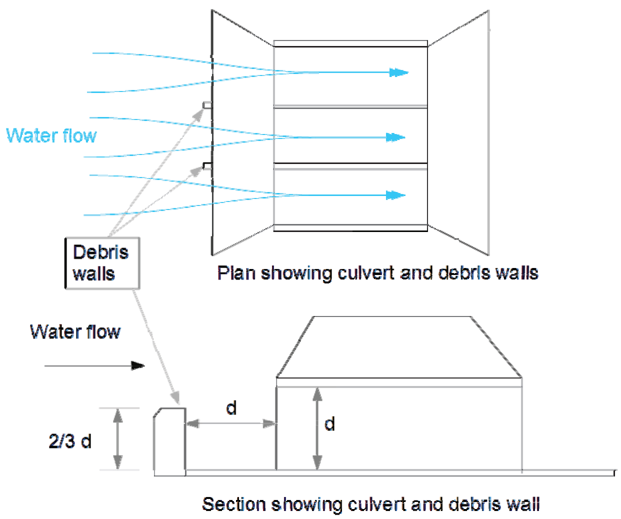

FIGURE 38 This diagram shows the placement and dimensions of debris walls in relation to the culvert

blockage i.e. the debris forms a weir across the entire river at the height of two thirds of the culvert opening, the upstream depth of water will be equivalent to the culvert opening being reduced by 30% by debris.

The chances of the blockage reaching right across the river are significantly reduced. The risk to flooding of upstream properties to the levels previously seen at the culvert without debris walls is greatly reduced.

DISCUSSION AND CONCLUSION

We are still in the learning curve with the use of debris walls in this way. As we have learnt so far, the mathematics can take you so far but the practical application highlights that the variables at each location require some intuition and adaptation. These variables include the type of debris, the flow regime of the stream, the configuration and alignment of the culvert crossing and the upstream channel shape.

The use of this debris wall design is being rolled out to the multicellular culverts throughout the eThekwini Municipality and is proving to be very successful in reducing the occurrences of overtopping and the associated damage. As highlighted in this paper, the training of the maintenance teams is imperative and it is only the combination of good design and installation and good maintenance programs that ensure the success of these debris walls.

The cost of installing the debris walls is considerably less than the cost associated with upsizing or replacing culvert crossing and therefore debris walls in this form, are cost effective ways of municipalities avoiding the damage cost associated with culverts blocked by debris.

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Equation (1) Mechanics of Fluids B.S. Massey

THE COLLECTION OF NETWORK LEVEL ROAD CONDITION DATA USING AN INTEGRATED TRAFFIC SPEED DEFLECTOMETER: A PARADIGM SHIFT IN ROAD ASSET MANAGEMENT PRACTICE

YESHVEER BALARAM[1], SIMON TETLEY[2]
1. General Manager - Asset Management, VNA Consulting (Pty) Ltd
2. Group Manager - Pavement/Materials Engineering Division, VNA Consulting (Pty) Ltd

ABSTRACT

The collection of Network Level pavement condition data in South Africa is traditionally undertaken by means of driven visual assessments. The issue of subjectivity and the time consuming nature of this exercise have long been acknowledged as a "stumbling block" in the data acquisition process. Furthermore, visual inspections only report on the "perceived" road condition and cannot give actual measurement/quantification of structural condition – this usually being undertaken by a Falling Weight Deflectometer (FWD).

In recent years, a few local consulting Firms have acquired semi-automated data collection vehicles which record visual condition data and profile measurements. Whilst this method of data collection is a significant improvement, visual data still needs to be condition rated. The latest generation survey vehicle is a Traffic Speed Deflectometer (TSD) which offers a fully automated solution. The TSD undertakes continuous deflection measurement using Doppler Laser technology, records surface profile measurements, captures continuous digital imaging, and employs an automated crack detector for crack detection/quantification, at a driving speed between 40 km/h and 80 km/h. The benefits in speed, repeatability and safety of data collection are obvious.

The first TSD began data collection on the Danish State Road Network in 2005. Since then, nine TSD's have been commissioned for various State Road Authorities or Research Institutes around the world including Australia/NZ, China, UK, USA, Denmark, Italy, Poland and South Africa. In April 2016, VNA Consulting (Pty) Ltd acquired the 10th TSD worldwide, the second in Africa, and the first such machine to be operated by a private enterprise. This Paper presents the TSD rationale and discusses the capabilities, outputs and benefits of the device.

INTRODUCTION

Road authorities are responsible for the planning, design, construction and maintenance of their road networks. For a road authority to successfully manage its road network, it needs to know its condition (Wix and Whitehead 2015). Given that the condition data is the key component used in Road Asset Management Systems (RAMS), enabling decision makers to generate advanced road maintenance strategies, the accuracy of this data is intrinsically critical in the identification of optimal cost beneficial strategies. RAMS adopts a systematic approach which begins with the planning and undertaking of road condition assessments. In the past decade, South Africa has seen a gradual shift from manual methods, to semi-automated methods of data acquisition. Road authorities have embraced the use of non-destructive survey vehicles which collect, inter alia, functional and structural road condition data.

Amongst these are Road Surface Profilers (Figure 1) which use lasers to collect functional parameters such as riding quality (in terms of the international roughness index, or IRI), wheel path rutting and macrotexture at traffic speeds. Profilers are often integrated with imaging systems which creates a digital record of the road, later used to "post" rate the road visual condition (as per the TMH9 visual assessment manual) and determine a Visual Condition Index (VCI).

It is clear that the recording of digital images has numerous advantages. The method is, however, also associated with an element of subjectivity, in that the visual data still needs to be assessed and condition rated – this from automated photographs as opposed to being physically assessed on site. Should an actual measurement of pavement strength / stiffness also be required as part of the road condition data set, the Falling Weight Deflectometer (FWD) is the standard device used to collect this information. Whilst the measurement of surface deflections / pavement response using the FWD is a tried and tested method, the process is slow as measurements can only be made while the vehicle is stationery. This requires detailed planning in terms of traffic control before the testing starts and, even with the best planning, congestion is almost inevitable, with associated safety risks to motorists and the FWD operators, particularly on roads which experience high traffic speeds.

FIGURE 1 Example of a Digital Road Surface Profiler with an integrated imaging system.

Subsequent to the data collection process is data analysis. The deflection, profile and visual condition data must be spatially aligned, and to some degree combined, before it can be entered into a RAMS. Whilst this "semi-automated" methodology and integration of data is considered to be a significant improvement on the use of pure field derived visual assessment information, the process of vetting and merging various data sets can potentially create misaligned data resulting in incorrect future maintenance strategies.

The latest available data collection device is the Traffic Speed Deflectometer (TSD) which is designed and built by Greenwood Engineering A/S. In May 2016, VNA Consulting (Pty) Ltd took delivery of the tenth TSD worldwide. The TSD measures pavement deflections at speeds between 40km/h and 80km/h. It includes an automated crack detector, which identifies and quantifies surface cracks and potholes, thereby removing the need to manually rate these distresses. All systems are integrated into a single user interface thus streamlining data analysis.

THE TRAFFIC SPEED DEFLOCTOMETER

In recent years, various researchers and road agencies have focused on developing high speed deflection measurement devices (Muller and Roberts, 2013). The TSD is a standard articulated truck which contains the various measurement components and systems attached to the rear trailer (Figure 2). Inside the trailer are seven Doppler lasers which are installed on a rigid frame located ahead of the loaded left rear wheel. The load consists of lead ballast mounted under the trailer. The rear axle load measures 9t which corresponds to the current South African design load standards.

In addition, several systems from the Australian Road Research Board (ARRB) group's "Hawkeye" suite of technology have been integrated within the TSD, including automated crack detection, roughness and texture lasers, pavement and asset cameras, and geometry tracking.

Behind the left rear wheel is a high resolution (20,000 pulses per revolution) distance measurement instrument (DMI). This, along with a differentially corrected GPS receiver mounted within the trailer, are interlinked to all the data collection systems ensuring precise distance and spatial positioning measurement.

MEASUREMENT SYSTEMS

Pavement deflection

Bearing capacity measurements are an essential "tool" in the identification of the optimal road rehabilitation design strategy at both a project level and also for input into network level rehabilitation / maintenance planning models. These are traditionally undertaken by a FWD, which, as already mentioned, is a slow process as deflections can only be measured whilst the vehicle is stationery. Another limitation is the relatively

FIGURE 2 Schematic of the ARRB TSD showing ballast loads and internals of trailer (Wix et al. 2015)

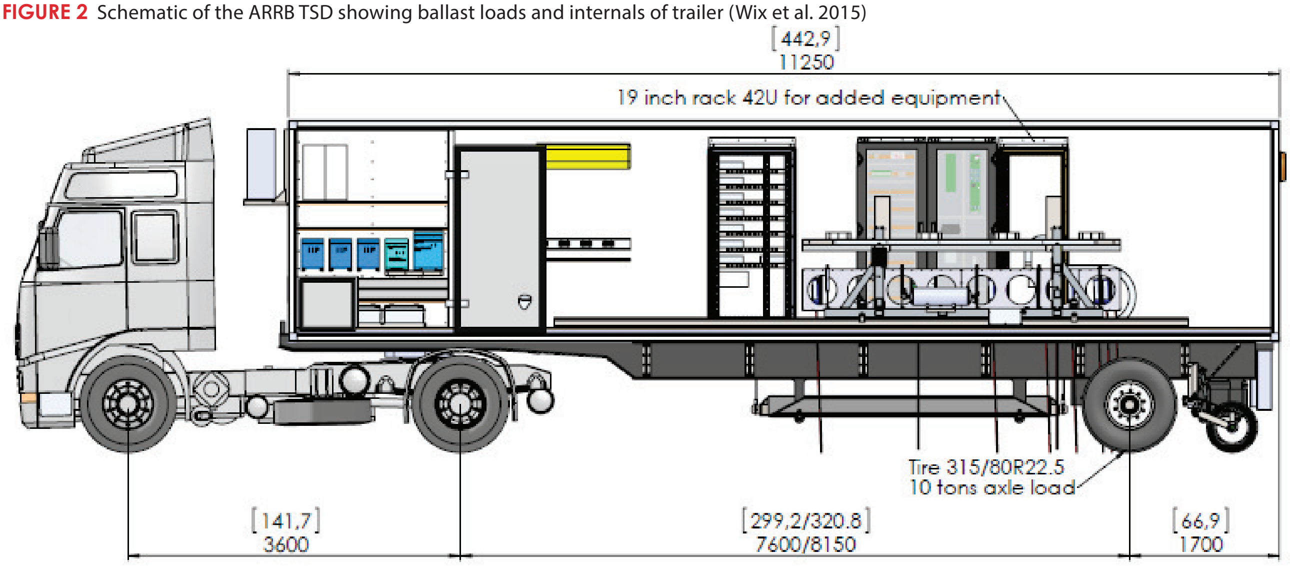


FIGURE 3 The VNA TSD during validation exercises (June 2016)

low amount of data produced, typically 10 measurement points per kilometer which usually take around 90 seconds per point or approximately 5 km/h. The TSD is capable of operating at traffic speeds, with a data rate up to 1050 pulses per second.

Instead of measuring absolute deflections as is the case with the FWD, the TSD uses a series of Doppler-shift laser sensors mounted on a rigid beam within the trailer. The sensors are positioned at 100, 200, 300, 600, 900 and 1500mm ahead of the rear axle. The beam is servo controlled to keep the sensors focused at a constant distance to the road surface. A reference laser is mounted at 3500mm ahead of the rear axle where it is assumed that the

FIGURE 4A AND 4B The beam which houses the Doppler laser sensors

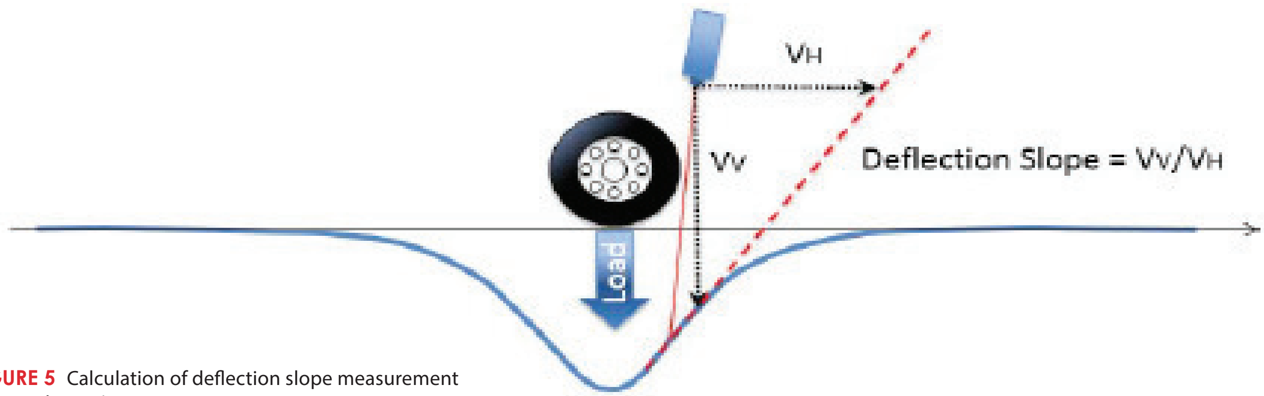


FIGURE 5 Calculation of deflection slope measurement (Wix et al. 2015)

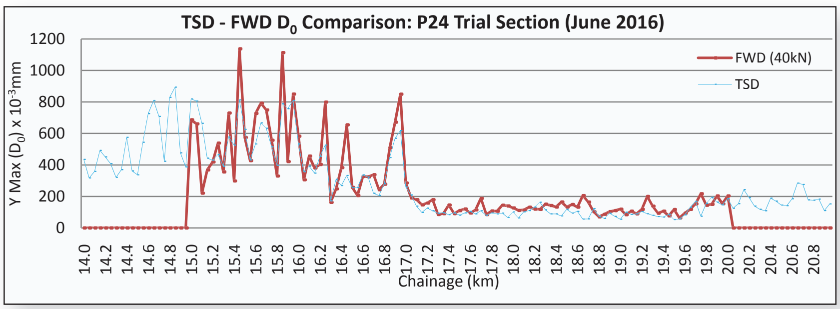


FIGURE 6 Comparison between TSD and FWD on P24, KZN.

pavement is unaffected by the axle load. The sensors are mounted on the beam at an angle of approximately 2 degrees, thus splitting the velocity of the deforming surface into a vertical and horizontal component as the load is applied. The horizontal velocity is calculated by the DMI. The deflection slope is then calculated by dividing the vertical velocity by the driving (horizontal) velocity (Krarup et al, 2006) as depicted in Figure 5.

The deflection profile of the road surface can then be determined either by curve fitting and numerical integration or by fitting pavement or empirical models to these measurements (Muller, 2015). More detailed information describing TSD deflection bowl predictions can be found in Muller and Roberts (2013).

During the commissioning of this TSD in South Africa, a 5km trial section located on Provincial road P24, in KwaZulu-Natal, was selected to undertake the acceptance/validation testing. In terms of visual condition, the first two kilometres (km 15 to km 17) of the trial section consisted of a moderate to severely distressed, and aged, pavement. The following three kilometres (km 17 to km 20) was rehabilitated in 2013 and was found to be in a good visual condition.

The FWD tested the road at 50m intervals in the outer wheel path, a total of 100 points over the 5km section. This testing took approximately 90 minutes and involved liaison with traffic authorities and the organisation of traffic accommodation facilities. In contrast, the TSD collected continuous measurements, approximately 200 000 individual readings over the same section, which was later averaged to 50m intervals. As the TSD measures the deflection at normal road speed, there was no interruption to normal traffic flows. The maximum deflection results are presented in Figure 6.

Both the TSD and FWD results were found to be similar in shape and magnitude, and clearly indicate the change in bearing capacity from the point where the pavement had been rehabilitated in 2013.

In fact, the TSD has proved to work well at detecting differences in the bearing capacity levels of pavements at the network level in many countries worldwide. This is confirmed in various papers including Baltzer et al. (2010) which describes the continuous bearing capacity measurements of 18 000km of the Australian road network in 5 months.

Due to certain limitations, which are discussed later in this Paper, it is not envisaged that the TSD will completely replace the FWD. For network level investigations, the TSD is a more feasible solution for a number of reasons including its high measuring capacity and comparative safety, which lead to reduced operational costs. However, the FWD remains a more attractive option for project level investigations where it is more cost effective and, inter alia, more flexible in its operation in that it can measure at varying target loads (40kN or 50kN) and at specific points as required by the pavement engineer.

Automated crack detection

In addition to deflection measurement capabilities, the TSD is integrated with a 3D Automated Crack Detection (ACD) system. The system, developed by Pavemetrics in the USA, employs high resolution optics which acquires a 3D profile of the road surface up to a width of 4m. It automatically detects and analyses cracks (greater than 1mm), surface ravelling, ruts and potholes. Algorithms built into the system are capable of categorising the type of cracks, such as longitudinal or crocodile, and measure such thereby eliminating the need to manually rate and quantify these distresses. It has proven to be advantageous in identifying previously sealed cracks which have since opened and are difficult to identify by eye.

Unlike previous generation surface profilers, which usually rely on lasers mounted in the wheel paths to measure rutting, the 4m wide laser spread

FIGURE 7 The ACD system installed at the rear of the trailer measures 4000 points (combined) across the lane. It also houses the rear facing asset cameras

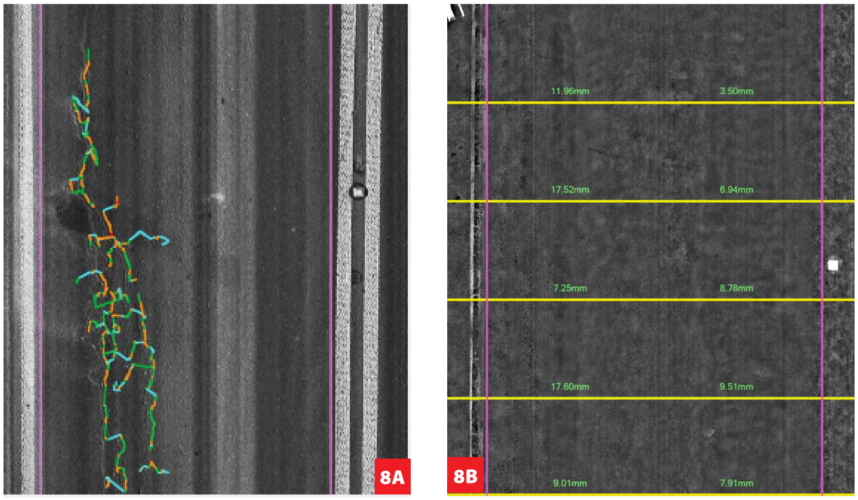


FIGURE 8A AND 8B Examples of crack detection (left) and rut measurements (right) from the ACD. The different colours on the left illustrate varying severity of the cracks (image on the right has been digitally enhanced for illustration purposes)

of the ACD caters for any erratic movement by the driver, ensuring that the maximum rut depth is always measured.

Additional systems

The rationale behind the importation of this TSD to South Africa is to offer the various Road Authorities a fully integrated "one stop shop" solution to network data collection needs. In addition to the bearing capacity measurements and the ACD systems, the TSD is able to measure surface profiles and road geometry, as well as record continuous digital images.

Profiles The TSD is equipped with a Class 1 Digital Laser Profiler that measures the longitudinal profile, roughness (IRI) and macrotexture (MPD) using two laser sensors with built in accelerometers installed in each wheel path.

Geometry In conjunction to the differentially corrected GPS, the system houses a Gipsi-Trac unit that uses a microprocessor linked to a gyroscope, accelerometer and the DMI, to calculate the vehicle position. This becomes beneficial when surveying in remote areas, such as tunnels or mountainous regions, where GPS coverage is limited. In addition, road geometry features such as longitudinal grade, cross slope and horizontal alignment are calculated.

Imaging Images provide a permanent record of the road at the time of measurement. A video acquisitions system records continuous video images at the front and rear of the vehicle. In all, there are five cameras - three facing forward arranged in a panoramic setup (with a range of approximately 150 degrees) and two facing rearward (beneficial for when surveying directly toward the sun). Images enable the identification and measurement of pavement characteristics such as lane widths and roadside assets such as guardrails, signage and even the soffits of overhead structures.

DATA ANALYSIS

It has long been established that the quality of data affects the integrity of any RAMS. Asset Management Systems are only as good as the data that is entered into it. One of the challenges that RAMS managers face is analysing extremely large volumes of data. Also, data which is collected from various sources must be vetted for spatial consistency. Whilst assigning unique indexing keys and spatial referencing assists the process, data managers still spend a lot of time and effort ensuring that the quality of the data is valid for input into the RAMS.

Even with stringent quality checks, together with "exception reporting" the potential for errors still exist and, ideally, the processing of data from the time of collection to entry into the RAMS should be as short, streamlined and automated as possible.

The convenience of the integrated system eliminates the need to combine the various datasets manually. The Hawkeye toolkit enables post analysis by integrating all collected data into a single user interface. All data is geo-referenced and time-stamped. In a single window, the user can view multiple images of the road (from the various camera positions), profiles, deflections, geometry and mapping information. The advantage of having the information integrated is that, as the images are accessed, either forwards or backwards, the associated data is automatically displayed for that particular section of road.

Provided that the TSD has been calibrated correctly, the user can use the software to measure parameters such as lane widths and guardrail heights. Also the co-ordinates of roadside assets such as road signs can be logged. The data is usually exported in a 'comma separated value' (.csv) format which can easily be imported into most RAMS and GIS platforms.

BENEFITS FOR NETWORK LEVEL ASSESSMENTS

The TSD has a high measuring capacity, with production rates up to 635km/day (Baltzer et al. 2010), this compared with an output of

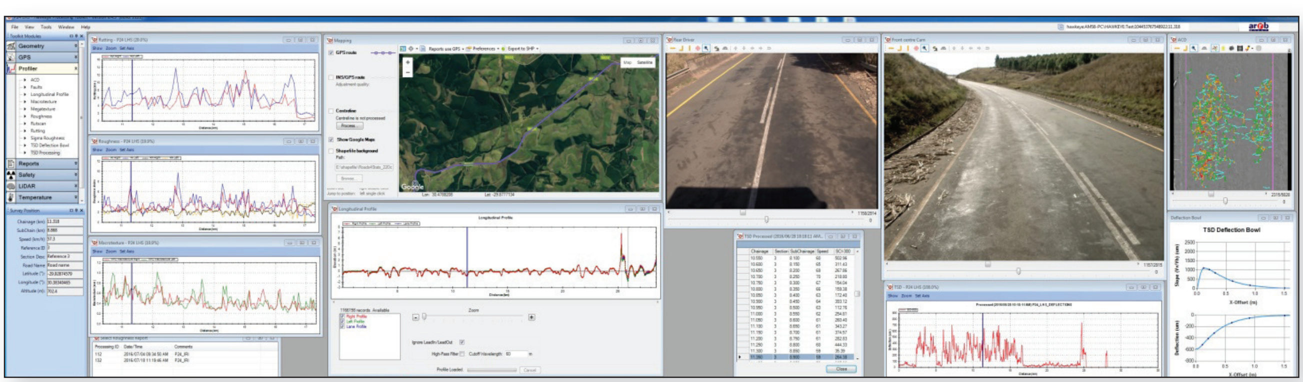


FIGURE 9 Screenshot of the Hawkeye processing toolkit with multiple windows displaying the integration of the several systems.

approximately 30-50 km a day using a conventional FWD. Data acquisition is carried out at traffic speed between 40km/h and 80km/h and therefore results in increased operator and road user safety as conventional traffic control, which often creates congestion and confusion, is rendered unnecessary.

The TSD:

- Measures bearing capacity in terms of structural stiffness,
- Automatically detects, identifies and classifies cracking.
- Automatically detects other defects such as potholes/failures and surface ravelling
- Measures roughness (IRI), texture (MPD) and rut depth,
- Creates a digital record of the road
- Measures grade, crossfall, horizontal and vertical curvature.

The collection of the above data is undertaken in a single pass which results in considerable costs savings on even a relatively small road network. Furthermore, there is added flexibility in survey planning as network assessments can be undertaken in shorter time frames due to the speed at which the data is collected.

Additional benefits are:

- All of the data is analysed in a single software application.
- There is a good comparison to the FWD when deflection velocities are analysed using the Muller-Roberts method. Furthermore, the results from various studies have shown the TSD to have a high degree of repeatability.
- The integration of all the collected data into a single user interface enables good data management practice as potential errors that could occur when working with various individual data sets are minimised or eliminated.
- The outputs can easily be exported directly into most RAMS software which significantly mitigates the loss of data integrity from manual data manipulation.
- The ACD is able to detect, categorise and quantify cracks, rutting and potholes. The automated approach removes the subjectivity associated with visually identifying and rating pavement distresses.

Images create a permanent record of the pavement condition at the time of measurement, which can be reviewed at any time. The geometry data can be used to identify potential dangerous sections of the road.

FIGURE 10 Screenshot of IRI measurements from trial sections measured in KZN 2016. Note correlation between IRI and deflection measurements illustrated in Figure 6

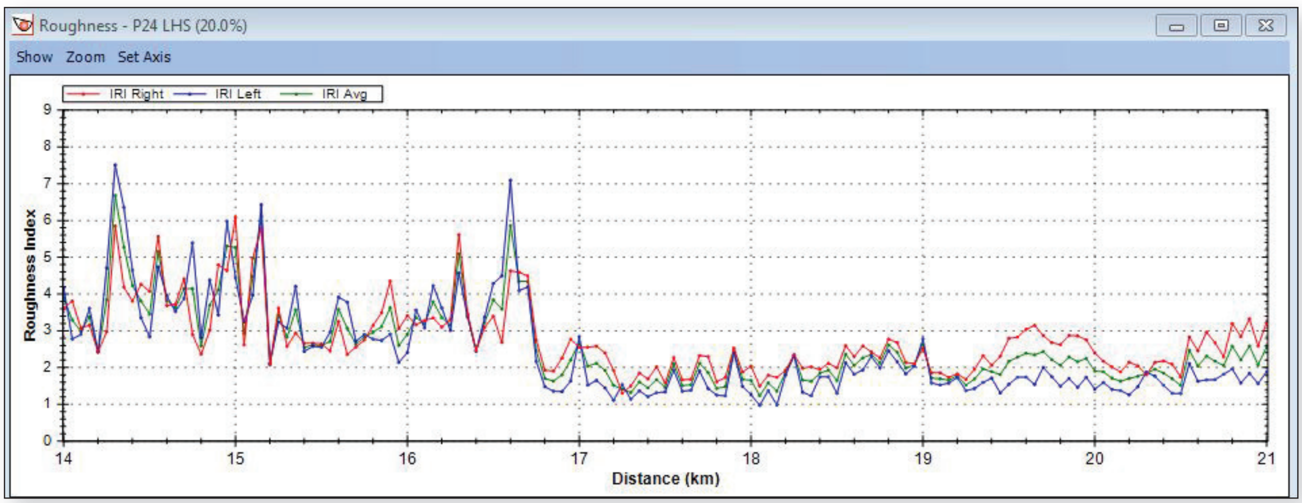


FIGURE 11 Screenshot of MPD texture measurements on P24 trial section.

FIGURE 12 Screenshot of Rut measurements at the trial section – good correlation between rut depth and IRI / deflection measurements

The above information is obviously extremely beneficial during individual project level rehabilitation investigation as well.

CHALLENGES AND LIMITATIONS

Due to the operational limits of some components, the TSD has a minimum operating speed of 40km/h. Additionally, the viscoelastic properties of flexible pavements were found to produce misrepresented deflection measurements at lower speeds. Gaps in reported data can be expected near traffic signals or traffic calming measures where the speeds are expected to be below 40km/h.

Another limiting factor is the size of the truck, which makes manoeuvrability on lower order roads difficult. The TSD is thus limited to operate predominantly on provincial and national routes in South Africa.

Very shiny new asphalt surfaces have been known to give problems, as the laser light is not reflected back but scattered from the surface. This notwithstanding, it is presumed that a new asphalt surface (and any underlying structure) will have been appropriately designed and, therefore, anomalies in the measurement of such surfaces will not be of consequence. It is worth mentioning that the TSD does not measure on unpaved roads (Baltzer et al. 2010). The Doppler sensors require substantial warm up time before measurement. However instead of waiting for the sensors to reach optimum temperature, the TSD is equipped with a timer which can be programmed to automatically start-up the system in advance of any planned measurements. A useful addition that is presently being investigated is the integration of ground penetrating radar (GPR) technology which non-destructively measures pavement layer thickness, thereby offering a more complete package.

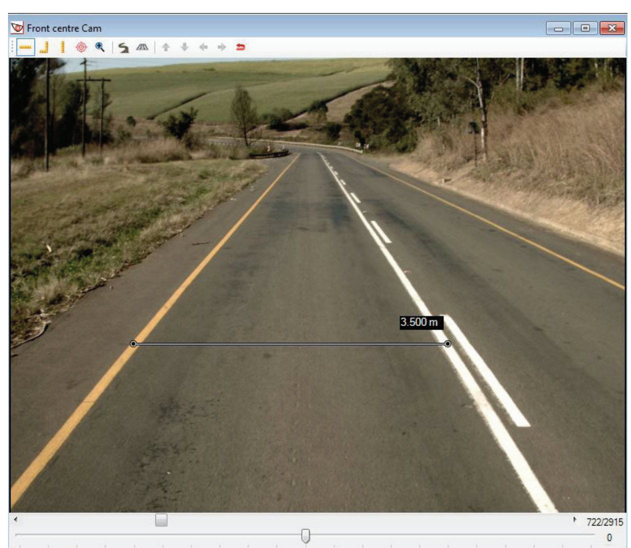
CONCLUSIONS

The TSD, whilst being a comparatively new methodology for the collection / analysis of road pavement data (since 2005), has been proven worldwide to be a reliable and accurate alternative to previously established methods of such data acquisition.

The system can improve the accuracy of data measurement and reduce subsequent misinterpretation errors, this whilst undertaking the data gathering at a significantly reduced risk to both road users and the operating team.

The TSD offers a "one stop shop" solution to network data collection

FIGURE 13 Example of forward-facing asset cameras depicting measurement capabilities



requirements. Apart from measuring pavement bearing capacity, the TSD also collects essential complimentary road condition data required for input into RAMS modelling - only ground penetrating radar is currently not included, though this will be a function going forward.

The data is collectively analysed in a single easy-to-use software application which not only reduces analysis time, but also mitigates the possibility of errors in the output information.

The information produced by the TSD is primarily aimed for input to automated Road Asset Management Systems and, hence, the optimisation of network level road maintenance planning. Notwithstanding, the data can, and is, utilised on a project level basis to assist in the refinement of rehabilitation designs.

Given size and speed constraints, the use of the TSD is limited to the open road (provincial, national and major urban arterials) However, given that the replacement value of these roads account for the vast majority of the entire South African paved road network, this is not considered to be a negative factor and, as the title of this Paper suggests, the TSD should be seen as a paradigm shift in the future management of South Africa's road network assets.

ACKNOWLEDGEMENTS

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TREATING UD FAECAL WASTE USING BLACK SOLDIER FLY (BSF): A MUNICIPAL, RESEARCHER AND CONTRACTOR PARTNERSHIP

N ALCOCK[1], D WILSON[2], D STILL[3], S MERCER[4], T GOUNDEN[2], C BUCKLEY[4]

1. Khanyisa Projects, 8 JB Mark Road, Glenwood, Durban, 4001. PO Box 30609, Mayville, 4058 Tel: 031 201 3005; email: nick@khanyisapr.co.za
2. eThekwini Municipality Water and Sanitation, Durban
3. Partners in Development, Pietermaritzburg
4. Pollution Research Group, University of KwaZulu-Natal, Durban

ABSTRACT

The Bill & Melinda Gates Foundation in conjunction with DFID requested proposals from Cities to test Business Partnerships such as service level contracts and incentivised contracts to deliver sustainable sanitation services. The eThekwini Water and Sanitation Unit identified the removal of faecal waste from over 85 000 Urine Diversion (UD) double vault toilets as a key sanitation service that could allow for the testing of various business partnership options. The key objective of these business partnerships would be to improve sanitation service for poor and marginalised communities, reduce service costs to the Municipality and create jobs and economic opportunities for small businesses.

The programme was divided into two elements which require some form of business partnership; (i) removal of faecal waste from the toilets and either burial on site with tree planting or transport to a processing site; and (ii) design and development of a processing plant for the production of marketable products from the faecal waste – the selected technology was Black Soldier Fly (BSF) larvae. During the planning phase the procurement options available to the Municipality were explored and the institutional requirements identified. Two business partnership options were selected for the project; (i) an incentivised contract using standard tender processes for the removal, disposal and transport aspect; and (ii) a service level agreement (SLA) for a 5-year period for the BSF plant operation.

A number of challenges arose during the business partnership establishment such as obtaining all the necessary approvals and the use of an innovative technology for the processing of UD waste. This paper aims to highlight the different procurement options available to a municipality wishing to create business partnerships, the reasons for the selection of the current model, the lessons learnt during this project, how the challenges were overcome and the key success factors.

INTRODUCTION

Commencing in 2002, eThekwini Metropolitan Municipality installed over 85 000 Urine Diversion (UD) double vault toilets at households (see Figure 1). This technology was selected to replace Ventilated Improved Pit Latrines (VIPs) as the municipality's basic onsite sanitation option for rural households at a density of more than 75m between household units (1). Waste is deposited in the chamber and dry absorbent organic material, such as wood ash, straw or vegetable matter is added after each use to deodorise decomposing faeces and/or control moisture and facilitate biological breakdown (composting). Urine is separated/diverted through use of specially adapted pedestals. This may be collected and used as a fertiliser. In desiccation systems, ventilation encourages the evaporation of moisture (2).

Traditional rural households in the Municipality consist of a cluster of multi-generational extended families of variable size. If the family consists of more than eight people, two UD toilets are generally supplied.