KwaMashu Interchange Upgrade

OVERVIEW

The pioneering conversion of the standard diamond KwaMashu Interchange to an innovative diverging diamond layout has provided a low-cost, effective means of enhancing the capacity and safety of the interchange. It is the first application of a diverging diamond interchange (DDI) in the southern hemisphere, that is also on a left-hand drive road system.

The original KwaMashu Interchange on the multi-lane N2 freeway, located to the northwest of the Durban central business district, experienced high levels of congestion, partially due to some heavy right-turn movements. Traffic backed up onto the N2 northbound carriageway for several kilometres during high peak periods. These delays caused irritation and frustration among drivers, leading to increased accident rates at the interchange.

SANRAL (SA National Roads Agency Limited) therefore required short-term, low-cost capacity improvements at the interchange while a long-term solution was being investigated. Aurecon was commissioned to undertake extensive traffic assessments, which ascertained that traditional improvement measures such as cross-road widening would not be able to provide the additional capacity required.

The project team thus proposed the innovative concept of a DDI layout. Extensive research and analysis of this...
layout solution, including micro-simulation using AIMSUN NG and preliminary geometric designs, confirmed that the KwaMashu Interchange was a potential candidate for conversion to a DDI.

SANRAL used this opportunity to implement the DDI as a pilot project in order to assess the feasibility of DDIs on South African freeways and for South African driving conditions. At the time, this type of interchange had been used in France, and was beginning to find favour in the USA, although it had never been introduced in the southern hemisphere.

Not only has this innovative layout improved the capacity and safety of the interchange, but traffic and pedestrian conflict points have also been greatly reduced, with a consequent overall reduction in accidents and a complete elimination of right-angled accidents.

AN UNCONVENTIONAL LAYOUT

A DDI is an innovative interchange layout in which the traffic flows in the two directions of the cross-road (non-freeway) on the opposite (right-hand) side of the roadway, between the two interchange intersections. Vehicles on an overpass or underpass briefly cross over lanes at a two-phase signalised intersection to drive on the ‘wrong’ side of the road, allowing free and unopposed right and left turns to and from the freeway. After crossing over or under the freeway, the vehicles return to their normal left-hand lane.

Apart from congestion and safety reasons, other reasons why the KwaMashu Interchange was appropriate for conversion to a DDI were:

- The very high left- and right-turn movements onto and off the south-facing ramps
- Relatively minor left- and right-turn movements onto and off the north-facing ramps
- The cross-road being at ground level, and the availability of land for the conversion
- A fairly high accident rate, including a high proportion of right-angled accidents
- Predominantly regular users familiar with the interchange.

ENGINEERING INGENUITY IN DESIGN AND CONSTRUCTION

In view of the pioneering and novel nature of the DDI proposal, extensive traffic studies were undertaken to assess the effectiveness and efficiency of the DDI concept.

This was followed by a sophisticated assessment of key geometric elements of the proposed layout to determine the suitability of the interchange for conversion to a DDI.

The design process used:

- AutoCAD 3D modelling – this is not commonly employed for road projects
- A rigorous quality assurance system for designs
- An internal peer review and verification process
- An external peer review by UWP Consulting Engineers.

TRAFFIC ASSESSMENT

A detailed traffic analysis using SIDRA and an AIMSUN NG micro-simulation model confirmed that the existing interchange did not provide sufficient capacity for the peak demand and that there were two major conflict points – one on either side of the interchange.

It was concluded that these were generally in accordance with the guideline traffic movement parameters for a diverging diamond layout, and that there was no particular traffic flow or movement that could adversely impact the efficient operation of a DDI.
Apart from providing more capacity to accommodate the entire peak hour demand, the DDI would improve all aspects of the interchange performance by varying degrees, depending on direction and approach, with expected improvements of between 0.2% and 59% in the performance measures.

**PEDESTRIAN ASSESSMENT**
The existing pedestrian movements at the KwaMashu Interchange were not considered to be excessive. However, the complex layout of a DDI requires specific attention for the accommodation of pedestrian movement through the interchange. A safe pedestrian route through the interchange along the M25 was designed and then signposted using standard way-finding signage.

Additionally, a pedestrian ramp and stairs were also provided from the M25 up to the N2, including a pedestrian footpath over the M25 to a new taxi lay-by on the N2 just north of the cross-road.

**ACCIDENT ANALYSIS**
The KwaMashu Interchange has a fairly high historical accident rate. The DDI is expected to reduce the two accident types that currently make up more than two-thirds of all accidents at the interchange. Research into accident reduction at DDIs showed that typically more than a 50% reduction in accidents is achieved. This indicated that a substantial potential benefit would accrue to the KwaMashu Interchange when it was converted to a DDI.

**DESIGN CONSIDERATIONS**
Substantial details of the preferred geometric layout for a DDI are provided in the Missouri Department of Transportation’s document *Missouri’s Experience with a Diverging Diamond Interchange, Lessons Learned* (May 2010).

Using these recommended design parameters as a guide, a conceptual DDI at the KwaMashu Interchange was prepared on a GIS aerial base.

This conceptual layout showed that most of the recommended design parameters could be achieved, and where they could not, the divergence or non-conformance was acceptable and/or remedial measures could be introduced to mitigate any adverse impacts of the non-conformance.

**CONSTRUCTION**
The completed detailed design included a geometric layout, signposting, road marking, traffic signal design, construction phasing and accommodation of traffic. The detailed design was subjected to a further review, including an external peer-review process, to ensure that all aspects of the design were in accordance with the recommended design parameters based on the American (Missouri) experience.

This also ensured that sufficient advance warning signposting, as well as signposting and road markings at the interchange itself, were in place to assist with navigation and to mitigate any motorist confusion.

The detailed designs were approved by the client in early 2012 and the design team proceeded with construction drawings and procurement documentation.

**CONDITIONING MOTORISTS TO IMPENDING CHANGE**
Before construction commenced, SANRAL inserted advertorials including diagrams in local newspapers. It also distributed flyers at the interchange during peak periods advising motorists that the layout of the interchange was going to change to a DDI and what the expected implications of the change were going to be.

The interchange was converted to a DDI layout early in the construction process under stop control, which was then converted to temporary signal control. The rationale behind this was to give motorist an opportunity to experience the DDI at much lower speeds during construction before the full interchange was opened. The strategy also helped to create a safer construction environment.

Whilst there had been construction-related complaints from the public, the general reaction from motorists was extremely positive.

Construction of the conversion of the KwaMashu interchange from a standard diamond to a DDI commenced in June 2012 and was completed in August 2013.

**FUNCTIONAL EFFICIENCY**
At this stage the success of the project is based on the observation of the significantly improved capacity of the interchange and substantially reduced queue lengths during peak periods, combined with positive feedback from the motoring public in the area. Safety has been enhanced with the elimination of all right-turn movements.

SANRAL has indicated its intention to carry out a post-implementation traffic study to quantify the effectiveness of this DDI project.
ENVIRONMENTAL IMPACT
Although an Environmental Impact Assessment was not required, a river runs close to the site and an Environmental Management Plan (EMP) was developed. This was monitored throughout the project by an independent environmental consultant to ensure compliance with the EMP.

The reduction in queue back-ups has had a significant beneficial impact on atmospheric pollution in the area by effectively reducing the carbon footprint of the interchange.

BUDGETARY COMPLIANCE AND MANAGERIAL COMPETENCE
The project was completed within budget, although it ran three months over the original programme due to heavy, unseasonal rains from October to December 2012.

Recognising the risks inherent in any pioneering development, the project team instigated exceptionally careful and methodical design and construction management throughout the project which included:
■ Regular project team meetings with the client
■ Construction and commissioning was structured to ensure the safety of users and acceptance by them of this unique interchange.

SOCIAL RESPONSIBILITY
SANRAL required that all unskilled labour working on the project be sourced from local communities situated in close proximity to the site. As a result there were no strikes or worker unrest.

IN CONCLUSION
The pioneering and successful conversion of the standard diamond KwaMashu Interchange to a DDI has demonstrated a low-cost, effective means to enhance interchange capacity and safety. The project realised the following key advantages of a diverging diamond interchange:
■ Capacity: overall interchange capacity increases by 15% to 20%, with delays through the interchange reduced by up to 60% for peak movements.
■ Construction timing / traffic disruption: a construction period of approximately nine months versus two to three years for typical directional ramps.
■ Cost: construction cost was less than R50 million versus more than R300 million for a typical directional ramp for a longer-term solution.
■ Safety: traffic and pedestrian conflict points were greatly reduced with a consequent reduction in accidents. Right-angled accidents are completely eliminated and rear-end accidents have been reduced.
SANRAL is to be commended for their boldness in agreeing to implement this unique layout, which has advanced road engineering knowledge in the country and has the potential to play a valuable role in alleviating some of the country’s infrastructure upgrading challenges.