UPGRADING/RETROFITTING THE N2 URBAN FREEWAY IN CAPE TOWN

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1. INTRODUCTION

In December 1995 the first stage of the upgrading of the N2 freeway was completed. The first stage included the re-grading of the N2 under bridges to provide standard vertical clearances, the construction of a concrete median barrier to improve safety and the improvement of sight distances on sharp curves. The second stage of the upgrading of the N2 freeway, the study area, is a three-kilometer length including seven interchanges and an 800 metre section where the N2 freeway and the M3 freeway merge and then diverge.

The purpose of this paper is to:

- discuss the operational problems in the study area,
- present the geometric improvements to the ramps (and the auxiliary lanes between ramps),
- show how, through the introduction of pre-selection lanes from the M3 to the N2, weaving can be reduced to provide additional capacity and improve safety, and
- conclude with general remarks on this study.

2. OPERATIONAL PROBLEM AREAS

From traffic surveys it was determined that the section of the N2 freeway under consideration carries daily traffic volumes in excess of 120 000 vehicles. Over the full length of the study section there are two through lanes in each direction, excluding the auxiliary lanes between ramps. Unforeseen high traffic growth since the completion of the freeway in the 1950's has resulted in a number of road sections where capacity is restrained.

On the westbound carriageway (towards the Cape Town CBD) the problem areas identified are (Refer to Figure 1 for schematic layout of the existing lane configuration in the study area).

The three lanes provided under the first stage construction ends between the first and second interchanges. The result is the formation of queues during the morning peak period as the traffic in the three through lanes are forced to merge into two lanes.

- At the second interchange (Black River Parkway), a system interchange, there is a large on-ramp volume from the south (M5), 2 400 vehicles in the morning peak hour. These vehicles need to enter the N2 on an approximately 210 metre long auxiliary lane between the on-ramp and the next off-ramp. The heavy on-ramp volume results in queues in excess of two kilometers on the N2 during the morning peak period as well as queuing along the M5 route.

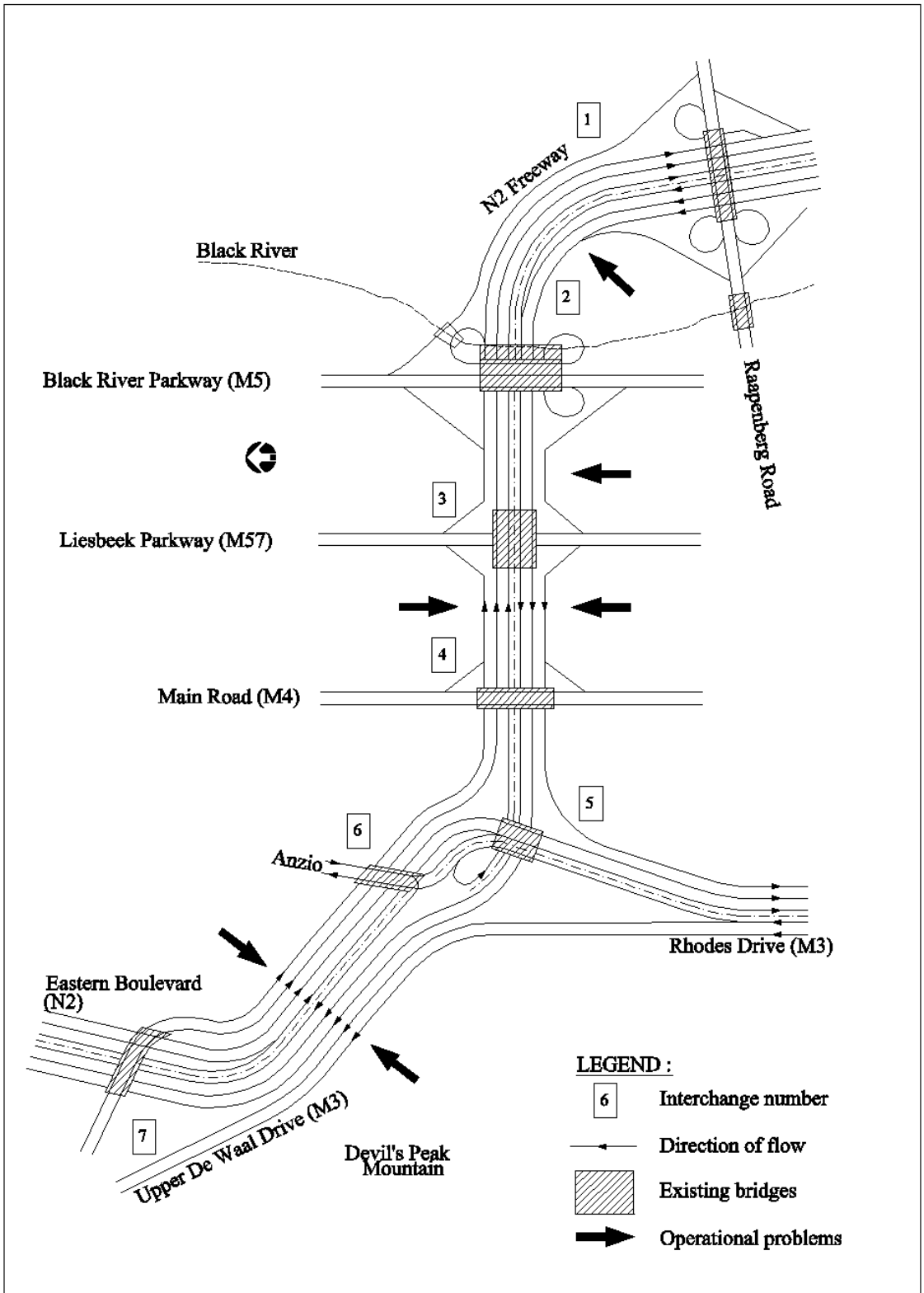

Fig. 1 - Schematic layout of study area: Existing lane configuration

- At the third interchange (Liesbeek Parkway) the distance between the on-ramp towards the CBD and the off-ramp at Interchange 4 (Main Road) is less than 155 metres. These two ramps create a cross weave of approximately 3 000 vehicles (1 800 entering the N2 and 1 200 exiting the N2). For the traffic exiting the N2 the weave is compounded by the continuation of the on-ramp auxiliary lane past the off-ramp.

- The total volume of traffic entering Interchange 5 (Rhodes Drive), a systems interchange, is 7 300 vehicles during the morning peak hour with the following splits at Interchange 7 (Upper De Waal Drive), a systems interchange:

  - 1 100 entering from the M3 and exiting to Upper De Waal Drive
  - 2 250 entering from the M3 and exiting to Eastern Boulevard
  - 1 050 entering from the N2 and exiting to Upper De Waal Drive
  - 2 900 entering from the N2 and exiting to Eastern Boulevard

  The 2 250 and 1050 vehicles weave across one another over a distance of 800 m on an upgrade of 6.5 %.

- The weaving between the Rhodes Drive and Upper De Waal Drive interchanges is further complicated by the on-ramp from Anzio Road (there is no corresponding off-ramp). During the morning peak hour 400 vehicles enter the freeway with 130 crossing the two N2 lanes to exit to Upper De Waal Drive. This movement takes place over a distance of 600 metres with the vehicles starting from a stopped condition thus there is a significant speed differential between this weaving traffic and the through traffic from the N2 and M3.

On the eastbound carriageway there are two main bottlenecks:

- At the Upper De Waal Drive interchange the three lanes from Eastern Boulevard enter on the southern side and the two Upper De Waal Drive lanes enter on the northern side. The shoulder lane from Eastern Boulevard merges with the fast lane from Upper De Waal Drive. By the diverge at the bottom of the hill the operation is reversed with the M3 lanes exiting on the southern side and the N2 lanes exiting on the northern side. The result of this is that traffic entering from Eastern Boulevard and wishing to exit via the N2 need to change lanes. The same applies for the Upper De Waal Drive traffic. Five lanes enter at the top and four exit at the bottom. The ramps for the sixth interchange were closed some time ago.

- The distance between the on-ramp from Main Road and the off-ramp Liesbeek Parkway is approximately 170 metres. With 1 500 vehicles entering the N2 immediately followed by 1 000 vehicles exiting the N2 the lane immediately adjacent to the on- and off-ramp is avoided by the through traffic. This forces the through traffic to merge into one lane creating long queues upstream during the evening peak period. These queues extend back past the Upper De Waal Drive interchange.

Given the complexity of operation on the study section any upgrading would have a major influence on route selection. The final challenge in the approach to achieving solutions to the problems described above was , therefore, to involve the public.

3. UPGRADING PROPOSALS

During the investigation into possible solutions the closure of on- and off-ramps was considered undesirable to both the planning authorities and the public. The process of understanding the operation in the study area, and the search to find a solution has led to the innovative upgrading shown on Figure 2. In terms of upgrading in the study area the primary objectives were the extension of the third lane on the westbound carriageway (inbound) and the improvement of safety.

The upgrading of the westbound carriageway was constrained by the need to limit capacity improvement. This limitation was placed on the upgrading by capacity constraints on the downstream road network where Eastern Boulevard and Upper De Waal Drive enter the Cape Town CBD. Thus the upgrading allows for the continuation of the third lane on the westbound carriageway through the study area, reducing weaving volumes between Liesbeek Parkway (Interchange 3) and Main Road (Interchange 4) interchanges and between Rhodes Drive (Interchange 5) and Upper De Waal Drive (Interchange 7) interchanges. On the eastbound carriageway the road network placed no constraints and the upgrading provides for maximum capacity.

For the purposes of presenting the solution the study area has been broken up into three sections. In each section the existing geometric issues are discussed and these are followed by the solutions.

3.1 Section 1: Interchange 1 (Raapenberg Road) to Interchange 2 (Black River Parkway)

3.1.1 Westbound carriageway (inbound)

The first on-ramp in section 1 at Raapenberg Road is under utilised with a maximum peak hour flow of 90 vehicles. The N2 bridge over the Black River is wide enough for a shoulder against the median, two through lanes and an auxiliary lane. The bridge does not allow for a shoulder on the outside. The auxiliary lane commences where the loop ramp from the M5 joins onto the N2 and runs to the off-ramp from the N2 to the M5. The loop ramp has an inside radius of 47,5 metres (design speed = 39 km/h) and joins onto the N2 immediately to the east of the Black River. It is worth mentioning that the lengths of the auxiliary lanes along the N2 route and the M5 route are 155 and 235 metres respectively.

The implementation of the upgrading proposal will require the widening of the N2 bridge over the Black River to allow three through lanes, the auxiliary lane and shoulders on both sides. The new cross section consists of:

- a 2,0 metre median shoulder,
- four lanes with the middle two 3.4 metres and the outside two 3,7 metres wide, and
- an outside shoulder of 1,5 metres.

The total widening is 5,5 metres. Widening the bridge reduces the inside radius on the existing loop ramp, which raised concerns regarding the safety of the ramp.

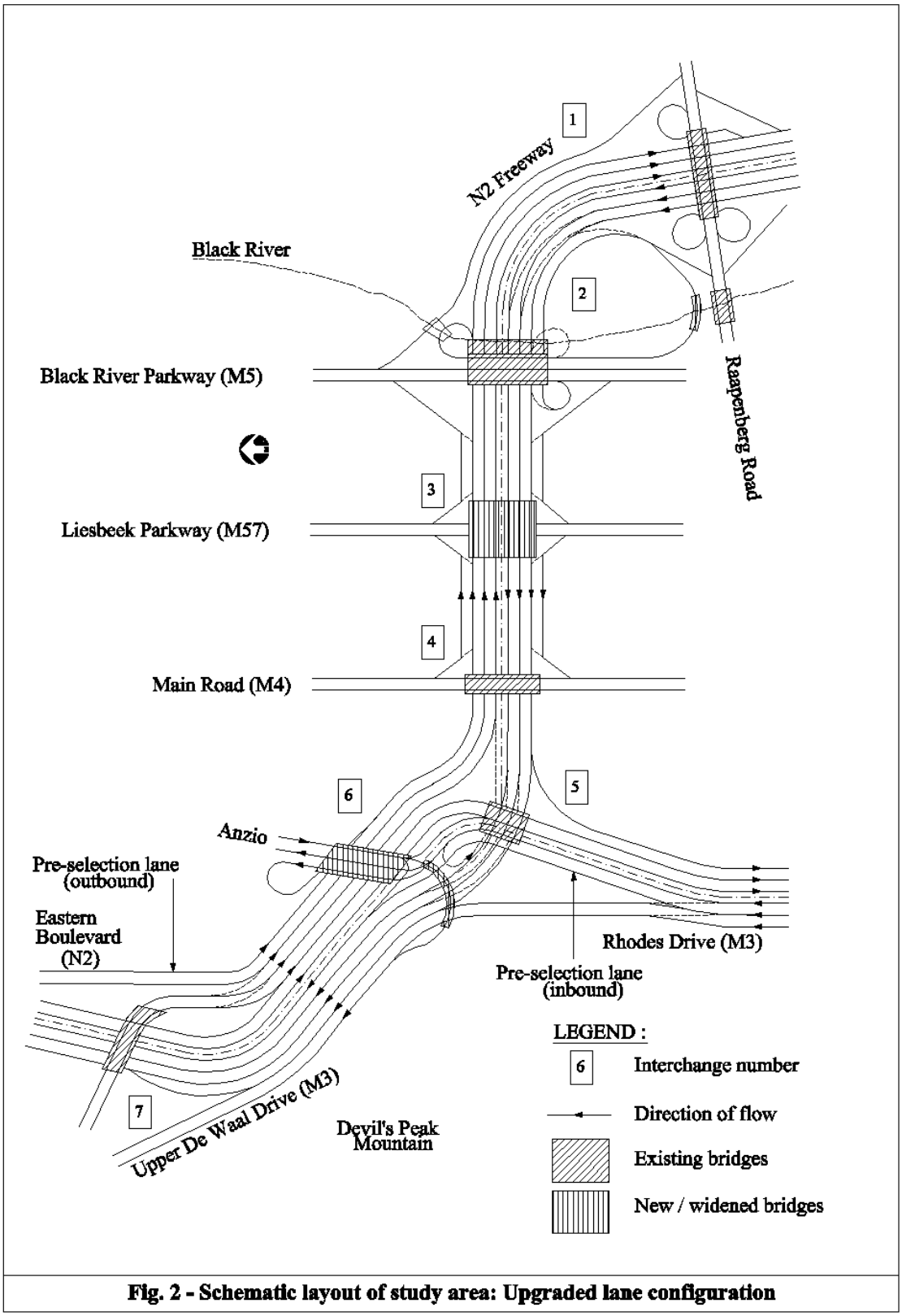

Fig. 2 - Schematic layout of study area: Upgraded lane configuration

It was therefore decided to use the opportunity presented by the under-utilised on-ramp at Raapenberg Road and construct a new ramp from the M5 to the N2. The area between the M5, N2 and the new ramp was as the same time reclaimed as a wetland. The existing loop ramp was closed and demolished. The new ramp presented design challenges as there was both vertical and horizontal deviation.

The new ramp has an inside radius of 88.2 metres with a super-elevation of 6,0 % that results in a design speed of 57,7 km/h. The ramp commences with a 120 metre transitional curve, continues along the circular curve for a length of 174 metres and joins the under utilised ramp tangentially. A short downstream lane is added to allow merging between the combined ramps before joining the N2 route. The vertical alignment was fixed on both sides due to the existing alignments of the M5 and the under utilised ramp of Interchange 1. The alignment between these fixed sections were further complicated by the requirements resulting from the 1:50 year flood line constraints of the Black River and also to minimise re-construction at the tie-ins. The alignment over the new bridge started with a vertical crest curve, continued through a 20,5 metre straight section and to tie-in with the existing, ended with another vertical sag curve. The construction of the bridge was done cast in-situ due to the complexity of the vertical alignment. The location of the new ramp increases the auxiliary lanes along the N2 route and the M5 route to 360 and 385 metres respectively.

The construction on this section was completed by March 1999.

3.1.2 Eastbound carriageway (outbound)

In Section 1 no upgrading is required.

3.2 Section 2: Interchange 2 (Black River Parkway) to Interchange 5 (Rhodes Drive)

For both the westbound and eastbound traffic the main restriction for improving capacity is the bridge over Liesbeek Parkway (M57). The cross-section of the bridge allows two lanes per direction (4,3 metre wide lanes) with no provision for shoulders. West of Interchange 3 there is no median barrier between opposing traffic flows even though the width of the median is less than 2 metres. It is worth mentioning that the spacing between these interchanges (Black River Parkway, Liesbeek Parkway, Main Road and Rhodes Drive), from east to west, are 650, 650 and 320 metres respectively (center to center).

3.2.1 Westbound carriageway (inbound)

Between Liesbeek Parkway and Rhodes Drive there is a 580 metre auxiliary lane that allows high traffic volumes to enter the N2 from Liesbeek Parkway.

The upgrading allows for the widening of the bridge over Liesbeek Parkway to provide three lanes per direction but still with no provision for shoulders. The final cross section allows a 3,55 metre median, 3,55 metre shoulder lanes and a 3,4 metre middle lane. Shoulders cannot be provided as concrete strengths and steel reinforcing in the existing bridge deck limited the width of the widening to conform to the design loading codes of bridges. The widening of the bridge will allow the third lane to be extended to the west of Interchange 3 to line-up with the existing auxiliary lane that will be converted to a through lane.

It is proposed that a new auxiliary lane be constructed between the on-ramp from Liesbeek Parkway and the off-ramp to Main Road. The length of the auxiliary lane will be 153 metres (accepted that the length is sub-standard however the physical spacing of the interchanges does not allow for a longer length). The provision of the auxiliary lane and the widening of the bridge will require that

portions of the on- and off-ramps adjacent to the N2 will need to be realigned and regraded. In addition to this the existing auxiliary lane between Black River Parkway and Liesbeek Parkway will be retained, but in a new position and will have a length of 212 m metres. *(The proposed auxiliary lanes were not approved by the road authority. However, the design has made provision to accommodate the auxiliary lanes in future.)*

Included in this contract is the upgrading of the existing on-ramp from the M5 route (M5 northbound to N2 westbound) that presently carries 2 400 vehicles during the morning peak hour. The existing radius of the curve just before it enters the N2 route is 130 m and the topography (including an existing retaining wall) limits the stopping sight distance to 55 metres, a design speed of 43,3 km/h. The ramp was realigned (inside radius of 128,7 m) to increase the stopping sight distance to 95 metres for a design speed of 70 km/h. This realignment resulted in the demolishing of a section of the existing retaining wall, relocating it with a new retaining wall to provide the required sight distance.

The final major component of the upgrading in this section is to be the construction of a median barrier on the narrow median between Liesbeek Parkway and Rhodes Drive.

3.2.2 Eastbound carriageway (outbound)

At Rhodes Drive the ramp from the M3 to the N2 (north to east) enters on the right-hand side of the N2 (for vehicles driving on the left side this is unusual). This results in traffic entering from the M3 and wishing to exit to Liesbeek Parkway having to cross one lane and merge with a second lane in order to exit at the M57 over a distance of 580 metres. Due to the poor connectivity of the adjacent road network there is a significant demand for this movement, 800 vehicles in the evening peak hour. Operation on this section is complicated by the fact that the shoulder lane that comes from before Upper De Waal Drive ends as a lane-drop at Liesbeek Parkway. Traffic that is in the shoulder lane and that wishes to continue along the N2 is forced to change lanes. With this traffic changing lanes and the traffic entering from Main Road considerable congestion, even during off-peak periods is evident.

The widening of the bridge over Liesbeek Parkway, as discussed in the previous section, will eradicate the lane drop and reduce the need for traffic to change lanes. Similarly traffic entering the N2 from Main Road will have a simpler merge in order to continue along the N2. The provision of the auxiliary lane and the widening of the bridge will require that portions of the on- and off-ramps adjacent to the N2 will need to be realigned and regraded. This results in lengths of auxiliary lanes between Main Road and Liesbeek Parkway, and between Liesbeek Parkway and Black River Parkway, of 173 and 257 metres respectively (accepted that the length is sub-standard however the physical spacing of the interchanges does not allow for a longer length). *(The proposed auxiliary lane between Main Road and Liesbeek Parkway was not approved by the road authority. However, the design has made provision for the accommodation of the auxiliary lane in future.)*

3.2.3 Ideal situation

The close spacing of existing interchanges is undesirable and the closure of Liesbeek Parkway would be ideal but due to expensive costs and public/business resistance, not viable. The N2 bridge will have to be widened considerably, to both sides, to make provision for auxiliary lanes between Black River Parkway and Main Road. The on-ramp from the M5 route, as discussed in section 3.2.1, then could be upgraded to a double on-ramp to cater for the heavy movement of 2 400 vehicles in the peak hour. This results in lengths of auxiliary lanes along the inbound carriageway

(between Black River Parkway and Main Road) and along the outbound carriageway (between Main Road and Black River Parkway), of 770 and 810 metres respectively.

3.3 Section 3: Interchange 5 (Rhodes Drive) to Interchange 7 (Upper De Waal Drive)

3.3.1 Westbound carriageway (inbound)

The next stage for the upgrading of the N2 route is between Rhodes Drive and Upper De Waal Drive where the M3 and N2 freeways converge at the bottom of the hill and diverge at the top.

There are presently four lanes, two lanes from the N2 route merging with the two lanes from the M3 route, entering at the bottom of the hill. An unconventional right-hand lane pick-up from Anzio Road joins the fast lane from the N2 route. This results in the five lanes going up the hill. These lanes then split into two lanes continuing along Upper De Waal Drive and three along Eastern Boulevard (Refer to Figure 1 showing the existing situation).

Traffic flow patterns during the morning peak hour that were identified during the Origin-Destination (O-D) traffic survey along the inbound carriageway and is summarised in Table 1 as mentioned in section 2.

Description of flow pattern		**Traffic volume**
From M3	To Upper De Waal Drive To Eastern Boulevard	1 100 2 250
From N2	To Upper De Waal Drive To Eastern Boulevard	1 050 2 900
From Anzio on-ramp	To Upper De Waal Drive To Eastern Boulevard	130 270

Table 1: Summary of O-D Survey along inbound carriageway

There is a major cross weave taking place along the 6,5 % uphill gradient that results in major delays and contributes to accidents taking place along the inbound carriageway.
One of the objectives of this exercise was to provide the continuation of the third lane along the N2 through Rhodes Drive (Refer to Figure 2 for discussion of upgraded situation). The existing horizontal clearance under the M3 over N2 bridge presently makes provision for two existing lanes and a surfaced shoulder as well as a 5,0 metre lane catering for the traffic from the M3 route to the N2 route. The additional lane will utilise the existing surfaced shoulder, but the existing vertical clearance of 4,76 metres is substandard.

To complicate procedures even more, the pre-selection lane along the M3 route was introduced to decrease the cross weave of 2 250 vehicles by at least 1 800 vehicles. This results in the widening of the M3 bridge crossing the inbound traffic from the N2 route to cater for the additional traffic lane. The first suggestion was to widen the bridge to the west, but the super-elevation on the bridge and the N2 route climbing at 6,2 % also towards the mountain, eliminated this option. The reason for the elimination is the necessity of re-grading of the N2 route by more than 1,0 metre to maintain the standard vertical clearance of 5,2 metres. The accommodation of traffic would be problematic. The recommendation is to widen to the east although this requires the relocation of the median barrier wall along the M3 route. Re-grading is still required along the N2 route, but not as excessive as for widening of the M3 bridge along the western side.

The pre-selection lane over the bridge lines-up with the under-utilised Anzio Road lane pick-up. With the provision of the pre-selection lane the Anzio Road on-ramp into Cape Town need to be closed. With such a scheme no major construction work is required along the mountain which is very sensitive from an environmental point of view. After a long Public Participation Process, showing all sorts of innovative proposals to accommodate this exit into Cape Town it was eventually decided to provide an overpass with an inside radius of 25,0 metres. This overpass will then join the main traffic flow as a standard on-ramp and the traffic would merge with the traffic flow at almost the same speed. A down-stream lane is proposed at the top of Hospital Bend to make provision for slow traffic from the new relocated Anzio Road on-ramp and for traffic that did not use the pre-selection lane from the M3 at the bottom of the hill. *(This proposed ramp was not approved by the road authority. However, provision has been made to accommodate the ramp if required in future.)*

The Public Participation Process focused around the treatment of the existing Anzio Road on-ramp. It is interesting to note that in general the public preferred accessibility above safety.

The lane configuration that makes provision for the pre-selection lane results in the relocation of the M3 to N2 loop. This movement carries 800 vehicles and the new loop will enter the N2 bound traffic as a conventional on-ramp.

3.3.2 Eastbound carriageway (outbound)

There are presently five lanes, three lanes from Eastern Boulevard merging with the two lanes from Upper De Waal Drive, entering at the top of hill. The fast lane from Eastern Boulevard terminates in the sharp bend at the top. This results in the existing four lanes going down the steep gradient of 6,5 %. These lanes then split into two lanes going to the N2 route and two to the M3 route. The two lanes to the N2 route are joined on the right-hand side by the M3 to N2 lane pick-up, just east of Interchange 5 (Refer to Figure 1 for discussing the existing situation).

If it is assumed that for the evening peak hour, the traffic flow patterns of the morning peak hour is reversed, then the flows will be as shown in Table 2.

Description of flow pattern		**Traffic volume**	**Lanes required**
From Eastern Boulevard	To N2 To M3	2 900 2 250	2 lanes 1.5 lanes
From Upper De Waal Drive	To N2 To M3	1 050 1 100	1 lane 1 lane

Table 2: Summary of expected traffic flow patterns along outbound carriageway

The are presently four lanes down the hill and the 2 900 vehicles from Eastern Boulevard presently have to cross the 1 100 vehicles from Upper de Waal Drive to enter the correct lane for their destinations. This cross weave together with the steep down gradient results in major delays and is a major contributory factor to accidents taking place along the outbound carriageway. Accident statistics reveals that the eastbound carriageway has twice as many accidents as the westbound carriageway.

For one of the major movements (2 900 vehicles) the one from Eastern Boulevard at the top of the hill to the N2 route at the bottom, all of the vehicles have to weave on a steep downhill gradient of 6,5 %. A pre-selection scheme is introduced at the top to relocate this movement to the left-hand side of Upper De Waal Drive traffic. (Refer to Figure 2). An additional lane down the hill is introduced to provide maximum capacity by achieving lane balance.

Two lanes from the N2 will form the pre-selection scheme that will pass Interchange 7 on the eastern side. The third lane that exists on the N2 at Interchange 5 originates from Upper De Waal Drive. The centre lane along Eastern Boulevard will diverge at the start of the pre-selection lanes, to feed the fast lane of the pre-selection scheme and the slow lane of the two lanes continuing the existing alignment of Eastern Boulevard. The slow lane of Eastern Boulevard (traffic bound for M3) that joins the Upper De Waal Drive traffic on the right-hand side can merge with the fast lane of Upper De Waal Drive, which has spare lane capacity as shown in Table 2.

The split at the bottom of the hill feeds three lanes to the N2 route and two lanes to the M3 route. This necessitates the relocation of the M3 to N2 loop. This movement of 800 vehicles will then be handle as a normal on-ramp from the left-hand side. The five lanes down the hill and the relocated M3 to N2 on-ramp, result in the demolition of the existing bridge at Interchange 6 and replacing it with a new bridge to provide sufficient horizontal clearances.
This proposed pre-selection scheme together with the additional lane along the outbound down the hill would significantly reduce the accidents due to the reduction in the cross weave and by reducing delays.

4. CONCLUSIONS

From the detailed study of this section of the N2 route it can be seen that the design engineers of the 1950's totally under-estimated the phenomenal traffic growth that has been experienced on this route. This under-estimation has been compounded by the application of poor design standards (necessitated to a large degree by the shortage of funds).

When considering the physical constraints that restricted the upgrading options and the financial constraints it can be seen that the traditional approach to engineering solutions does not always provide the best solution. In South Africa the experience has been that new transport corridors are difficult to motivate (environmentally and financially). This requires that the engineer of today must be prepared to think laterally and innovatively to utilise the existing infrastructure to the maximum (retrofitting).

The interaction between public participation and engineering can contribute greatly to the success or failure of a project and it is imperative that the engineer is seen to be taking cognisance of issues and concerns raised by the public.

The completion of the project will result in significant capacity and safety improvements, achieved at a reasonable cost (R 51 million). Although the main objectives have been achieved, the public participation process must still be brought to a conclusion.

ACKNOWLEDGEMENTS

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