DIGITAL VIDEO ASSESSMENT (DVA) AS CATALYST FOR SKILL TRANSFER IN THE ROAD AND AIRPORT VISUAL CONDITION SURVEY ENVIRONMENT IN RSA

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ABSTRACT

Government clients require that 30% of work be done by Exempt Micro Enterprise (EME) and Qualifying Small Enterprise (QSE) sub-consultants and can be difficult to achieve in high technology environments such as specialist pavement condition assessment. Tender requirements for experience with a proven track record as pre-qualification qualification work against such capacity-building objectives. Multi-Functional-Vehicles (MFV's) used for instrument surveys typically already have accurate Geographic Positioning Systems (GPSs). The addition of high definition video cameras enables a technology coupling innovation approach to the normal manual visual survey methodology. The Digital Video Assessment (DVA) software system was developed with pre-calibrated camera settings to enable accurate measurements of grabbed photos at pre-set length intervals. The TMH 9 for Visual Condition Index (VCI) and also the American Society Test Method (ASTM) for Pavement Condition Index (PCI) survey templates are used to record the various forms of distress in terms of degree and extent. The survey data is analysed by the DVA software in the safety and comfort of an office environment. Surveys can thus be done with initially inexperienced EME and QSE sub-consultants. The DVA allows "on the job training" as their surveys can be checked by a qualified experienced visual surveyor numerous times with no additional travel and stay cost until they are trained and quality ensured. A recent comparative study using manual visual surveys versus this DVA survey methodology found that this DVA survey is not only more accurate and better quantifiable but can provide more detail with geo-referenced image records than what is required at project-level investigations. This DVA software and survey approach offer tremendous opportunity for capacity building of new entrants to this specialized field of visual survey with accuracy in a safe survey mode.

Keywords: Visual assessment, Digital Video Assessment (DVA), TMH 9, ASTM D5430-12.

1. INTRODUCTION

Tendered appointments by government or semi-government clients require that 30% of such work be done by Exempt Micro Enterprise (EME) and Qualifying Small Enterprise (QSE) sub-consultants. In a high-technology and specialist environment such as visual assessments of paved areas, this requirement becomes onerous. This capacity-building objective is contradicted by the tender requirements for experienced persons with the

correct qualifications. It makes it very difficult to meet such contractual requirements and also provide the training and technology transfer contractually specified. A classic case of innovation via technology coupling was used to meet such technical and capacity building objectives.

The Technical Method for Highways (TMH) 9 for manual visual assessments of paved areas is well calibrated for application on roads and airports paved areas. The requirement is normally for such manual surveys to be done by an experienced and qualified surveyor to ensure clients have consistent quality visual surveys. The trend overseas is to use high-technology instrument surveys such as laser-based equipment which can be attached to a Multi-Functional Vehicle (MFV) to do such surveys in a semi-automated mode. Proprietary software does various distress type image recognition and automatically converts cracks and other defects to digital format to calculate degree and extent which allows fast and reliable visual assessment. Such equipment is currently still seen as prohibitively expensive for routine or network level type surveys in South Africa. It is also worth noting that it actually still needs “hand-holding” making it in effect only semi-automatic. This contributes to the reasons why it has not yet been routinely implemented in SA.

High-quality imaging has become readily available due to the demand from the consumer market and the film industry in general. Cameras are increasingly sophisticated and become more affordable. The evolution of the cameras in cell phone technologies is an additional testimony of this advancement. Personal Computers have become more affordable and nowadays have previously-unimaginable computing capabilities. The modern engineer can now describe the process whereby computer programs, or analysis software, are “taught” to follow a set of rules to mimic the observational skills of a trained visual inspector. These concepts fall within the broader understanding of “Artificial Intelligence” and “Machine-Learning”. It begs the question of what this future will hold for low-skilled employees in the civil engineering field, specifically visual inspectors and subsequent condition assessments.

This paper explores and demonstrates the use of Digital Video Assessment (DVA) in the specialist field of visual condition survey of paved infrastructure in Pavement Engineering. The emphasis is not only to increase the accuracy and precision of observations noted during visual inspections but to ensure that this disruptor technology links to sustainable socio-economic factors pertaining to skill transfer and increased employment opportunities for entry-level or low-skilled South Africans.

The DVA is described here as a facilitator for skill-transfer in the road- and airport environment within South Africa, specifically regarding visual condition assessments. This exclusive set of skills was previously only accessible to individuals with the financial means to expensive equipment, mobility means and who could attend courses with the required tertiary education. Using DVA, there is an immediate bridge in the accessibility gap, which allows for high-quality training of currently low-skilled entrants.

2. IMAGE INSPECTION TECHNIQUES AND SKILL-TRANSFER

2.1 Position of DVA Versus Existing Automated Visual Detection Systems

The top of the range automated system for condition assessment of paved surfaces (roads and airports) is the Laser Crack Measuring System (LCMS). The LCMS, typically a mobile instrument attachment to the multi-function vehicle (MFV) can do the VCI determination inclusive of crack detection. Using laser technology and sophisticated software, the

images are used to produce the quantification of cracks and other forms of distress. Surface distresses, for instance, ravelling, potholes, etc. are also surveyed and can be enhanced with High Definition Video (HDV) images, enabling VCI determination in a semi-automated fashion. The LCMS survey is normally conducted in a series of 3.5m wide parallel traverse tracks overlapping by 250mm. Such sophisticated automated survey and analysis systems do not provide the opportunity for the capacity building requirements, mainly due to the entry barriers of price and high-level automation.

The DVA described in this paper is positioned as a technology set, operating below the cutting-edge technology of automated visual survey technology with automated image processing software. DVA is a deliberate technology coupling innovation specifically developed to enable and enhance the skillsets of entry-level persons in the field of visual condition assessment.

The focus in the DVA description is limited to “off-the-shelf” equipment which is coupled in an intelligent way. This necessitates the training of inspectors/surveyors in different skill sets, as the DVA produces a verifiable/auditable database on a Geographic Information System (GIS). The use of the highly accurate Global Positioning System (GPS) also makes this a very precise analysis and image recording tool, ideal for Pavement Management System (PMS) and obviously even more so at project level investigations. A detailed image record is also produced and can, over time, can be used in conjunction with condition assessment reporting of PMSs.

2.2 Socio-Economic Advantages and Awareness

There is currently no affordable commercially available software that can aid, or replace an experienced visual inspector’s judgment. The application of such analysis tools, should they become readily available, should not seek out to replace inspectors, but rather create more opportunities in a unique socio-economic climate in South Africa. It is a widely accepted fact that job creation is fundamental in providing economic independence for individuals, but has always been the luxury of people with disproportionately many opportunities at their disposal.

The proposal is therefore made to assist with job creation by providing specialist skills to South Africans with little to no tertiary education. The rationale behind this is that someone does not require a diploma to be able to see and discern defects consistently. Skill transfer in this respect would be to teach individuals the correct methods in noting their observations in the correct TMH 9 format.

2.3 Increased Attentiveness to Safety

The risk with the fast traveling public poses a very high risk to anyone working on or next to the road. Apart from that, visual inspectors are rarely allowed to stroll on an airfield and take photos. The risk to the individual is simply too high. Advanced camera technologies, smarter computers, and technology coupling are a blessing when vehicles can now easily do surveys at speeds of 60kph and are in considerably less conflict with the moving traffic. The use of the DVA enables inspectors to sit in the safety of an office to survey the condition of the pavement. Another advantage is that inspectors can “reverse” and look again, in contrast to the physical site visit. Areas with noted accessibility concerns, such as the runways or highways with high-speed traffic, drove the need to such an extent that mobility and associated safety concerns of the inspector are no longer a concern. This, in turn, creates an advantage when the physical human presence on site is no longer

required or necessary. The employment of older, even disabled persons like wheelchair-bound persons, or entry-level skilled people is now a realistic and feasible solution.

3. DESCRIPTION OF THE DIGITAL VIDEO ASSESSMENT (DVA) SOFTWARE

3.1 Capturing Visual Data

Apart from storing digital images on a server or mass storage unit, the sorting and correct referencing must be done. A long stretch of asphalt highway can appear to the untrained eye as a jumbled collection of varying degrees of blackish-grey rocks, sticky bitumen with painted stripes. The scenario to the contrary, where only defects are imaged, can create the misleading impression that the entire road is substandard when in actual fact, the inspector only took fifteen images of the same pothole.

The national road network is conveniently subdivided into descriptive route sections with unique numbering. The signs that show this information are scattered all along the road reserve on small, concise blue reference marker boards. Even if these signs should all go missing at the same time, geospatial data does not change. Therefore, a complete GIS containing a vast image collection is the most simplistic and elegant solution. This does, however, necessitate the use of an accurate global positioning system (GPS) installed on the MFV, with narrow margins of error.

3.2 Description of the Data Compiling Process

Some of the survey service providers in South Africa are capable of doing a number of high-quality instrument surveys with their MFVs. For a number of years, some of them already added high definition cameras and video equipment to their MFVs when doing other instrument surveys. Such instrument surveys include typically skid resistance, riding quality (IRI), rut depth and macrotexture (MPD) measurements. It is also possible to use the same visual survey technology in conjunction with the Falling Weight Deflectometer (FWD) as a structural analysis tool. In the past, this information was mostly used as additional background information.

3.3 Analysis of Collected Data

The MFV was fitted with additional back- and side HDV cameras to the vehicle rig. The data is captured and geo-referenced with front-facing and back-facing cameras. The “grabbed” high-quality images were taken at intervals of 5m in spacing, to ensure enough overlap, allowing the recording of valuable information and observations. Figure 1 illustrates the functions of the replay screen in DVA’s Logger Software which is displayed on the dual set up with Very High Definition type TV screens. An image with some arbitrary item, like a pen or car keys, has always been the site engineer’s best tool to provide a scale on a static image. Likewise, the technology coupling within the DVA was to calibrate a statically mounted array of cameras with a digitally super-imposed grid to enable more precise estimations of failure mechanisms in accordance with TMH 9. This significant increase in precision allows for quantity estimations that do not rely on the inspector’s memory or “guestimation” of what was just observed while slowly driving over the road surface. A GIS-linked photo record can be revisited and quantified with such a calibrated measurement tool. The left-hand top image in Figure 1 is superimposed with a perspective measuring grid. This measuring grid set-up is calibrated beforehand at the premises of the service provider for the specific front-mounted camera setting as described elsewhere. Apart from that an actual length and area calculator mouse action had been added to

accurately quantify length of crack or area of defect on the go and record it as illustrated in Figure 1.

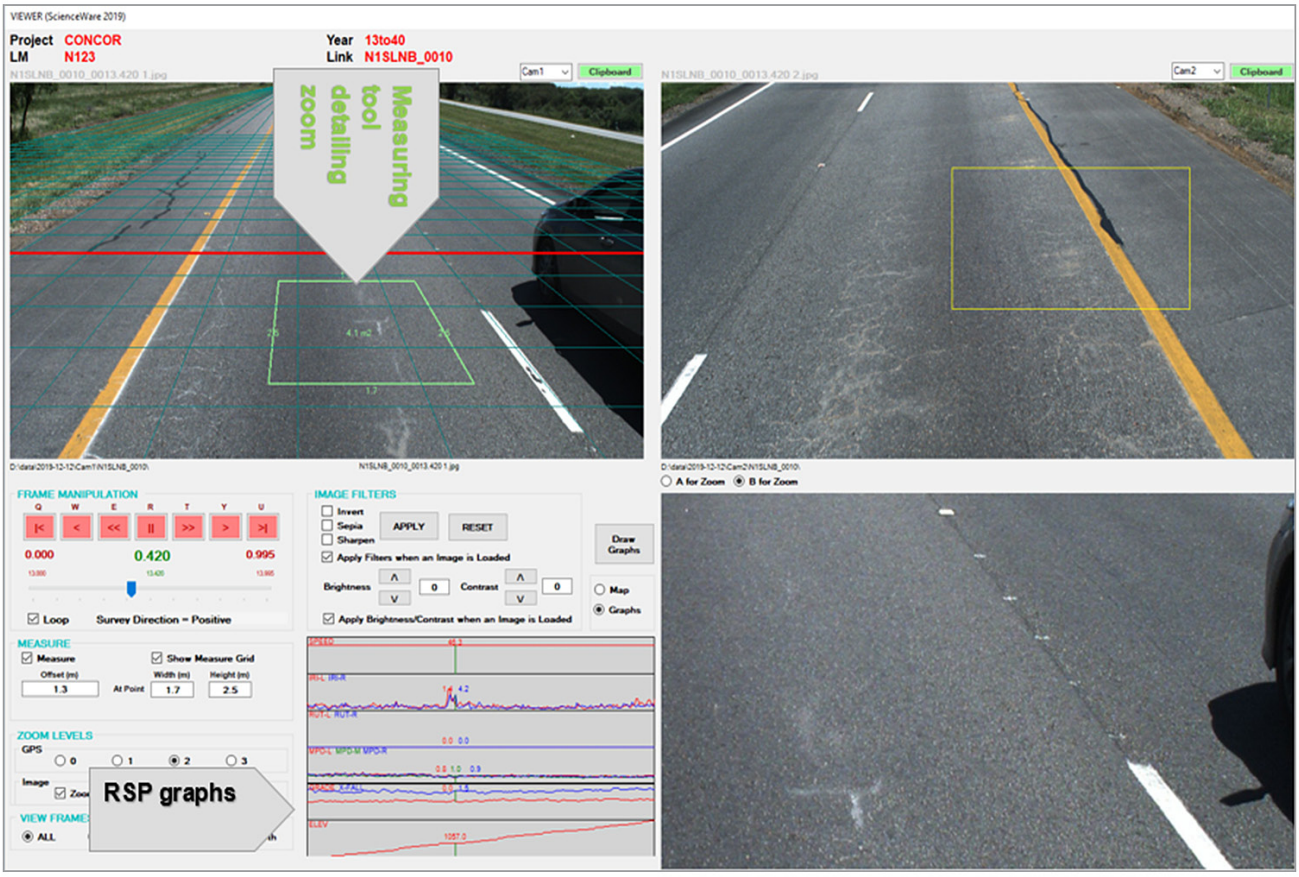

Figure 1: The video replay screen with the Road Surface Profilometer (RSP) graph and measuring tool with the 'Measure grid' switched on

The DVA software input screen for road and section detail is shown in the left-lower screen. The specifics of the route section etc. are registered. The top-left image (with the measure grid switched on) displays the front view of the MFV. The top-right image can be switched between the side- and back view camera angles. The yellow block in the top-right screen is a zoom facility, in this case, positioned as the bottom-right image. The buttons below the top-left image are used to play forward or rewind the images. Images can also be 'filtered' by enhancing visible elements, which may possibly be missed in some lighting conditions. Brightness, contrast, and even the sharpness can be adjusted if required so by the user. The 'Invert' of images can be used to identify smaller failures harder to identify with the eye, for instance, aggregate loss. Below, the button controls – "Frame Manipulation" – is the section's start and end kilometre.

The GPS geo-referenced instrument survey can be utilized with the instrument graph display facility to enhance visual survey recordings. This graph view can be superimposed on part of the HDV screen to enable manipulation and adds additional instrument measured information enhancing the accuracy and functionality of the DVA evaluation. This instrument survey data graph enables the viewing of the various instrument survey details while doing the visual assessment with the DVA software. By using the road roughness (IRI), rutting and macrotexture (MPD) graphs generated by the DVA software of the section, more attention could be given to road sections with a warning to severe measurements. The vertical green line on the graph displays the location of the image,

identifying the different instrument measurements. This vertical line will move automatically forward or back as the images are viewed.

The DVA makes use of the same visual evaluation criteria described in TMH 9 (2016) to determine the VCI of paved surfaces. In Figure 2 one of the screens used, as if it is a TMH 9 form, is illustrated as it appears on the laptop screen used during the evaluation process. In this case, merely toggling a degree or extent of the distress is needed and correctly recorded. These screens per photo image can be switched to evaluate the typical TMH 9 survey recording of general, engineering- surface, engineering, structural, functional, summary rating and logging of an image of the distress observed.

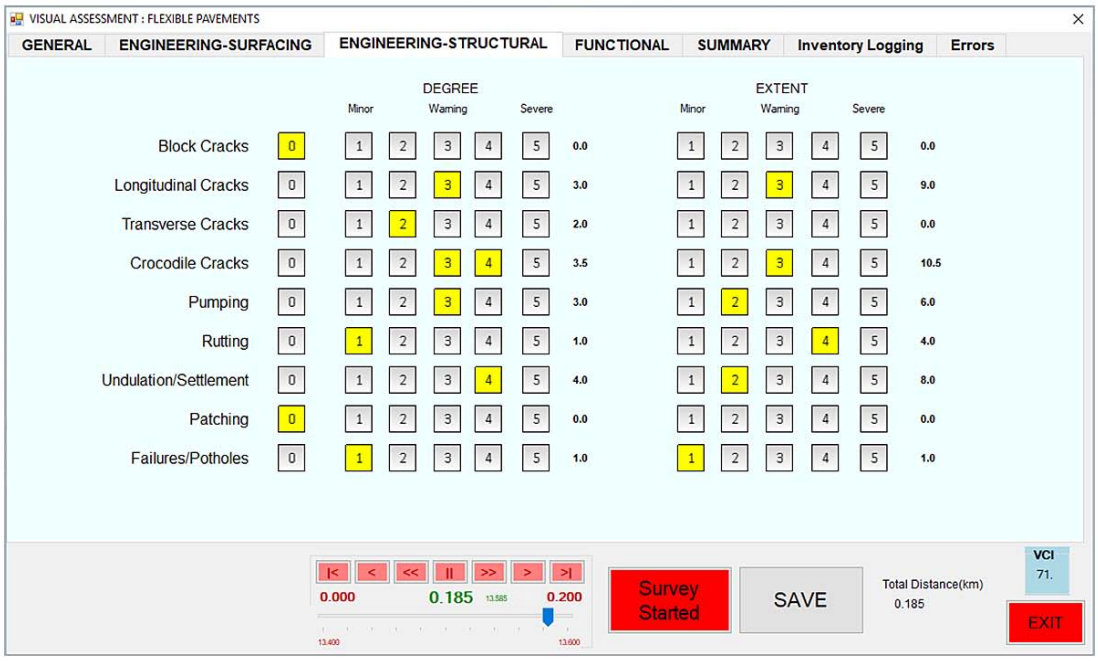

Figure 2: Typical TMH 9 recording screen

4. COMPARISON BETWEEN DVA AND MANUAL PROCESS

The question of accuracy of the DVA versus the trusted and calibrated use of an experienced condition surveyor arose for obvious reasons. An opportunity arose where a section of a dual highway could be surveyed with the DVA and make a direct comparison with the manual PMS type visual survey done on an annual basis. This section of the highway is part of the road network of the toll concessionaire, Bakwena. The road network is surveyed annually via visual survey methodology by an experienced and qualified surveyor as well as surveyed with the MFV with the full set of instrument surveys including the Falling Weight deflectometer (FWD) tests for the PMS update. DVA project-level visual assessments were done in both directions of a 30 km section of dual highway on the Bakwena road network.

It must be emphasized that the information received by using the DVA Software is at project-level compared to the manual visual survey, which is specified in TMH 9 at a network level. The DVA could be divided into 200 m length sections per linear lane compared to the manual survey. The manual survey was done assessing a 1 km section length over a full road width that included a two-lane per direction plus shoulder. The DVA's 200 m section lengths were converted (summarised) to 1 km lengths for a direct comparison to be made.

In Figure 3 the manual PMS type survey results expressed as calculated VCI is shown (orange line) for the southbound direction. It must be remembered that this is per km length and inclusive of the full pavement width, which includes the combination of the fast, slow and shoulder lanes. The blue line represents the DVA average for the three lanes averaged over the same 1 km lengths. The comparison between the manual and the DVA shows a remarkably good correlation with a few minor variations. The variations can be explained by the white line in Figure 3 which is the 200 m DVA detailed VCI calculation indicating variation per 1 km length in the slow lane. The implication of this is that the DVA provides much more detail per lane and overcome some of the subjective aspects related to the experienced surveyor having to “remember or visualize” what was observed over all three lanes and make “guestimates” of degree and extent post-viewing. The DVA allows us to measure and remeasure in 5 m lengths possible, therefore the accuracy is higher.

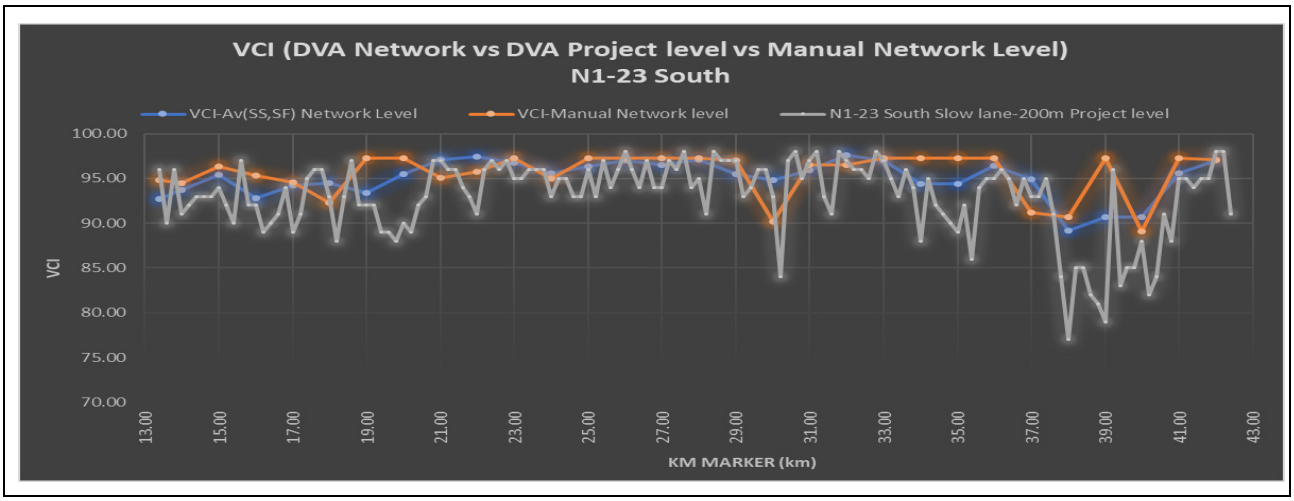

Figure 3: DVA’s VCI rating comparison between the network - and project level

The more detailed observation with the DVA program also showed up some interesting observations. In Figure 4 the northbound direction comparison is shown where it is known that the distress occurs mostly in the slow lane. For this reason, the VCI of the DVA average on the slow lane (blue line) was compared to the manual PMS 1 km survey (orange line) as a combination of all three lanes. It shows that in this case, the VCI of the slow lane as per DVA correlates very well with the manual three-lane combined survey result. To emphasis this apparent subjective assessment even for an experienced surveyor, the fast lane DVA average for the fast lane is also shown in Figure 5 versus the whole width as evaluated by the experienced surveyor. It clearly shows that the fast lane is virtually perfect, but the whole width normal manual survey overcompensates for the slow lane as previously discussed in an obviously distressed condition.

This serves to illustrate that the DVA survey provides the same results as the manual survey over the same width and length (1 km), but also shows that much more detailed results per lane or even shorter lengths of the road are possible. As mentioned, the DVA software allows the geo-referenced capturing of specific distress forms in an image. The DVA survey can at any time be reviewed and in fact, be audited by an experienced surveyor or the client expert representative in the office. Therefore, quality control can be improved significantly versus the laborious quality control of literally surveying a portion of a road network.

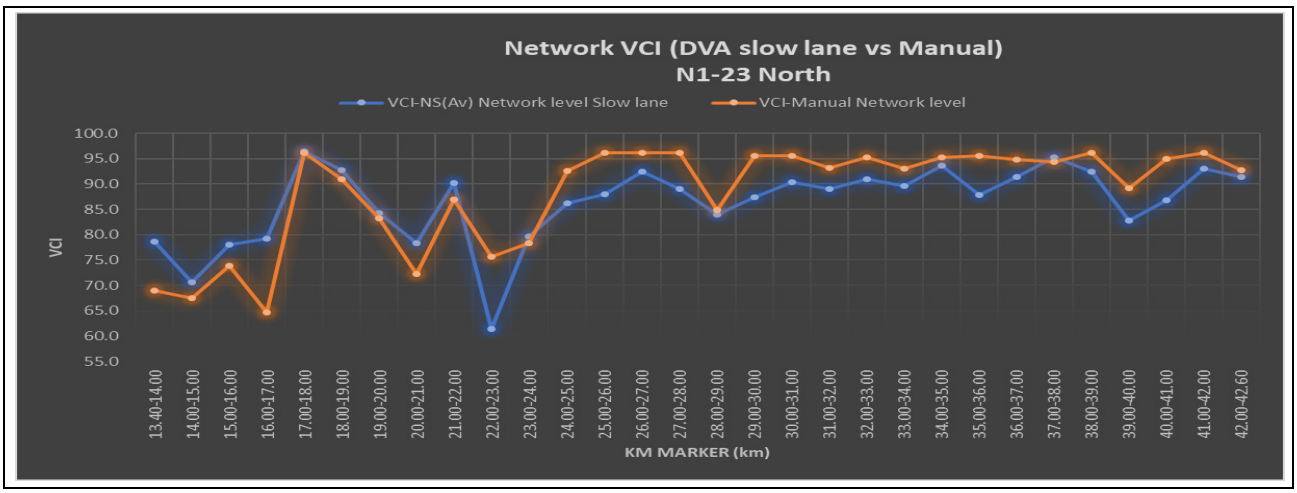

Figure 4: VCI data comparison between the Digital Video Assessments and the Manual Visual Survey on the northbound slow lane

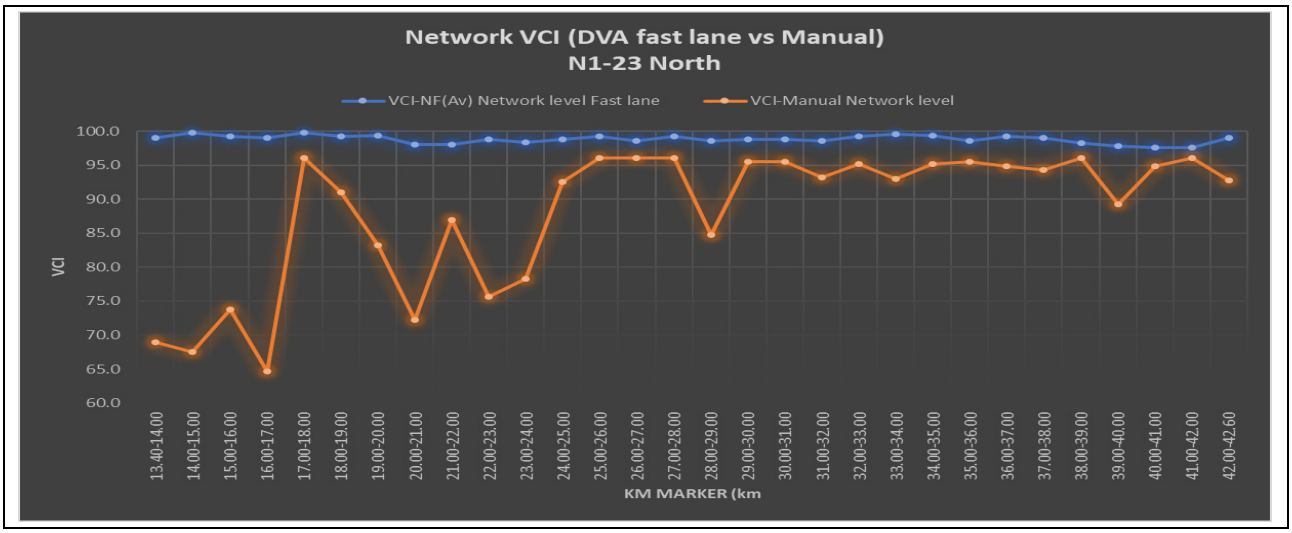

Figure 5: VCI data comparison between the Digital Video Assessments and the Manual Visual Survey on the northbound fast lane

4.1 Experience With the DVA Application

The DVA survey and analysis methodology was recently used in support of doing the required visual surveys on the nine airports of Airports Company South Africa (ACSA), as part of the contractual obligation to develop an Airport Pavement Management System (APMS). As indicated the contractually specified QSE involvement could be met by "tasking" them with the actual visual survey process. In the case of the nine airports, each airport's inventory was described in detail for each element or branch, sub-element or section with a specific identification. The surveys by the MFV could also be planned beforehand with specific traverses guided by the high accuracy GPS on-board the MFV. Runways with a width of up to 90m were typically done in approximately 5m width traverses in one direction, describing the runway in two shoulders and two keel sub-element. As surveys are done at speeds of up to 60 kph maximum over a typically 2 km or 3 km length runway, it can be completed within one hour as a single traverse took merely 2 to 3 minutes.

The persons volunteered by the QSE had virtually no experience in the road-surveillance environment and qualifications were often a matric certificate. It is obvious that these persons had to be trained first to ensure they understand the whole approach and method specified by TMH 9. The TMH 9 protocol and evaluation were done as well as the internationally accepted ASTM D5430-12 with its deduction system to calculate the Pavement Condition Index (PCI) for airports. The PCI compared to the VCI works similarly, except having different deduction values, but the PCI is the recognized term used by the International Civil Aviation Organisation (ICAO). A 2-day lecture and practical session on roads were done before they were exposed to the DVA methodology. An experienced visual surveyor was present to audit and help the learners gain confidence in the evaluation process.

It was found that the DVA training hereafter could be done very efficiently as the experienced surveyor could literally either “hover” over them while doing the survey or very quickly roll back the video after surveys and go over it with them to talk them through the evaluation. In spite of the original base of knowledge and experience of the aspirant QSE surveyors, they very quickly trained to a very proficient level. The safe situation in an office environment is illustrated in Figure 6 where the surveyor looks at a large VHDF TV screen and with the laptop to register the defects. An observer or experienced surveyor can sit and literally look over his shoulder to help correct and audit by merely rewind of the images.

The first airport was literally surveyed manually under the guidance of an experienced visual condition surveyor while also surveyed by the MFV with the required HDV cameras setup. It offered a direct comparison of the PCI manual survey results versus the DVA. In this case, the APMS requirements are closer to that of a project level investigation as elements of an airport are much shorter than a road survey. Typically, a runway is in the order of 2 km and can be subdivided into sections as short as 200 m.

Figure 6: Demonstration of big-screen viewing and laptop recording in a safe office environment

The actual DVA survey with the MFV could be done on average in two days on the regional airports. The larger international airports often required more survey sessions on a sunny day, merely due to slots made available by the Air Traffic Navigation Services (ATNS) tower. Such slots could often be as short as 30 minutes. Such short slots are known to be disastrous for the logistics and safety arrangements for normal manual surveys with obvious safety being the main concern. When only DVA surveys were done the access and safety protocol reduced dramatically in processing and administration effort. The frustration value, both for the surveyor and the client safety accompany equipment and persons alone is much lower. The busiest airport in Africa OR Tambo International Airport (ORTIA) could typically be surveyed over a two-week period of intermittent slots made available. The previous service provider could only finish the same survey on ORTIA over four months with four experienced surveyors on a full-time basis. This direct comparison in itself sums up lowered safety-concerns associated with the lower exposure times to a high traffic environment.

Throughout the DVA analysis by the now trained and calibrated QSE personnel, the experienced surveyor could check-in at any given time in the comfort of the office environment to do spot check audits on the surveys done. It often meant that sections could be re-run quickly with the surveyors and feedback given directly. The fact that the software also requires to regularly capture and store images of distress types at a GPS location, meant that indirect control was also imposed on the QSE surveyor to give proof of evaluation. This method aided to calibrate them on a continuous basis. The video facilities also enable a quick run by the experienced surveyor, as if in normal manual survey mode, to do a quick check on the evaluation as the length of airport sub-elements are short lengths.

5. CONCLUSION

In this paper, the comparisons between a new software-based approach of conducting visual surveys versus the standard TMH 9 manual method were discussed. The following is a summary of what content was discussed and the benefits the DVA visual analysis can add:

1. The video quality of the DVA was discussed, with image intervals at 5m lane lengths possible providing high detail recording possibility
2. By simultaneously using the instrument surveyed graphs in the DVA software, the degree and extent of visual observations of distress can be enhanced.
3. A good comparison of VCI values exists when comparing the manual visual survey and converting the 200 m intervals of the DVA into 1 km sections to a road network level. The current network level survey manually completed by an experienced and calibrated inspector is a good reflection of the average condition on the road section. However, the DVA average VCI value (Network level) is more accurate compared to the manual network-level survey, as the condition of both lanes is taken into consideration.
4. The DVA visual assessment is ideal for project-level visual assessment, and when done annually can provide historical data coupled with pavement deterioration graphs.
5. The DVA makes it possible to conduct visual surveys in a safe environment, compared to the manual survey method. This will even enable disabled persons (e.g. paraplegic) personnel to conduct visual assessments.

6. Improving the quality management system and training of personnel is also possible when the use of the DVA is implemented correctly. Typically, an experienced surveyor can audit a number of new surveyors by literally going back to a wrong evaluation and explain the change in rating required without travel and stay costs involved.
7. The DVA is a time- and cost-saving operation when comparing manual project level surveys to the DVA survey.
8. The DVA data processing can ideally be presented on a GIS-linked interface with a RAG colour coding evaluation for sections.
9. The Digital Video Assessment (DVA) is a classical technology-coupling innovative approach utilizing and advancing the manual visual survey expertise in a safer more accurate way and allows entry of new personnel to this specialized environment with good learning and auditing (QA/QC) opportunities.
10. The use of a QSE sub-contractor could be demonstrated from an untrained level to a proficient DVA surveyor for use on nine airports. The safety and empowerment aspects were very well demonstrated in meeting the onerous contractual obligation. Quality control was made easy by doing audits in various ways in a safe office environment.

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