Introduction of Level of Service and Safety Improvements on the R44 Incorporating Access Management Principles - A Case Study

M L Watters (PrEng)[1], G R Tyndall (PrEng)[2] and B A Phillips(PrTechEng)[3]

[1]Land Transport, Western Cape Government, 9 Dorp Street Cape Town, Malcolm.Watters@westerncape.gov.za

[2]Kantey & Templer Consulting Engineers, 119 Hertzog Boulevard, Cape Town, royt@ct.kanteys.co.za

[3]Kantey & Templer Consulting Engineers, 119 Hertzog Boulevard, Cape Town, bertiep@ct.kanteys.co.za

ABSTRACT

The R44 is a major four lane divided arterial route linking Somerset West on the outskirts of Cape Town to the nearby town of Stellenbosch. Daily traffic volumes have increased exponentially from some 5,000 vehicles per day in 1975 to 30,000 vehicles per day in 2015.

Associated with this increase in traffic, there has been a gradual reduction in the level of service and an increase in the crash rate along the route over time. Mindful of this the Road Authority commissioned a study to gather the background data relating to the current operational characteristics of the roadway and safety characteristics including accident statistics (location and type), roadway geometry, intersection location and spacing, as well as intersection and link operational characteristics in terms of level of service. Of critical importance was the investigation and reporting on the location and suitability of all existing accesses and median openings.

Various critical factors were identified as being the predominant contributors to the poor safety record on the route and a range of intervention measures were investigated inclusive of access relocations, access consolidations, the introduction of backage roads, the closure of median openings and the accommodation of U-Turns.

Proposed measures include closure of all the median openings and accommodation of U-Turns by means of roundabout interchanges where vehicle conflicts are reduced substantially and pedestrians, bicycles and public transport is accommodated more effectively. Alternative intersection arrangements varying from stop-control to traffic signals to roundabouts to interchanges were rigorously evaluated at key intersections on the route.

An extensive public participation exercise was embarked upon as part of the process required in order to obtain environmental authorisation of the proposed improvements. A detailed economic analysis was undertaken as part of this exercise in terms of which of the cost-benefit ratios of the various alternative proposed improvements were determined. Multivariate analysis of the benefits and cost in terms of average delay, accident reduction and air quality was used to evaluate the overall performance of the proposed scheme. The results indicate that the implementation of the project would be considered a robust economic deployment of public funding.

The paper provides an insight into the abovementioned background, the investigations and findings as well as the recommended scheme improvements.

INTRODUCTION

The R44 is a strategic mobility link in the form of a dual carriageway linking the metropolitan region of Somerset West in the south to the town of Stellenbosch in the north. The road is a Class 2 Primary Arterial with two 3.7m lanes per direction with surfaced shoulders 2m wide and a 10m wide median. The posted speed limit is 100km/h reducing to 80km/h at signalised intersections.

The roadside environment is mostly semi-rural in character with numerous farm accesses and median openings along the length of the route. Development pressures along the route and in the secondary study area via side roads have naturally increased over the years and many new developments and land uses have been approved.

The R44 carries large volumes of traffic between origin and destination and is recorded at 30,000 vpd at the Eikendal permanent counting station on the route. Traffic growth is in the order of 4% per annum and the high levels of congestion experienced in the peak periods have caused driver frustration and resulting in delays, queuing and decrease in levels of service (LOS). The directional split is 80:20 representing a strong commuter pattern between Stellenbosch and Somerset West.

An important issue that was established at the outset of the project was the basic function of the corridor and its relative importance in the overall Provincial road

network. The Provincial Government identified the route as a strategic mobility corridor in a preceding study and as such is pursuant on maintaining this status.

There are a significant number of crashes taking place on the route and therefore road safety is a growing concern of the Road Authority and the general public. The problem and inherent risk relates to the numerous direct property accesses most of which have corresponding median openings. Consequently the speed differentials of turning and through volumes and conflicting movements result in frequent crashes.

Problem Statement

The study area being predominantly semi-rural in character and agricultural with numerous vineyards and farm stalls has resulted in many direct property accesses (driveways) onto the R44 with median openings at several locations along the road. These median openings are known to present considerable risk from a traffic safety point of view as the slower moving right turning vehicles need to negotiate both carriageways and merge with vehicles on the road travelling at high speeds. This is particularly attributable to the high traffic volumes on the mainline of the R44. The vehicles turning right from the mainline need to decelerate in the fast lane and the following vehicles need to change lanes accordingly increasing the risk of crashes.

Figure 1 shows the frequency of driveways and the numerous corresponding median openings between Winery Road and Annandale Road.

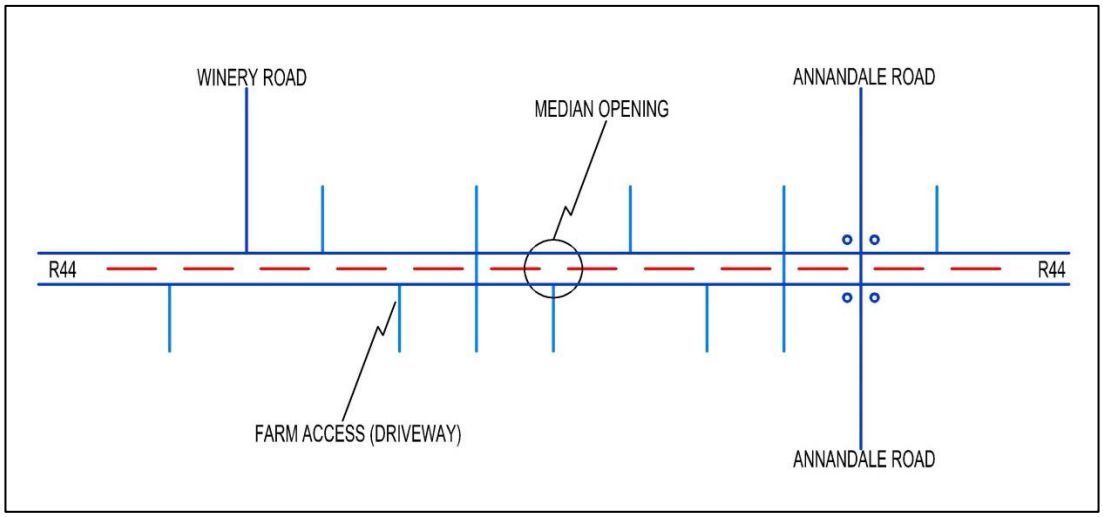

Figure 1: Existing median openings and intersections

In terms of access management it is important to make the following statements which reinforce the need for intervention in the abovementioned access management problem.

1. An important access management principle to recognise is that a driveway is an intersection with numerous turning movements increasing the risk of collision.
2. A driveway or access is therefore a high conflict turning movement environment with significant speed differentials.
3. Frequently spaced driveways tend to result in overlapping spheres of influence which increase the risk of crashes.

Aim of the paper

The paper aims to explore the road authorities intention is to close all the median openings and accommodate the resulting U-Turn requirements by providing U-Turn opportunities at strategic locations along the route along with roundabout interchanges replacing signalised and stop controlled intersections as the volumes of commuter traffic exceeds the limit state of at-grade solutions.

The aim of the paper is to show how by reducing in the number of accesses and closing the median openings, which in effect manages access far better from a road authority and road user perspective will improve road safety. The closure of all the median openings along the R44 requires an appropriate response in order to provide reasonable access to the adjacent land uses.

This paper aims to present the innovative solution to the problems experienced as well as the access management principles for improving LOS and safety on the R44 whilst maintaining mobility on the strategic route. The paper serves as a case study with a strong emphasis on access management.

Scope of Paper

The project aims to close all of the medians on the R44 and to address access by means of grade separated roundabouts which facilitate U-Turns in a safe and effective manner. The operational characteristics of the grade separated roundabouts will protect the mobility function of the R44 and safely accommodate all turning movements whilst maintaining an acceptable LOS.

The through traffic is unimpeded and hence the LOS should improve along the route. The speed can be controlled by average speed over distance monitoring which is an integral part of the scheme.

With the closure of the median openings the direct property accesses becomes Left-In Left-Out (LILO) only driveways (RIRO in the USA) with fewer conflicting movements and hence concomitant safety benefits.

The median openings and accesses are effectively full accesses with 32 conflicting movements at each intersection. As soon as the median openings are

closed you reduce the conflicting movements to four, which will result in a significant reduction in crashes on the R44.

Figure 2 shows the closed median regime with roundabout interchanges to manage U-Turns and access to properties on the opposite side of the R44.

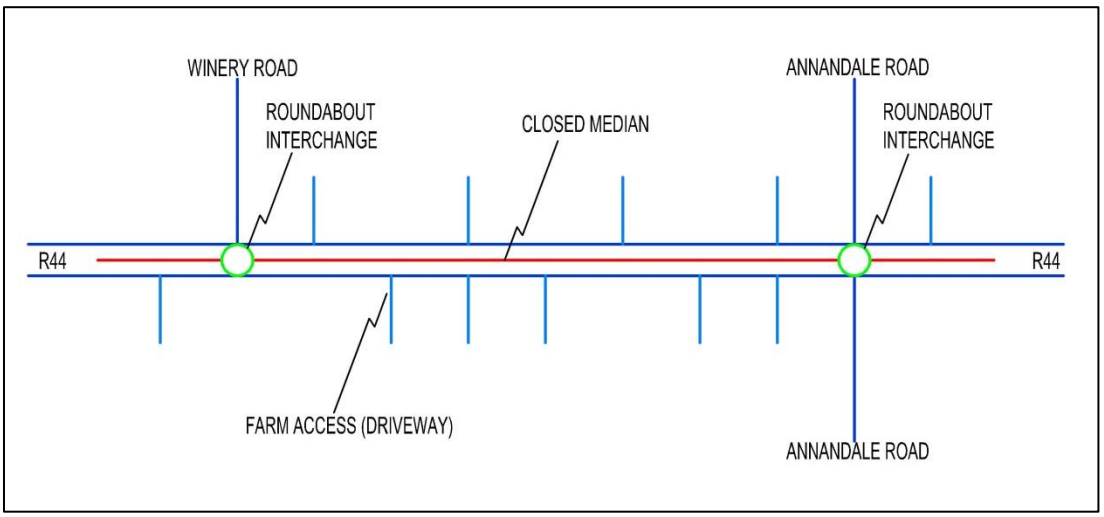

Figure 2: Concept of the proposed closed medians and roundabout interchanges

Of critical importance in order to obtain maximum benefit is the need to introduce the components as one overall holistic approach to the LOS and safety of the R44 as opposed to isolated piecemeal improvement approach.

Benefits of the project

The benefits of the project are the maintenance of long term mobility of the strategic route between Somerset West and Stellenbosch and the access management of the numerous driveways that intersect directly with the R44.

The most important benefit or consequence of the scheme is the predicted safety improvement achieved by modifying certain key intersections to roundabout interchanges and the closure of all the median openings, in line with the principles of access management and thereby eliminating numerous conflicting movements that are currently taking place on the R44 with their associated safety hazards and high crash rates.

Figure 3 below shows the difference in the number of turning movements with the closed median regime as compared to that with the median openings. The conflict diagrams also apply where the number of conflicts can be significantly reduced by a factor of eight from thirty two potential conflicts to four conflicts.

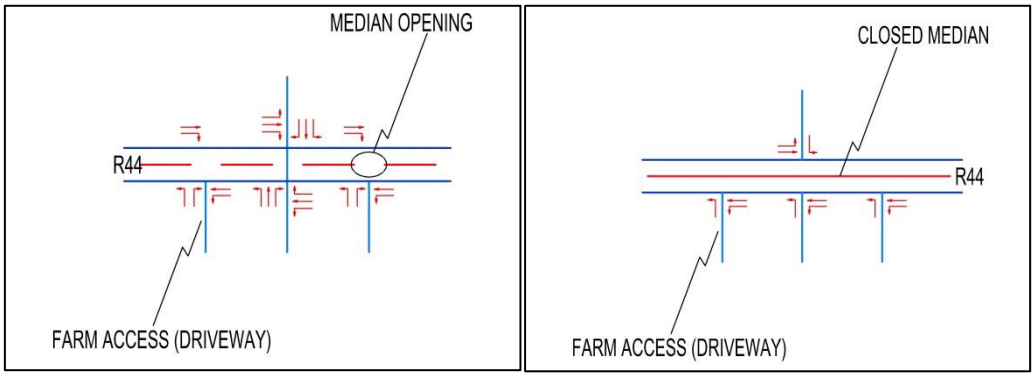

Figure 3: Comparison of turning movements of median treatments

Accident Statistics

The crash rates were equated to crashes per annum at the access locations along the route. Table 1 which ranks the locations in terms of number of crashes per annum. It is interesting to note that the number of crashes at signalised intersections is far greater than at stop controlled intersections. This is probably due to the higher number of turning vehicles at signalised intersections and the usual problems of speeding and red light violation. The signals require a speed limit of 80km/h and this is not always adhered to within the general 100km/h speed limit of the route.

Table 1 Accident Statistics on the route

Access No.	km	Intersection Type	Location	Accident Type			Accident number per year
				Fatal and serious injury	Minor injury	Property damage only	
42	31.200	3-leg signalised	Blaauwklippen	1.1	6.3	28.0	35.4
48	32.990	4-leg signalised	Van Reede	1.1	5.5	24.8	31.4
40	30.280	4-leg signalised	Tegno	1.1	5.4	24.5	31.0
39	29.600	4-leg signalised	Webersvallei	1.1	5.3	22.4	28.8
46	32.010	3-leg signalised	Trumali	1.1	5.3	20.5	26.9
23	26.590	4-leg signalised	Annandale	0.9	4.5	19.2	24.6
		Multilane divided roadway sections	Stellenbosch Square section	2.0	6.7	12.3	21.0
		Multilane divided roadway sections	Parmalat section	1.3	4.3	8.1	13.7
5	21.960	4-leg stop controlled	Bredell / Klein Helderberg Road	0.4	4.0	4.8	9.2
		Multilane divided roadway sections	From Winery Road south	0.9	2.9	5.2	9.0
11	23.380	3-leg stop controlled	Winery Road	0.7	2.9	3.2	6.8
		Multilane divided roadway sections	Golf Course section	0.6	2.0	3.6	6.2
9	22.780	3-leg stop controlled	Nooitgedacht Sondans	0.7	2.5	2.7	5.9
28	27.150	3-leg stop controlled	Stellenrust	0.7	2.4	2.8	5.9
44	31.720	4-leg stop controlled	Paradyskloof	0.2	2.2	3.1	5.5
30	27.980	3-leg stop controlled	Jatan Farm	0.6	2.2	2.6	5.4
34	28.490	3-leg stop controlled	Drie Lande Farm	0.6	2.0	2.4	5.0
		Multilane divided roadway sections	Before Jamestown	0.5	1.6	2.9	5.0
15	24.680	3-leg stop controlled	Eikendal Farm	0.6	2.0	2.3	4.9
16	25.400	3-leg stop controlled	Sommerbosch Farm	0.6	2.0	2.3	4.9
12	23.960	3-leg stop controlled	Sweetwell Farm	0.6	2.0	2.3	4.9
10	23.190	3-leg stop controlled	Avontuur Farm	0.5	1.9	2.2	4.6
		3-leg stop controlled	Stonewall Farm	0.5	1.9	2.2	4.6
37		3-leg stop controlled	Cemetry	0.5	1.7	2.2	4.4
25	26.670	3-leg stop controlled	De Wilge Farm	0.5	1.8	2.1	4.4
29	27.650	3-leg stop controlled	Aerodome	0.4	1.5	1.9	3.8
33		4-leg stop controlled	Kleinbosch Farm	0.1	1.3	2.0	3.4
17	25.510	4-leg stop controlled	Rosenview Farm	0.1	1.3	2.0	3.4
35	28.850	4-leg stop controlled	Uitsig Farm	0.1	1.3	2.0	3.4
		4-leg stop controlled	Roulou / Mooiberge Farmstall	0.1	1.2	1.9	3.2
13	24.620	4-leg stop controlled	Eikendal Road	0.1	0.9	1.6	2.6
19	26.090	3-leg stop controlled	Klein Schuur Farm	0.2	0.7	1.1	2.0
			Total	**20.5**	**89.5**	**221.2**	**331.2**

Environmental Impact Assessment (EIA)

The project was subjected to vigorous EIA regulations and included a number of specialist studies most important of which was the Economic Study which found the proposed project solution to be robust in terms of the indicators such as net present value (NPV), benefit cost ratio (BCR) and internal rate of return (IRR).

In Table 2, the four alternatives arising from the public participation process are compared. Alterative 1 is the two roundabout interchanges, Alternative 2 is the two roundabout interchanges with turning lane and signal improvements towards Stellenbosch, Alternative 3 is the two below ground roundabout interchanges with signal improvements and finally Alternative 4 is the below ground diamond interchanges with signal improvements.

Alternative 1 shows the cost of the project reflected as R317,1m and the benefits at R550,2m and the resultant BCR of 1.73 and the IRR of 16% and NPV of R233m. If one takes signalised intersection improvements into account for the signals entering Stellenbosch then the results for Alternative 2 improve to a BCR of 2.01, IRR of 18% and NPV of R377m, which is the best alternative from an economic point of view.

Table 2. Results of the Benefit Cost Analysis

Present Value of Costs and Benefits Rm, 2013 prices	Alternative 1 Two Grade Seperated Roundabouts (GSRs) Above Ground	Alternative 2 Two GSRs Above Ground Plus Lane & Signal Improvements	Alternative 3 Two GSRs Below Ground Plus Lane & Signal Improvements 30% Rock	Alternative 4 Two Diamonds Below Ground Plus Lane & Signal Improvements 30% Rock
Costs				
Initial Capital Costs	156.7	207.7	354.6	276.8
Land Acquisition	6.1	6.1	6.1	6.1
Maintenance Costs	7.9	10.4	12.0	12.3
Professional Fees	24.9	33.0	55.5	43.8
Additional Travel	121.6	116.8	116.8	116.8
Total Costs	**317.1**	**374.1**	**545.0**	**455.7**
Benefits				
Time Savings	245.5	442.0	442.0	442.0
Accident Savings	295.8	293.0	293.0	293.0
Reduced Emissions	8.9	16.0	16.0	16.0
Total Benefits	**550.2**	**751.0**	**751.0**	**751.0**
NPV	233.0	377.0	206.0	295.3
BCR	1.73	2.01	1.38	1.65
IRR	16%	18%	12%	14%

Other specialist studies included a botanical survey, freshwater assessment, groundwater specialist study, heritage study and visual assessment. A substantial public participation process ensued with open days and public meetings with fairly strong objection from directly affected land owners and interest groups in the area.

The visual impacts of the proposed roundabout interchanges were assessed and found to be of medium to high impact before mitigation and medium after mitigation. The possibility of placing the interchanges below ground was investigated and found to be significantly more expensive due to excavation costs and the unknown percentage of rock to be encountered.

The EIA found that Alternative 2 shown in Table 2 consisting of two grade separated roundabouts plus lane and signal improvements towards Stellenbosch to be the most effective alternative.

Figure 4 below is an aerial perspective of the proposed roundabout interchange at Annandale Road which shows the traffic on the R44 going under the roundabout. The main point being that the through traffic is unimpeded and the turning movements are all safely accommodated in a roundabout with inherent traffic calming properties. The roundabout also deals most effectively with the U-Turns that need to take place as a result of the closed median regime.

Figure 4. Aerial perspective of proposed roundabout interchange

CONCLUSIONS

There are numerous lessons to be learned from this project which focusses on road safety and LOS improvements to a high mobility dual carriageway corridor.

First the access management principle of reducing the number of conflicts in order to improve road safety is applied. This is achieved by closing the median openings and thus eliminating all the risks associated with the predominantly right turn manoeuvres and accommodating U-Turns at roundabout interchanges and associated infrastructure improvements.

Second the following quote sums up the importance of roundabouts on corridor routes as compared to signalised intersections. This quote encapsulates the essence of the project and is a profound way of concluding that the project is well aligned with established access management principles.

"On a corridor level, roundabouts create more access management opportunities compared to signalized intersections. One key differentiating consideration between corridor types may be safety at midblock access points. Opportunities to use roundabout U turning qualities could potentially eliminate right turns to or from driveways along the corridor. Reducing turns at driveways would reduce vehicle conflicts at these locations and positively influence overall corridor safety performance." (NCHRP 772)

Third, corridors with closed medians have been found to have lower accident rates than those with median openings. This is largely due the reduced number of conflicting movements at these locations and speaks to the access management principle of reducing the number of conflicts in order to improve road safety.

Whilst the project is still in the basic assessment phase it is difficult to satisfy all the stakeholders as the project becomes politicised. There is a perceived negative visual impact on the cultural and historical landscape for the Stellenbosch Winelands district, which is difficult to counter and hence the exploration of below ground interchanges was considered.

Large projects of this nature always tend to become contentious to the few directly interested and affected parties without considering the rest of the population who have a right to a safe and efficient road environment.

ACKNOWLEDGEMENTS

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