffic generally only enters the rotary crossroad when gaps present themselves, occupying the gaps so formed;
- existing traffic flows had to be accommodated during construction;
- signposting difficulties;
- pedestrian activity at the interchange is moderate and had therefore to be accommodated. A pedestrian crossing of the yield-type was installed on Armitage Road, 30m from the rotary, and a wide sidewalk provided from this point, across the new bridge and then along the west side of Sanctuary Road.

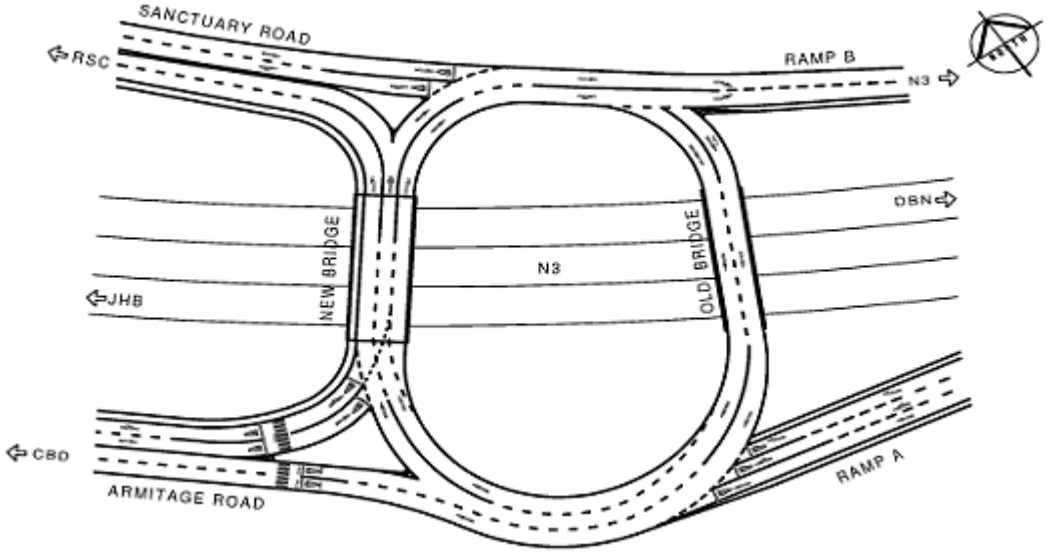

Figure 2. Plan.

The **geometry** is summarized in Table 2 below:

Table 2. Geometric characteristics.

Road Element	Length (m)	Lanes	Shoulders	Maximum Gradient	Minimum Radius
Ramp A	270	3 x 3,5 m	1,5 m	+7%	N/a
Ramp B	270	2 x 3,5 m	1,5 m	-7.2%	N/a
Circular Crossroad (80 m x 60 m)	320	2/3 x 3,5 – 4,5 m	None	+2.3%	27 m
External road links	N/a	2/2 x 3,5 m	None	+5,5%	N/a

Notes: 1. Lane widths on rotary crossroad vary inversely with radius of curvature.
2. Crossfall on rotary crossroad is 3% outwards (negative camber).

The decision as to whether to provide crossfall or superelevation on the rotary crossroad was influenced by several factors. The pre-existing bridge over the N3 has a 2% crossfall 'inwards' and superelevation would be operationally more 'comfortable'. However, superelevation would have entailed considerable and rapid development and run out, as all of the approach roads have profiles which were contrary to this option.

It was therefore considered preferable to construct the entire rotary crossroad, with the exception of

the portion formed by the pre-existing bridge, at a crossfall of 3% 'outwards'. A value of 3% was selected to expedite storm water runoff since the gradients were flat and road widths are up to 14m in places.

The circulating crossroad represents a large roundabout being slightly elliptical (80m x 60m) incorporating the existing overpass structure for the north to south movement of traffic. A new bridge was constructed to the west of the existing structure for the south to north movement. The rotary crossroad has a minimum of two lanes and a maximum of three lanes, the lane balance being dictated by the need for traffic capacity. The east to west and south to north movements require three lanes whereas the west to east and north to south movements only require two lanes. All roads approaching the rotary crossroad are controlled by yield conditions as for a typical roundabout application and can be converted to signalisation in the future if the need arises.

Signage posed specific challenges because:

- the rotary is not a conventional roundabout;
- the draft South African Road Traffic Signs Manual (SARTSM) offers little scope for deviation from the criteria as laid down therein;
- the decision sight distances are short;
- destinations are varied (many names to be considered).

The signage strategy eventually adopted was one in which the requirements of the SARTSM were strictly followed. This resulted in some confusion during the first few weeks of operation and will be expanded on in Section 5 following.

Since Ramp A is relatively short and terminates in a yield condition with the left lane being a 'straight through' lane the danger exists that speeds approaching the yield condition would be excessive and failure to yield to opposing (circulating) traffic would obviously constitute a serious traffic safety hazard. It was therefore decided to install a series of rumble strips and rumble humps, the strips preceding the humps and commencing 150m prior to the yield line. These devices were evenly spaced being comprised of three sets of rumble strips followed by two sets of rumble humps the last rumble hump being located approximately 30m from the yield line.

Finally due to client deadlines the design and production of tender drawings of the rotary interchange (as well as the design for the remaining road network serving the new shopping centre) was completed in three months.

4. CONSTRUCTION

Construction of the interchange was completed in 10 months. This included a 40m x 14.5m bridge over the N3. The interchange was constructed whilst maintaining traffic flow on the south facing ramps, the existing crossing road and on the N3. Traffic flow on the N3 was interrupted on four days, one day each for the erection and removal of the staging on each of the northbound and southbound carriageways. The closures took place on weekends.

During this time construction traffic was also active on the interchange and strict traffic control was necessary. Only one collision took place due to a construction vehicle not obeying a stop/go board.

The programming of the construction was crucial to achieving the completion deadline whilst maintaining efficient and safe traffic flow at all times. With the exception of the collision mentioned above these objectives were achieved. The N3 received special construction signing so as to obviate the possibility of an overheight vehicle striking the new bridge under construction.

5. COMMISSIONING

The interchange was opened to traffic one week prior to the opening of the shopping centre. Traffic movements during this week were principally a continuance of the commuting patterns similar to that prevailing prior to the construction of the new rotary interchange.

The problems encountered by drivers were as follows:

- Familiarisation with the concept of the one-way circulation (this even though a major roundabout exists 0,5 km away on one of the approach roads to the interchange).
- Lane selection - drivers were very ill-disciplined whilst traveling around the rotary and ignored lane lines and lane arrows.
- Failure to yield on approaching the rotary crossroad, particularly from Ramp A, probably due to there being no, or certainly very little, opposing traffic on the circulatory crossroad. This would change once the shopping centre opened.
- Confusion in understanding the directional road signs. The finer points of road signage as detailed in the Draft SARTSM are not understood by a large proportion of road users.

At this stage the users of the interchange were largely commuters and other regular users who had been to some extent familiarised by observing the construction over many months and were naturally familiar with the localised road network. However, when the shopping centre opened, shoppers from far afield were attracted to the area and were faced with an unusual traffic device through which they had to navigate. Furthermore, as is usual with the opening of a long awaited, high profile shopping centre with opening specials and promotions, traffic generation levels were in excess of that as designed.

Problems encountered at the interchange were as before and in addition as follows:

- General lack of familiarisation of many drivers with the area.
- Misunderstanding of road signs.
- Congestion. The lack of overflow parking at the centre impacted on the interchange with excessive congestion taking place. This fortunately only occurred over the first three days of opening.

These problems were addressed by providing additional roadmarking as well as additional regulatory signage and minor modification of certain directional signage, as discussed below:

5.1 Roadmarking

Two roadmarking modifications were required in response to the problems encountered. Firstly channelising lines were extended in places to reinforce the need to select a lane and to remain in that lane. Secondly, additional lane arrows and painted direction messages were provided. The interchange has a vertical profile somewhat resembling an inverted saucer. If the information roadmarking is spaced too far apart it often lies ‘over the horizon’ and is not clearly discernable leading to uncertainty for the driver. Also, at the intersections stationary vehicles often obscure the road marking text. Additional, more frequent messages were therefore installed and proved to be a constructive improvement.

5.2 Signage

Additional no-entry signs and turn restriction signs were installed to warn drivers not to proceed into one-way roadways and minor modifications to directional signage were made such as changing the angle of an arrow to more appropriately convey the instruction to the driver as to where they should proceed.

During the design of the direction signage the use of diagrammatic map type guidance or direction signs were considered but were not favoured because the signs would have been non-conforming

and since the rotary is not a typical roundabout, the standard roundabout signage was deemed inappropriate. Subsequent to the commissioning of the interchange there exists a strong opinion from both the public and several traffic engineers that the use of non-conventional map type diagrammatic signage would have been better understood by the motoring public.

6. TRAFFIC PERFORMANCE

The interchange performance has been observed on frequent occasions during both morning and evening peak hours as well as off-peak periods and at weekends. Formal monitoring has also been undertaken to determine the accuracy of the predictions. The results indicate that the traffic generation rate during the evening peak period is slightly less than that originally postulated. This is in line with trends at other shopping centres in Pietermaritzburg.

Traffic operational quality of the rotary interchange is excellent, the dynamics of the rotary are very similar to those of a conventional roundabout. The distribution of the approach volumes coupled with the lane balance results in operational quality which correlates well with the SIDRA results. Traffic on Ramp A experiences minimal delay and queuing and operates at LOS A during the peak periods. Traffic on the Armitage Road approach likewise experiences minimal delay and operates at LOS A.

The Sanctuary Road approach experiences some delays and average queues of approximately 30m to 50m occur representing a LOS C. It should be pointed out though that this condition only prevails during the Friday evening peak period.

The southbound entrance ramp onto the N3 is a two-into-one-lane ramp and operates efficiently. Merging is minimal because it seldom occurs that two vehicles side-by-side enter the ramp together.

There have been no reports of any serious collisions. There have been a number of minor collisions and several conflict situations have been observed (at relatively low speeds) where drivers have failed to yield satisfactorily at the entrance to the rotary crossroad and where vehicles have strayed out of their lanes.

The interchange is at present operating at approximately 60% of its capacity and is therefore suitably placed to absorb traffic growth in the years to come. It has a life of at least 10 years in its present format and has been designed such that capacity improvements can be implemented when this need arises.

The improvements envisaged are;

- signalisation of certain intersections;
- widening of the portion of the rotary between Sanctuary Road and Ramp B to three lanes; and
- widening Ramp B to two lanes over its entire length.

7. CONCLUSION

The design and construction of this innovative interchange was necessitated by the need to achieve a solution which satisfied the many and varied constraints, which severely limited the scope of options.

Furthermore the decision to pursue an unconventional interchange configuration on a major national route and a major local arterial entailed rigorous research and analysis in order to determine the appropriateness, efficiency and ultimate success of such a device.

Extensive work-shopping of the concept and detailed design with colleagues, client and the road authorities took place in order to ensure the full support of all affected parties.

The design and construction was completed in a very short space of time, a total of some 12 to 13 months with minimal incidents and disruption to traffic.

Commissioning the interchange revealed a number of minor problems relating to roadmarking and signage but here too the process was without major incident.

The performance of the interchange surpasses all other interchanges on the N3 in the Pietermaritzburg area in that traffic delays and queues are minimal with traffic flow being maintained even during the morning and evening peak periods. The conflict between the different travel needs i.e. commuters versus shoppers are managed with little difficulty resulting in an efficient traffic solution.

An added advantage to the decision to utilize this type of interchange is that it has an inherent capability to accommodate significant traffic growth.

To summarise therefore, whilst the interchange may be unconventional in nature, its performance has exceeded all expectations and has unlocked the adjacent land for extensive development by giving efficient access to the N3 for both existing and future traffic.

8. REFERENCES

[1] Akcelic & Associates Pty Ltd, 2000-2002. aa SIDRA (traffic analysis software). Victoria, Australia.

[2] CSIR. Geometric Design Guidelines. South African National Roads Agency, Pretoria.

[3] Trafficware Corporation, 1993-2001. SimTraffic 5.0 and Synchro 5.0 (traffic simulation software). Albany, California, USA.

[4] Transportation Research Board, 1994. Highway Capacity Manual, Special Report 209, Third Edition. National Research Council, Washington, D.C., USA.

[5] South African Roads Board / Department of Transport, 1999. South African Road Traffic Signs Manual. National Department of Transport, Pretoria.

ROTARY INTERCHANGE ON NATIONAL ROUTE 3

Walden, S. and McGuigan, D.J.

BCP Engineers (Pty) Ltd, PO Box 94, Pietermaritzburg, 3200, South Africa.
Tel: 033 345-3211. Fax: 033 342-6271. E-mail: derekm@bcp.co.za

BIOGRAPHY

Derek John McGuigan was born and educated in Glasgow, Scotland. He obtained his BSc in Civil Engineering from Paisley College of Technology in 1978 and, after moving to South Africa, a Postgraduate Diploma in Engineering from the University of Natal in 1995. He worked in the maintenance, traffic, structures and construction departments of the Strathclyde Regional Council until 1982 when he relocated to Cape Town joining Ninham Shand, undertaking various township and road projects. Since joining BCP Engineers in 1986, major projects he has been responsible for have included the identification and design of transportation needs at several retail and commercial developments as well as facilitating the compilation of both provincial and municipal road safety plans. He is presently an Associate in the Traffic and Transportation Division of their Pietermaritzburg office, where he is involved primarily in the fields of traffic engineering and road safety.