Big Data for Big Decisions

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FA5 – INNOVATIVE PRACTICE TO OPTIMISE ROAD NETWORK DELIVERY

Abstract

Managing a road network is a complex and challenging task. There are numerous elements to manage and take into account. In the turmoil, keeping track of far flung roads on an extensive network becomes an impossible task. In this case the adage proves true "if you can't measure, it you can't manage it". Road infrastructure is expensive but it is a vital part of the economy. As such wrong decisions come with a hefty price tag. In order to make informed decisions you need reliable up to date information.

Data collection has always been a difficult task . the application of modern technology has made this data collection somewhat easier but in turn has brought its own set of challenges. Collected data must be processed, stored, and then made accessible in a manner that allows for effective decision making. In this paper, the methods of collecting and managing data at SANRAL

Paper

1) Introduction

Managing a road network is a complex and challenging task. There are numerous elements to manage and take into account. Across an extensive road network it Is impossible to have a first-hand knowledge of each and every section and component. Without a systematic method of measuring and reporting data pertaining to the network it becomes impossible to effectively manage the assets under your authority.

In the turmoil, keeping track of far flung roads on an extensive network becomes an impossible task. In this case the adage proves true "if you can't measure, it you can't manage it". Road infrastructure is expensive but it is a vital part of the economy. Budgets are always constrained therefore prioritizing maintenance actions to ensure the best return on investment for the network is critical. Road maintenance and construction is expensive. As such wrong decisions have long term ripple effects across the network. In order to make informed decisions you need reliable, up to date information.

Data collection has always been a difficult task. the application of modern technology has made this data collection somewhat easier but in turn has brought its own set of challenges. Collected data must be processed, stored, and then made accessible in a manner that allows for effective decision making.

The methods of data collection, processing storage and effective usage of the data as used by SANRAL will now be explored

2) Pavement condition assessment

a) Vehicles

Before SANRAL was established and still part of the Department of Transport, road condition information was collected since early in the 1990's by means of automated instruments. First with LDV devices and later with more modern devices such as sonar based high speed profiling devices. These surveys were mostly conveyed by service providers outside of the Department of Transport and later SANRAL.

Figure 1 Figure 1 SANRAL RSV 2006

Because of the long turn-around time of receiving data and the rising cost of these surveys, SANRAL decided to invest in its own survey equipment and purchased the Road Survey Vehicle (RSV) in 2005. This was a learning curve for SANRAL as the original systems that were installed on the system were later replaced with better advanced systems as technology progressed over the years, but at the time it was state of the art.

The main component on the RSV is a High Speed Profilometer (HSP) consisting of 17 lasers. Three of these are 64kHz lasers and the rest is 16kHz lasers. From the HSP, International Roughness Index (IRI), Texture – Mean Profile Depth (MPD), Rutting and Water depth are calculated. These measurements form a key part of SANRAL's pavement management system and road network performance indicators.

Figure 2 Original Crack Detection system with incandescent lamps

Figure 3 RSV 2010. Newer Video capturing system and crack detection system

By middle 2009, the original crack detection system was replaced by an automated crack detection system made by Waylink systems, that used infrared lasers for its lighting source instead of 24V incandescent lights, which proved to be a huge enhancement. This system can detect and classify cracks at 90km/h. Together with a Video capturing system from Trimble (earlier from Geo3D and later bought over by Trimble), these turned out to be data generating monsters and a major headache for SANRAL's IT department. Generating in the order of 3 to 4 Terabytes of data in a week and dumping it on the network, caused them to scurry around fiercely to get more storage space, in a time where 1 Terabyte drives was still very expensive and Petabytes of storage systems unheard of.

All the systems use integrated Omnistar® corrected DGPS data provided by an Applanix LV420 system with an integrated Inertial Measuring Unit (IMU) and Distance Measuring Instrument (DMI) that can provide GPS coordinates to an accuracy of less than 0.5m at 100km/h, even when satellites are obscured when for instance going through tunnels.

Figure 4 The Waylink Crack detection system used infrared lasers for its light source

Traffic Speed Deflectometer

Up until 2009, SANRAL endeavoured to do network wide FWD surveys and tried to measure the whole of the network on a bi-annual basis.

The problem with FWD surveys is that the vehicle needs to be stationary to do a measurement before it can move to the next point. This turned out to be very dangerous when the road is not in totality closed for traffic. Because of major accidents during these contracts, SANRAL decided to stop doing network wide FWD surveys and invest in a Traffic Speed Deflectometer (TSD), which could measure deflections at 80km/h. This meant that measurements could be done at traffic speeds and the risk of accidents were minimised. In 2013, SANRAL received their TSD which was assembled in Denmark and shipped to South Africa.

The TSD is equipped with doppler lasers to measure the deflection under a loaded axle. The advancement from highly risky FWD surveys taken on some dangerous trafficked network roads at intervals of 50 to 200m to almost continuous deflection measurements at traffic speeds, make the TSD an invaluable and very safe tool for network management in SANRAL.

The TSD is also equipped with a Trimble MX8 system to collect right of way video. The MX8 is also equipped with 2 Riegl lasers that collects a laser point cloud to determine features like roadway signs and poles, roadway geometry, horizontal and vertical clearances, and 3D breaklines including edges, crown and lane markings.

A Waylink 3D crack detection system is also mounted on the TSD. This system is used to detect cracks from 1mm and more through an automated post-process. The Waylink system is also used on the TSD to determine Rut Depths.

Figure 5 SANRAL's Traffic Speed Deflectometer

3 Texture lasers are also mounted on the TSD to determine MPD as well as IRI values in the left and right wheel-paths, as well as the middle of the travelled lane.

The GPS data is supplied by an Omnistar® subscription on an Applanix LV520 system with an integrated IMU. This combination can supply GPS coordinates to an accuracy of less than 0.2m at a speed of 80km/h, even through tunnels, when the GPS satellites are obscured.

Because SANRAL want to do research, as well as network wide surveys, with the TSD, the axle load can be varied and increased to up to 12 metric tons to research the effect of overloading on its network. This turned out to be a huge problem for registering the TSD trailer as a special vehicle on e-NATIS (South Africa's vehicle register and license system), especially at a time when there were disputes about e-NATIS and never ending legal actions that made registering a special vehicle a big problem. Besides this, SANRAL needed the vehicle to be able to operate without a special abnormal permit at any time in order to perform this research. For this it needed special permission from the minister of transport which also lengthened the process of getting the trailer registered. All these problems prevented the TSD from starting network wide surveys as the vehicle could not operate legally on SA public roads. In the interim, SANRAL obtained special 3 day permits at a time to do comparison testing with FWD measurements and to start doing research on experimental sections constructed near Cullinan in Gauteng province.

By the end of 2017, SANRAL was eventually successful in getting the trailer registered as a special vehicle.

Creating lots of data, turned out to be even easier with the TSD. At around 1 Gigabyte per kilometre the IT department at SANRAL is now prepared for the influx of data that will be generated with the TSD in the coming years. With more than 2 Petabytes of storage space currently available and the ability to grow this even more, they should be ready for the hordes of data, which we now call Big Data, to come in the future.

Figure 6 The MX8 and Waylink systems together with the Doppler Deflection system makes this a one of a kind TSD

b) IRI

On the RSV, IRI data are collected from the HSP beam mounted in front of the vehicle. IRI can be calculated on 13 of the lasers, as only 13 of them are mounted perpendicular to the road surface. The other 4 are mounted at an angle to give the beam a reach of 3.7 meters without having the lasers standing out too far from the vehicle.

On the TSD, IRI is calculated from 3 texture lasers (64kHz) mounted below the body of the trailer, just in front of the trailer wheels. IRI can be calculated in the left, right and in between the wheel-paths. The left and right lasers are mounted at a distance of 1.75 metres from each other.

c) Texture

On the RSV, texture data are collected with 3 high frequency lasers mounted in the HSP and expressed as MPD (Mean Profile Depth). These are mounted in the middle and in the left and right wheel-paths. The left and right texture lasers are mounted 1.75m from each other. These also provide the data for calculating the IRI in the left and right wheel-paths.

On TSD the texture data is derived from the 3 texture lasers that also provide the data for the IRI calculations and is mounted under the trailer just in front of the trailer wheels.

d) Crack

On the RSV the crack information is provided by a Waylink Automated 2D Crack Detection system. This system can distinguish between lateral, transverse and crocodile cracks at a speed of 90km/h. Data is written into a database on the recording computer and can also be re-analysed as a post-process if needed. This is also an automated process. Unfortunately, this system was decommissioned in 2015 due to a camera and software driver licensing issue by a third party.

On the TSD, SANRAL installed an improved system from Waylink, called the 3D Pavevision System that can now detect cracks from 1mm and more from 3D cameras. The crack detection algorithm is now an automated post process and not done while recording, as it is just too processor intensive.

e) Rut

On the RSV the rut depth is determined by calculating the rut profile from the 17 mounted lasers in the HSP. The 17 lasers are placed at strategic locations, with closer spacing near the wheel-paths to increase the accuracy of the profile in and near the wheel-paths.

On the TSD, the rutting is calculated from the Waylink 3D Pavevison System. Eight 3D cameras integrate to record a matrix of points with a resolution of 1mm of the road surface.

f) ROW video

The RSV is equipped with 2 Right of Way cameras, one facing 30 degrees to the left of the driving direction and one facing 5 degrees to the right of the driving direction. From these videos a post process is done to extract inventory data like road signs, guardrails, fencing, line markings, lane widths, shoulders widths, drainage structures, rest stops, bus stops, intersections, interchanges and structures like bridges, gantries, large culverts etc.

The TSD is equipped with a Trimble MX8 system that is equipped with 4 cameras, one facing directly in the driving direction and mounted inside the cab of the tractor, a camera mounted on each side of the trailer and one camera facing backwards. Together with the laser point cloud from 2 Riegl lasers, processes can be automated to detect structure clearances horizontally and vertically, extract poles, roadway geometry, horizontal and vertical clearances, and 3D breaklines including edges, crown and lane markings etc. Road sign positions can also be automated but classification of road signs still needs to be done manually.

g) Deflection

Deflection cannot be measured with the RSV. SANRAL uses external service providers to collect deflection measurements by Falling Weight Deflectometers.

The main function of the TSD is to collect deflection measurements. This is accomplished through doppler lasers which measure the deflection of the road surface under an 80kn loaded axle. This can be varied by up to 120kN on the axle to research the effects of overloading. The TSD is equipped with 10 doppler lasers at distances of 100, 200, 300, 450, 600, 750, 900, 1200, 1500 and one mounted at a distance 3500mm from the axle. The 3500mm laser is mounted outside of the deflection bowl and serves as a reference laser.

With all the automated data that SANRAL has collected over the years, the number of records for only the exported data for IRI, Rutting and Texture records, which is stored in an Oracle database at 10m intervals, is currently at 14 482 651 records. From the 10m data, summaries for reports are calculated for 100m intervals, 1km intervals, Segment summaries, Section summaries, Route summaries and Regional summaries.

3) Structures condition assessment

Unlike the pavement asset condition where the majority of measurements can be automated. Structure inspections still rely on a manual visual inspection methods. Each structure is unique and there is no automated method available to fully assess the condition of a structure. Structures are inspected by a bridge or culvert inspector. As this is a complex task it is a requirement for prospective inspectors to attend a training session where an exam is written. There is also a requirement for candidates to submit a CV detailing their experience in structural design.

The submissions are evaluated by a panel from different road authorities.

There are three categories of inspector Culvert inspector, bridge inspector and Senior bridge inspector

There is a standardised methodology used for the inspection and rating of structures conditions this Standardised method is detailed in TMH 19. This system uses the Degree extent and Relevancy rating system. From these ratings, a Condition index is calculated.

During inspections each structure is photographed, with detailed photos being taken of the observed defects. These photos need to be geotagged

Data from inspectors is captured on software. This can be one off line or on line. When online data can be committed to the SANRAL servers. Should the inspector's computer be lost broken or stolen the latest copy of the data is still available.

The inspector captures all the condition ratings, uploads the photographs taken during the inspection and updated the structure inventory.

Once complete the inspector signs off the inspection electronically. There is data quality check form the SANRAL side where the inspection is either approved or can be sent back.

Once approved the data is stored in the database and inspection reports can be accessed through the ITIS portal.

4) Traffic information

Traffic information is vital to the engineering assessment of the road network. The life of a road pavement is often presented as a number of years. This is in fact untrue. Road pavements are designed for axle load repetitions. Measuring the number of axles and their respective loadings gives the vital data to know if a road is performing as designed. Knowing the traffic volumes allows to predict pavement deterioration and forecast when a maintenance intervention may be required.

Having traffic data available also allows to select what type of intervention is likely to be most suitable. It also assists in triggering when capacity improvements are required, these could be measures like adding climbing or passing lanes, constructing additional lanes or upgrading the road to a dual carriageway.

Traffic is counted using Technologies with different detection capabilities. For each situation, the most applicable method must be selected. In certain cases, Higher accuracy requirements are necessary. This warrants the installation of a permanent traffic counting station that operates continuously for more than 3 months. In other cases, the traffic volume and composition can be estimated accurately enough by performing a short term traffic counting and using the data to get an estimate of the traffic volumes for the year using calculated expansion factors.

Different technologies are available. This ranges from manual counts through to automatic counters that can use radar, induction loops, cameras or piezo cables.

In the past the method of counting was specified along with the technical specifications to the installation of the equipment. However, this approach did not allow for innovations or advances in technology. In order to overcome this, SANRAL only specifies the quality of data to be collected as well as the accuracy level. The service provider must demonstrate that the traffic monitoring system that they want to use can meet the level of accuracy specified. Once they have demonstrated this they may commence with counting.

Demonstrating accuracy is done through an accreditation body. There are two types of accreditation that must be acquired. The first is to demonstrate the capability of the traffic monitoring system to reach the desired level of accuracy. The second is to demonstrate the Service provider can install and operate the equipment effectively. This method allows for the effective collection of reliable traffic data while allowing for cost savings through the use of technological innovation.

The bulk of traffic counting performed on the SANRAL network is done by automated traffic counting stations. In the majority of cases the data is collected at regular intervals using GPRS. This has the advantage of preventing data loss due to equipment malfunction or theft. It also allows for the early identification of a problem so that a maintenance team can be dispatched. The service provider is responsible for these processes. After performing their data quality checks, the service provider then submits the data to SANRAL via the internet in a prescribed format.

5) As-built data

Currently absolute pavement is reported from sites on Paper/ pdf reports. This data then needs to be manually captured into the database. SANRAL is working on a system to have the As-built data captured on site during construction and submitted electronically directly to the data base.

6) Post-processing and Collation of data

Pavement and traffic data require post-processing before it can be used. Once the survey vehicle returns to head office the survey data is transferred and post-processing can begin. Certain data can be processed automatically without human intervention, examples of this are Rut IRI ant Texture. Other data like Cracks data are partially computer processed but need human checking before they are finalised.

The traffic data uploaded by the traffic counting service providers is processed and subjected to data quality checks then stored in the data base. The sheer volume of this information requires allocation of significant computing resources in order to handle the volume of data. Approximately 36 Gb of raw data is received every month. Once the data is processed it is stored in the Oracle Database where it is then immediately accessible through ITIS.

7) data for decision making

Ultimately all the data that is collected is stored in the Oracle Database. In this organised format reporting and decision making are now possible through the ITIS web or software interface.

The data is accessible through the ITIS web based portal. This give access to relevant data to all SANRAL employees. Data can be extracted in reports, queried, or viewed electronically. Live dashboards summarise and visually display information.

There is also an interactive map tool that allows specially referenced data to be viewed on a map. The mapping tool has an intuitive interface allowing users with minimal training to navigate and display or overlay different layers. The mapping tool links to other GIS databases so that information from other data providers such as for the Surveyor General or Stats SA can be viewed together with SANRAL’s data. Spatially displaying data and overlaying different data sets provides valuable insights that other data reporting methods can’t provide. This is very useful in management and decision making.

Additional benefits of having the data organised in a single data base is that the data can be written out in a format that can be input into software used to predict road deterioration and perform road maintenance prioritisation under constrained budget scenarios. This saves significant time in setting up models in the necessary other software packages.

The data is also used in the calculation of statistics for financial reporting, network performance measures, asset numbers and asset values.

References

TMH 19 bridge inspections

TMH 14 traffic data format

TMH 3 Specifications for the Provision of Traffic and Weigh-in-Motion Monitoring Services,

TMH 8 Traffic and Axle Load Monitoring Methodologies and Procedures,

TMH 14 South African Standard Automatic Traffic Data Collection Format