# A MAJOR FUNCTIONAL UPGRADE TOWARDS A COMPREHENSIVE PROVINCIAL ROAD NETWORK INVENTORY: THE GAUTENG CASE STUDY

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## ABSTRACT

An efficient road network consists of a vast series of carriageways interlinked by slipways and ramps that allow for both economic and societal movement. The Gauteng Province encompasses approximately twenty percent of the entire South African road network. Each element of the provincial road network is regarded as a vital record within a Road Asset Management System (RAMS), maintained accordingly and routinely updated. This paper builds on the GIS methodology involved in the functional classification and assembly of all digital road links in order to form an operational Road Network Inventory (RNI). It elaborates on the revised spatial geometry and status of each road link within the Gauteng provincial RNI after it has been functionally classified as guided by the South African Road Classification and Access Management (TRH26) and the TMH22 Road Asset Management Manuals. By reconstructing and updating the historical RAMS carriageway dataset, the first provincial RNI geodatabase to include dual roads, on- and off-ramps, slipways and sections of municipal roads located within the provincial road reserve was produced. Simultaneously, the link node allocation policy has also been revised to contain a more comprehensive set of descriptive attributes, since just more than 76% of these nodes represent physical road intersections. The impact on the RAMS was that the upgraded provincial RNI contained 44% more road links, 35% more nodes, 62% more dual carriageways than before and increased the total carriageway length by about three percent.

## INTRODUCTION

In most countries, the proper management and maintenance of its road transport network and associated assets are imperative as it forms the primary means of mobility and access in both economic and societal sectors. South Africa has Road Access Management (RAM) guidelines in place on national, provincial and municipal levels, collaboratively put together by road engineers and other transport specialists. Following the 1996 guidelines, it was found that roads need to be identified corresponding to the function they serve (Holderness and Stander, 2008). Function has since been classified according to road access, mobility, design, traffic volume (counting stations) and the presence of public facilities. Major routes are also classified according to the classes thereof and the access associated with them. In Gauteng the RAM has become the Road Asset Management

System (RAMS). It is a fully integrated system typically comprising the road network, bridges and culverts, and other assets or land parcel(s) accounted for and verified.

An efficient road network is of utmost importance to the economy of the country. Accessibility to business and service areas, as well as the safety of routes are important decision making factors to consumers and business owners, resulting in favourable and unfavourable business areas to service. Furthermore, by identifying the assets involved with the network and investing funds appropriately, the costs involved with transport is reduced whilst encouraging trade within the province as well as nationally and internationally (COTO, 2012).

The Western Cape and Gauteng Provinces appear to be the leading provinces in developing and providing comprehensive spatial road network systems to the management authorities. The Western Cape Road Infrastructure Branch also incorporates a full inventory of road assets. The Western Cape system, however, is different from that of Gauteng as different methodologies were used. The Western Cape uses the Road Access Guidelines prepared by the provincial Department of Economic Affairs, Agriculture and Tourism: Transportation Branch (2002). The RAMS guidelines on the other hand allows for the relevant road authorities to apply best practices in conjunction with their current data and systems (COTO, 2016). This is a possible downfall with guidelines being in place and not set practices – it allows for inconsistencies between provinces. Local metropolitan areas, Nelson Mandela Bay Municipality for example, have also taken the initiative to use the RAMS guidelines. Even though South Africa is implementing these systems more widely, the country is still relatively slow on the uptake in this regard when compared to the rest of the world. This study attempted to rectify this situation in Gauteng according to the relevant available guidelines to achieve a uniform and integrated system for the Gauteng Provincial Department for Roads and Transport.

## STUDY RATIONALE

Gauteng is home to one fifth of the South African population and is the economic hub of the country. It is predicted that the population growth rate of the province will be reasonably high due to socio-economic growth (Tomaschek *et al*., 2016). The transportation network within, as well as in and out of the province is therefore of great importance as it directly influences the economy of the province and of the country. Due to the dynamic nature of change associated with this growth, the RAMS roads geodatabase component should be fully up-to-date and totally complete because a dated, sub-standard road network dataset can seriously impede routine decision-making, planning and management activities and even result in discrepancies and concerns following an audit of the associated Financial Asset Register (FAR). The challenge remained to proficiently identify, classify and assemble all the relevant road elements and represent them in a fully integrated GIS in order to operationally support the RAMS on a day-to-day basis.

**STUDY REGION AND METHODS**

The study was conducted in the Gauteng Province in South Africa (Figure 1) and used the previous RNI version (v9b) as the base dataset.

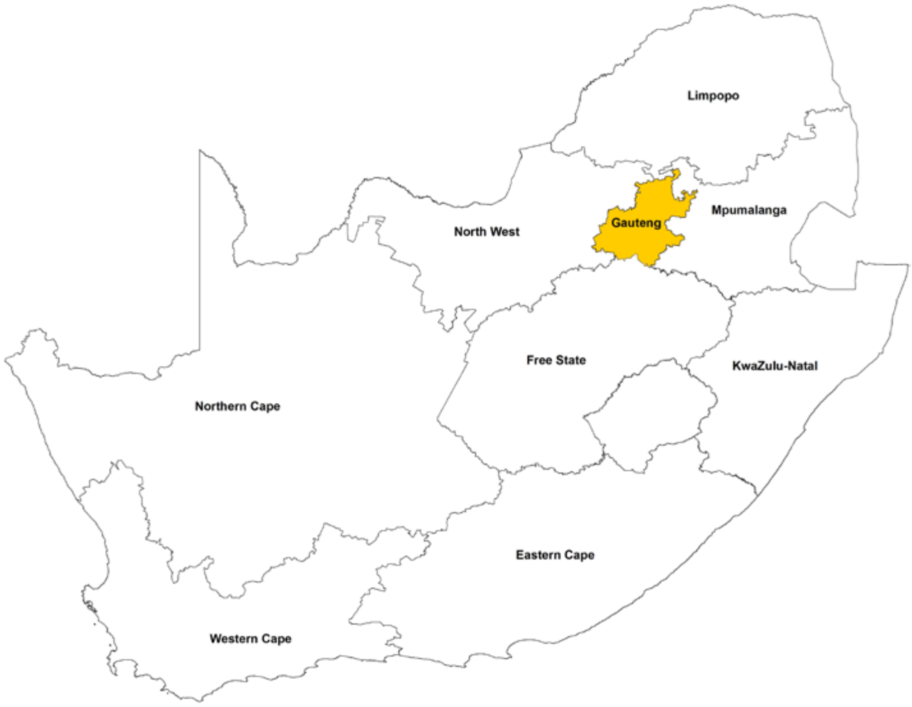


**Figure 1. Location of the Gauteng province within South Africa**

Geographic Information Systems (GIS), along with many other similar and supporting technologies, are deeply rooted within the geospatial community for their daily operations and decision making. Mapping science has become a huge commodity with growth in mapping markets (Tao, 2000). In terms of road network analysis, digital mapping increases the accessibility and efficiency of managing road network infrastructure (Bulai and Ursu, 2012).

The previous major Gauteng Provincial Road Network Inventory (RNI) update in 2015 was described by Veramoothea *et al*. (2015). During this process the roads were classified according to the function served, as guided by the TRH26. This paper discusses the 2016 upgrade of the RNI. It includes new elements as well as alterations to the existing elements to achieve a more comprehensive set of attributes. New roads were added to the RNI and decommissioned roads were removed.

All roads were considered according to the TMH22 and TRH26 guideline documents by the Committee of Transport Officials (COTO). These documents "*provide(s) a template, guidance and methodologies on the manner in which the road infrastructure assets should be managed. It establishes a uniform and integrated system on which the asset conditions are collected and reported on to ensure an equitable funding distribution so that the maintenance and rehabilitation of the road infrastructure is ensured*," (COTO, 2016). The lessons learnt in Gauteng will inform future updates to the guidelines. The TMH 22 (2016) has been drafted to provide the relevant road authorities with guidelines to manage assets in accordance with the lawful acts pertaining to the management of road assets and the finances thereof (COTO, 2016).

The data used in this study were the RNI consisting of links and nodes, very high resolution remotely sensed imagery and ancillary data (SANRAL road network, administrative boundaries, the AfriGIS 2014 roads layer (data used in accordance with AfriGIS standard EULA) for Gauteng). Geodatabases and relational tables were used in order to logically link the road attributes. This allows for an automated way to update, display, query and manage data for the RAMS system. The THM22 manual stipulates that the databases put into place should encompass simple interfaces and tools so as to ensure data interoperability and the easy transfer thereof (COTO, 2016). This paper used an array of attributes, both physical and descriptive, to highlight current road conditions for asset identification and valuation within the RAMS.

The road segments between nodes constitute the road links which were classified according to its location and properties. A link is thus a linear channel of traffic flow. Each road link would have its own unique primary key useful for identifying this specific section of road. Link nodes were placed where a link begins and ends, where there is a surface change in the road, where a road intersects with another road, and where a road intersects with a boundary.

## RESULTS AND DISCUSSION

### Link upgrade results

The 2016 upgraded naming policy allows for different provinces to use the same naming convention whilst preventing any duplication in link name. The road link primary key consists of the road name, the link's position in relation to the road in its entirety (by virtue of its sequential number), the province that the road is contained by, the survey direction and the type of road described. Road links were distinguished according to carriageways (C), slipways/intersections (I) and ramps (R). The unique primary key that was created contained a 14-digit alphanumerical identifier. The details of this key can be seen in Figure 2. The naming convention has changed from 0004 to 0040 (indicating link 4) to allow for new links added to be denoted by the last digit. This is a convention that has gained popularity in other studies and applications as the addition of elements to the existing network does not result in the other elements requiring change. For example, if there are two new elements added to link four, the second link added would be named P158/1_0042GPC.

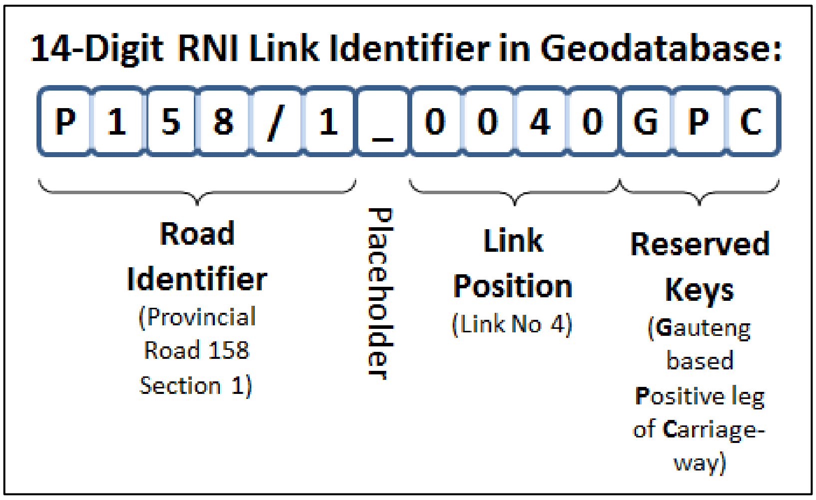


**Figure 2. 14-Digit RNI link primary key**

Ramps and slipways were very important new elements manually added to the RNI. Ramps and slipways are road segments deviating from a parent road to join another road. The segment is considered a 'slipway' when there is no grade separation between the two roads being joined, and a 'ramp' when there is a grade separation between the two adjoining roads. High resolution satellite imagery was used to differentiate between the two at respective intersections. Others have used high resolution imagery to extract roads and associated features (Karaman *et* al., 2012; Ye, *et al*., 2006). The TMH 22 discourages this as foot paths and the like can be wrongfully extracted as roads (COTO, 2016).

Roads with branching slipways were ordered according to the main links from the first link to the last, followed by the main slipways, and thereafter the branching slipways per sequential link (Figure 3).Instances occurred where a single slipway could be allocated to more than one intersecting road. In this case, the slipway inherited the details of the highest order road. New roads (municipal or other) added to the RNI, which were yet to be allocated a name, were given a prefix of 'M-' joined with the name of road that it most closely associated with. For example, a municipal road added to the RNI that intersected with the D51 was named 'MD51' and the links would be given the primary key "MD51_0001GPC" and so forth. The inclusion of new roads and municipal roads to the RNI were additional to regular maintenance that was done.

### Node upgrade results

The node dataset included XY coordinates of the nodes, a unique node ID, the roads being intersected (if any) as well as the node's position in terms of kilometres down the respective road. At intersections, nodes were allocated to the higher order road being intersected. Each node was allocated in alphabetical order per node number. The operator strived to allocate nodes in a clockwise fashion, however this was not always possible and no set rule exists as to the order in which the nodes should be allocated. The node ID consisted of four alphanumeric characters, starting from 'A', and includes the link node identifier. The link node identifier denotes border intersections with the link (B), road surface changes (S), road intersections (I), and the start or end of a road (E), eg. 0905B_I denotes node number 0905, 'B' indicates that it was the second node allocated to 0905, and ‘I’ indicates that it was allocated at an intersection. Each node is associated with street furniture and other road assets, and therefore a comprehensive set of nodes allows for the RAMS to allocate these accordingly to location.

Figure 3 shows a hypothetical example of an RNI interchange created using the methodology described in this paper. Node 0001A_E depicts the begin node at the starting of road D1. The begin node is always at the 0km marker. Node 0002A_I was placed where the road splits into two due to a physical barrier. Nodes were placed where all eight ramps associated with the interchange began and ended. The links were numbered from the start of the road, until the end, and the ramps and slipways were added thereafter. In the example, road D1 has 17 links, therefore the first ramp is named D1_0018GPR and the ramps and slipways thereafter follow suit.

## Impact on RAMS

The upgraded RNI resulted in a significant increase in road surface. This can be seen in Table 1. The regular maintenance of the RNI results in an accurate and up-to-date FAR. The decision to include ramps and slipways in this update of the RNI highlights the effect on the FAR. A 44% increase in number of links can be largely attributed to the addition of ramps and slipways and the addition of new roads. This will have a considerable effect on the asset value of the roads associated with the ramps and slipways in the FAR.

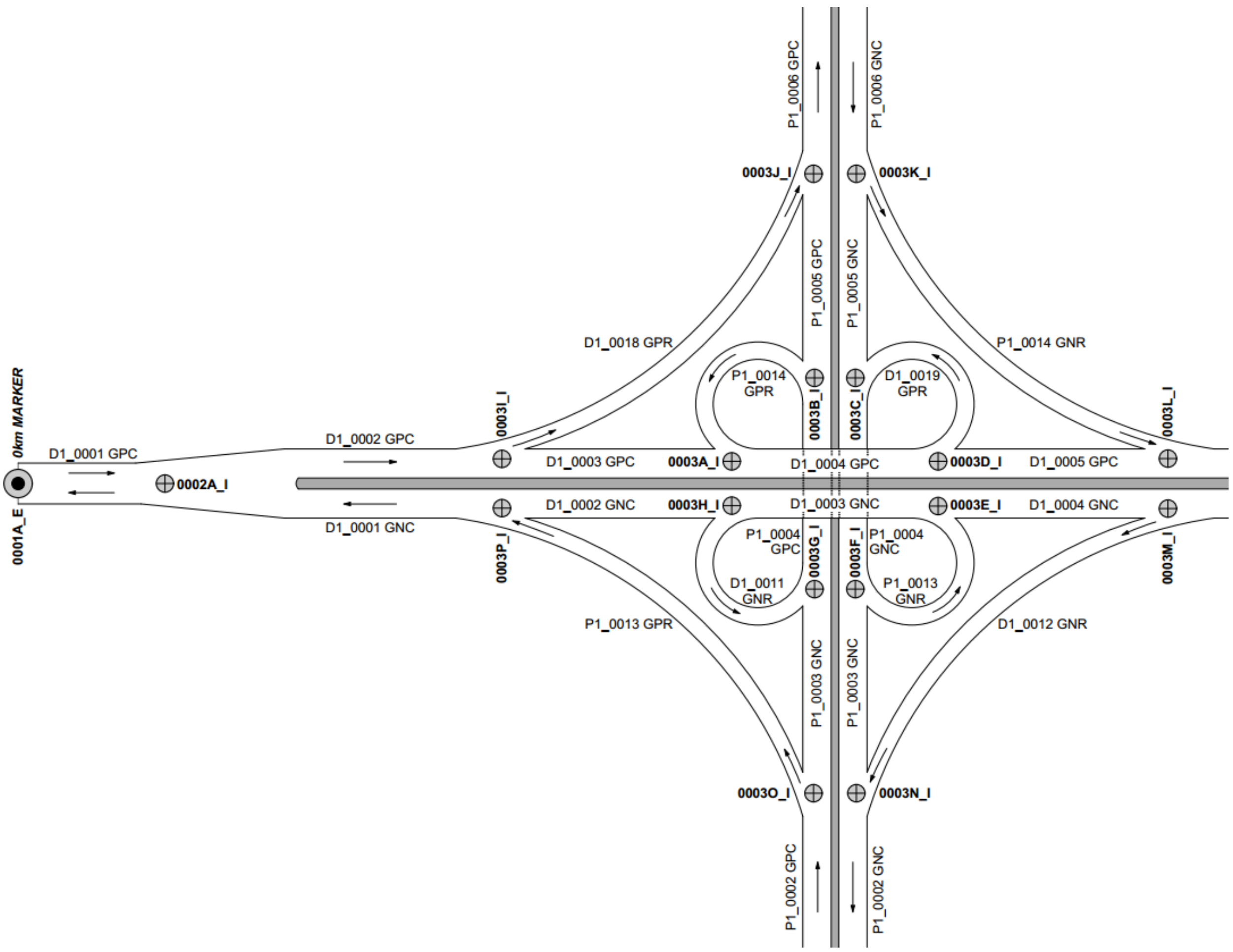


**Figure 3. Hypothetical representation of an interchange in the upgraded RNI**

**Table 1. Resulting figures from upgraded RNI**

| | V9b | V10 | % Increase |
|---|---|---|---|
| No. of nodes | 1961 | 2647 | 34,98 |
| No. intersections | n/a | 2018 | n/a |
| No. of links | 2503 | 3600 | 43,83 |
| Total combined road link length | 5747 | 5931 | 3,20 |
| No. of dual c/ws | 985 | 1594 | 61,83 |
| Length of dual c/ws | 1369 | 1468 | 7,23 |

The functions of roads can and do change over time, especially with the expansion of cities and residential areas that Gauteng sees annually. Therefore, regular updates of the RNI are necessary (Holderness and Stander, 2008). A complete and correct network will allow for appropriate decision making and planning by the relevant authorities to accommodate the growth dynamics of the province.

The methodology of this exercise can now be incorporated into the appropriate guidelines, such as the TRH26 and TMH22 to allow for a national RNI. The TRH26 provides guidelines for the classification of roads and was used for classification of the RNI by Veramoothea *et al*. (2015). Figure 4 shows the historic placement of a variety of nodes (Breytenbach et al., 2016). Historically, the RNI had a single line representing all roads, including dual carriageways. The new node dataset has inherited the intersection control node names to ensure traceability to the historic dataset - in this example the intersection control node is 405. These numbers are retained even with the addition of new elements (dual carriageways, slipways, etc.). Traffic counting stations were referenced to the intersection control node. Due to the addition of elements, a major challenge exists as to the identification of the exact location of traffic counting stations on the RNI. Traffic points will in the future be allocated to the node dataset. This will influence the maintenance and management of those points, which is of great importance for the FAR.

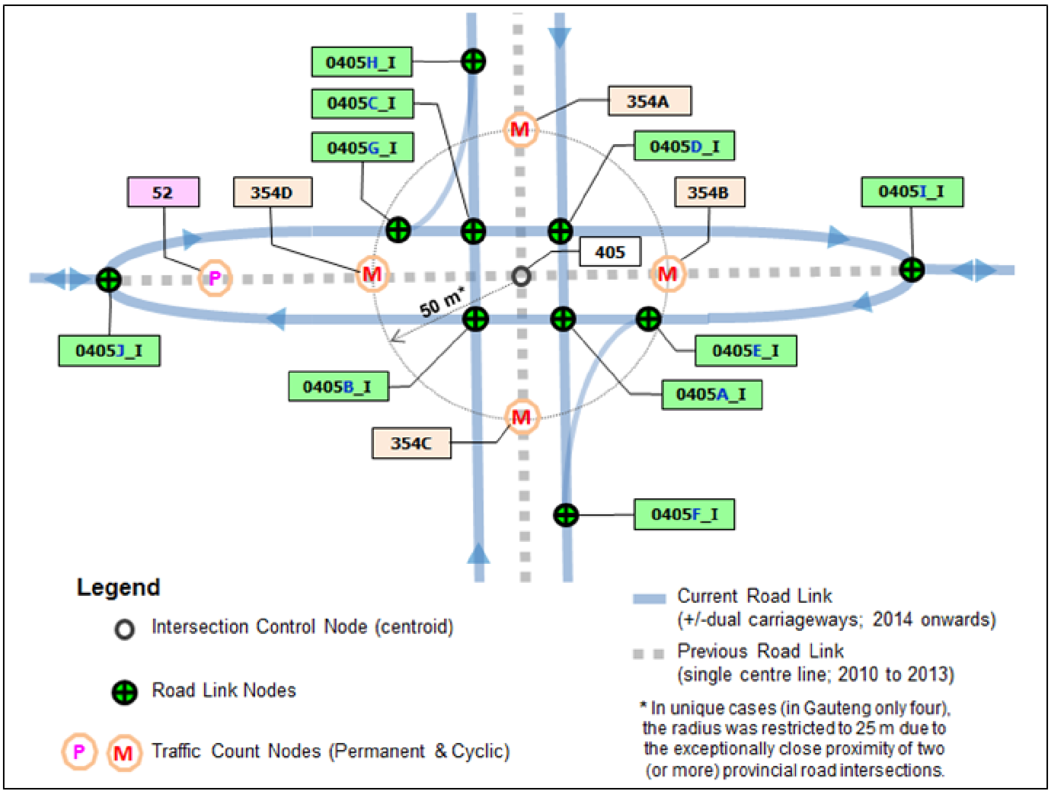


**Figure 4. Typical GIS placement of the road intersection node, road link nodes (after the integration of dual carriageways), and traffic counting stations .**

### Future developments

As a huge focus is currently on alternative methods of transport viz. the Gautrain, Rea Vaya, bicycle lanes, etc., the RNI will also incorporate these dedicated routes in future upgrades. This will provide a more comprehensive database of transportation routes.

## CONCLUSION

The RNI has been upgraded to represent the Gauteng provincial road network with greater accuracy in the geometry and correctness in the data than in the past. The elements of the FAR can be linked to the RNI through routine GIS maintenance to ensure a system that is consistently up-to-date. A better representation of the real world enables an optimal use of GIS tools for monitoring and planning purposes, as advocated by Sadeghi-Niaraki *et al*. (2011).

Every upgrade of the RNI sees new elements being added, as well as greater opportunities for future integration, due to the accuracy being achieved. This will assist the Gauteng Provincial Department of Roads and Transport maintain and manage the road network optimally, which leads to satisfied road users, as well as efficient economic transfer within and in/out of the province.

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