Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 14 (2016) 3060 – 3069

Transportation Research Procedia

www.elsevier.com/locate/procedia

6th Transport Research Arena April 18-21, 2016

Experience gained investigating, acquiring and operating the first Traffic Speed Deflectometer in Australia

Richard Wix [a,]*, Chad Murnane [a], Michael Moffatt [a]

[a]*ARRB Group Ltd, 500 Burwood Highway, Vermont South, 3133, Australia*

Abstract

To manage a pavement one must know something about its condition. The more you know, the better informed your decisions are. In Australia, road agencies have been utilising automated data collection systems to assess the functional condition of their pavements for the best part of the last two decades. However, during this time, the assessment of structural condition has been limited to manual, slow moving or point-based testing. This has made collection of this data across entire networks unrealistic, even though this information is desirable. Therefore, it is no surprise that Australian road agencies have shown significant interest in the Traffic Speed Deflectometer (TSD), a device they hope can provide the network-level structural information they desire.

This paper provides the background leading to the initial Australian TSD trials and how ARRB Group was able to procure a TSD for Australia and New Zealand. It also details the integration of additional data collection modules and how they allow the functional and structural condition of the pavement to be measured at the same time. Finally, the paper documents some of the lessons learnt throughout the TSD's acceptance testing and first 18 months of use on the Australian and New Zealand road networks. During this time, over 60,000 km were surveyed with the TSD.

Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)

Keywords: TSD – Traffic Speed Deflectometer; data collection; deflection; functional condition; pavement; strength measurement; structural condition

---

* Corresponding author. Tel.: +613-9881-1636; fax: +613-9887-9820.
E-mail address: richard.wix@arrb.com.au

Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)
doi:10.1016/j.trpro.2016.05.450

1. Introduction

Australia has one of the lowest gross population densities in the developed world, and yet is one of the most urbanised. Approximately 85% of the population lives in urban areas, and almost 40% live in either of the two largest cities – Sydney and Melbourne. The Australian road network is over 800,000 km long, and approximately 40% of the network has a bituminous or concrete sealed surface. Road travel is the major mode of domestic transport and, significantly, over 65% of freight is carried by road (Austroads 2005).

As a result of its low population density, highly urbanised and widely spaced population centres, and an economy based largely on the export of primary agricultural and mineral resources, Australia is the heaviest user of road freight on a tonne-kilometre per capita basis in the world (Austroads 2005). It follows that the growth of Australia's economy is heavily linked to the movement of freight by road. It is, therefore, not a coincidence that road infrastructure expenditure is significant, and that decision makers and engineers are continually seeking improved ways of ensuring that the available resources are put to the best use.

There is a long history of collecting road condition data on Australian and New Zealand road networks, and using this data to measure organisational performance, guide investment decisions, and inform detailed analyses for new and rehabilitated pavement designs. At the network-level, functional road condition data (i.e. roughness, rutting, surface macro-texture) is routinely collected and used. With regard to structural road condition, pavement surface deflection data is collected and used to assess and quantify pavement strength, primarily at a project-level. Large networks and the relatively slow data collection technologies used to date have precluded comprehensive collection of deflection data at the network-level. Falling Weight Deflectometer (FWD) surveys have been conducted across large networks, but the intervals between measurements are typically in multiples of hundreds of metres.

2. Traffic Speed Deflectometer technology trials

The development of the Traffic Speed Deflectometer (TSD) by Greenwood Engineering in Denmark in the early to mid-2000s (Rasmussen & Hildebrand 2002), offered the tantalising promise of assessing the structural performance of a road network across its entire length and reporting the results at much smaller reporting intervals. In 2009/10, following initial investigations into the performance of the TSD in Denmark, the New South Wales and Queensland state road agencies contracted the Danish Road Directorate to undertake a trial survey of some 18,000 km of road length over a three-month period (Baltzer et al. 2010).

Some samples of these results were reviewed as part of an independent and national assessment of the applicability of the TSD to Australian and New Zealand conditions and practices (Kelley & Moffatt 2012). The trials assessed the repeatability of the TSD across numerous test sites and compared its outputs with those from other deflection measuring devices such as deflectographs and FWDs. Based on the analysis of the TSD data, it was concluded that the TSD could be used as a network-level screening tool to identify suspect pavements and to target follow-up testing. Additional work was recommended to fully operationalise the TSD for Australian and New Zealand conditions, and to undertake further work to determine Australian state and New Zealand road agencies' support for the value of acquiring network pavement strength data.

Recognising the importance of obtaining an estimate of maximum deflection – a measure which the TSD cannot directly physically obtain – Muller and Roberts (2013) began their development of an alternative analytical technique to derive a full deflection basin from the three Doppler sensors used by the TSD trialled in Australia.

3. Determining wants and needs

Using a questionnaire survey directed to eight Australasian road agencies regarding structural condition (deflection) data, Martin (2012) identified and clarified the then current perceptions and realities regarding the benefits and risks of network-level deflection data, including its then current uses, limitations and opportunities. Martin (2012) found that there was strong support among most agencies for network-level strength assessment if a device such as the TSD was available. Most agencies favoured the use of the TSD as a screening tool to identify the weak and vulnerable pavements in the road network. The next most favoured use of the TSD was for the estimation of major rehabilitation and reconstruction budgets.

Commercial concerns, for both road agency clients and potential TSD operators and data providers, were also identified by Martin (2012). If pavement strength testing annual budgets did not change significantly from their then current levels, the overall costs of using the TSD on a commercial basis were calculated to be approximately comparable to those arising from using the FWD but with the added benefit of gaining continuous network strength assessment and increased safety of data collection. Martin (2012) concluded that road agencies would have to commit to an agreed amount of annual network test length for several years to secure a reliable stream of revenue for the TSD operator to pay back the capital borrowings over a defined period. It was recognised that some agencies may not have been in a position to commit to this in view of the uncertainty associated with annual budgets.

4. Procurement of the TSD

The positive results of the trial and the perceived benefits of the technology ultimately led to a five-year agreement for data collection services between ARRB Group and three road agencies to operate a TSD in Australia and New Zealand – the Roads and Maritime Services, New South Wales; the Department of Transport and Main Roads, Queensland; and the New Zealand Transport Agency. The agreement included a commitment from the agencies to surveying a minimum length of road network each year at an agreed rate. In addition, ARRB committed to integrate a suite of additional automated data collection systems into the TSD to allow the simultaneous collection of functional pavement condition parameters, including automated cracking, which were offered to the agencies at less than commercial rates. Based on this commitment, ARRB Group was able to procure a TSD with seven Doppler laser sensors situated at 100, 200, 300, 450, 600, 900 and 3500 mm from the centre of the rear axle in the outer wheel path.

In the meantime, TSD systems had been purchased by other organisations around the world. To ensure that the future Australasian TSD equipment, survey technique, data reporting and date use would represent world’s best practice, the experience of others was monitored via published literature, committees, conferences and informal contact (Moffatt & Martin 2013). Revisiting data collected during the 2009/10 trials, augmented by data provided by other TSD owners, the Muller and Roberts (2013) analysis method was progressively refined (Moffatt et al. 2014).

5. Importation and registration

After satisfactorily passing Greenwood’s factory acceptance testing in Denmark, the TSD, along with the German-built prime mover tractor unit with an additional generator for powering the TSD, was transported by ship to Australia. The TSD arrived in Port Kembla on the New South Wales coast, four weeks later in January 2014. The shipping of the equipment was relatively straightforward but the process still required considerable planning and communication.

Obtaining a permit to drive the TSD from the docks in Port Kembla to Melbourne, a journey of approximately 1000 km, proved to be harder than expected as the 10-tonne load exceeded the allowable load capacity for a single axle trailer and the trailer was not yet Australian Design Rules compliant or registered.

Once again, due to the uniqueness of the TSD being a non-freight trailer with a high axle mass, the registration of the trailer took much longer than expected, approximately four weeks, during which time no on-road testing could be undertaken. Additionally, throughout the course of surveys in Queensland, New South Wales and New Zealand, the TSD needed excess weight and bridge permits which added to the survey preparation time and administration workload.

6. Acceptance testing and integration of additional systems

As mentioned previously, the TSD underwent factory acceptance testing in Denmark prior to it being shipped to Australia. The acceptance testing consisted of a series of calibrations, checks and data collection exercises to assess the performance of key individual components and of the system as a whole, including the following:

- servo system: a dynamic system which controls the vertical position of the frame housing the Doppler lasers to ensure they remain within their operational range during data collection. The position of the frame is determined by measurements from a laser height sensor which measures the distance to the road surface
- strain gauges: the TSD has four strain gauges fitted to the rear axles (one above and one below on each side) to provide an indication of dynamic loads. These were checked to ensure they were correctly calibrated and that the drift within the sensor was within allowable limits
- odometer wheel: a high resolution distance measurement device used to accurately measure speed and distance, which are critical to the slope velocity measurements. This was calibrated over a 1 km distance calibration site
- temperature sensors: numerous sensors are situated within the trailer to assess the temperature of the beam to which the Doppler lasers are mounted and the temperature distribution in the trailer, as well as external sensors for measuring the ambient air and pavement temperature. The performance and accuracy of the sensors was assessed.

Data measurements were also made on two test sections located in the vicinity of the Greenwood offices, one of which was a low deflection site and the other medium, to assess the repeatability of the deflection slope measurements. These results were also compared against another TSD. Based on the results of the testing, the TSD was assessed to have passed the factory acceptance tests and was deemed to be fully operational.

Upon its arrival in Melbourne, the TSD was essentially grounded for a period of four weeks until the trailer could be registered, during which time only static tests could be undertaken. However, this still allowed the performance of the servo system, temperature sensors and strain gauges to be assessed. It also provided additional time for integration of the additional data collection systems. Therefore, by the time the TSD was registered, the majority of the complementary data collection systems for measuring the functional condition of the pavement had been integrated into the TSD using ARRB’s proprietary data acquisition and processing platform known as Hawkeye, and were ready for testing. The systems included a five laser profiler system for measuring road roughness and macro--texture, a five camera digital imaging system with forward and backward views for road asset identification, and a 3D pavement imaging system for automated crack detection and transverse profile measurement. The size of the trailer and its already available power supply provided plenty of space for the integration of these systems.

During the Melbourne on-road acceptance trials, it was found that the cooling system needed improvement and that the data rate from one of the Doppler sensors was significantly lower than the other sensors. The results of the initial Australian TSD validation and repeatability trials, also undertaken in Melbourne, which included comparisons against structural condition measurements from a FWD and a deflectometer, and the validation of the other functional pavement data collection systems, is documented in the report by Muller and Wix (2014).

At the beginning of April 2014, some weeks later than originally planned, the TSD was deployed to undertake its first network survey in Queensland.

7. Doppler laser calibration

The most important TSD calibration is the Doppler laser calibration, which determines the differences in the relative mounting angles of the Doppler sensors. The Doppler lasers are mounted approximately 2° from the vertical plane so that the velocity measurement can be split into two velocity components; one in the vertical direction and the other in the horizontal direction. This is required to be able to calculate the deflection slope (Rasmussen et al. 2002). However, as it is impossible to mount the lasers at exactly 2°, there is a need to derive a correction factor for the differences in the angles of the lasers. This correction needs to be precise, as an error in angle as small as 0.005° could produce a large error in the final results of up to 25%. Errors are also dependent on other factors, including the speed of the survey vehicle (Ferne et al. 2009). To ensure that the angles have remained unchanged during transit or from extended use, this calibration process also needs to be undertaken at regular intervals.

Presently, there are two calibration methods recommended by the manufacturer. The first is referred to as the ballast method. This involves making several repeat runs with the TSD in its standard configuration over a section of road, followed by a second set of runs with the ballast loads removed (the ballast consists of numerous lead ingots located in two receptacles, one forward of the rear axle and the other behind, to provide a 10 tonne load over the rear axle). The average slope of the deflection for each sensor is then calculated for the entire road section, with and without the ballast. Based on the assumption that the change in pavement response is linear, the slope of deflection at zero load is estimated by plotting the slope values (y-axis) against load (x-axis) and drawing a straight line through the two points, extrapolating it and identifying the point at which the line intersects the y-axis. This value is assumed to be the contribution from the error in the angle.

This method was attempted several times during the commissioning of the TSD in Melbourne and at various sites in Queensland during the first month of the road network survey. However, large variations in the results were observed and, as such, the ballast method was not used to calibrate the TSD. One potential flaw in the methodology is that it relies heavily on the assumption that the pavement response is linear, which is often not the case.

The second method, which is the one that has been adopted in Australia, is known as the offset method. This requires sliding the measurement beam from its standard position to the central section of the trailer, where it is assumed that the pavement is un-deflected (i.e. there is no influence on the pavement from the trailer or the prime mover drive axles). As the Doppler sensors are spread over a 3500 mm length, the shifting of the measurement beam must be completed in two stages, which are commonly referred to as the A and B positions. In the A position, the 100 to 900 mm position sensors are shifted into the un-deflected area; and in the B position, the 900 and 3500 mm sensors are shifted into the un-deflected area. Three repeat runs over a section of road are measured in each of the A and B positions, with the road acting as the reference.

The Doppler laser results are then analysed using calibration software developed by Greenwood, and sets of calibration factors for each combination of run and position are calculated. A single set of calibration factors, deemed to give the most consistent results, is then subjectively selected from the nine combinations. Although the offset calibration method also has its limitations, it has been found to produce the more consistent results over longer periods of time, and appears to be much less site-dependent than the ballast method.

Because the TSD travels vast distances whilst undertaking road network surveys in Australia and New Zealand, ARRB has had to locate numerous offset calibration sites to enable regular calibrations to be undertaken. Ideally, each calibration site should be a flat, straight section of road at least 1 km in length, and have a smooth consistent surface condition and strong structure. However, homogeneous sites with these characteristics are often difficult to locate. Several potential sites were identified along the east coast of Australia, between Melbourne and Cairns, and on both the north and south islands of New Zealand; however, only four sites were found to be suitable. These were located at Nar Nar Goon (Victoria, Australia), Deception Bay (Queensland, Australia), Londonderry (New South Wales, Australia) and Christchurch (New Zealand). The process of identifying a Doppler laser calibration site was often fast-tracked by performing an offset calibration over a section of road containing several potential sites in quick succession. Sites that produced inconsistent results were then eliminated as potential calibration sites. Having multiple calibration sites, even in close proximity to each other, is advantageous as they can help to determine whether an observed change in calibration is due to a change in the TSD or the calibration site itself.

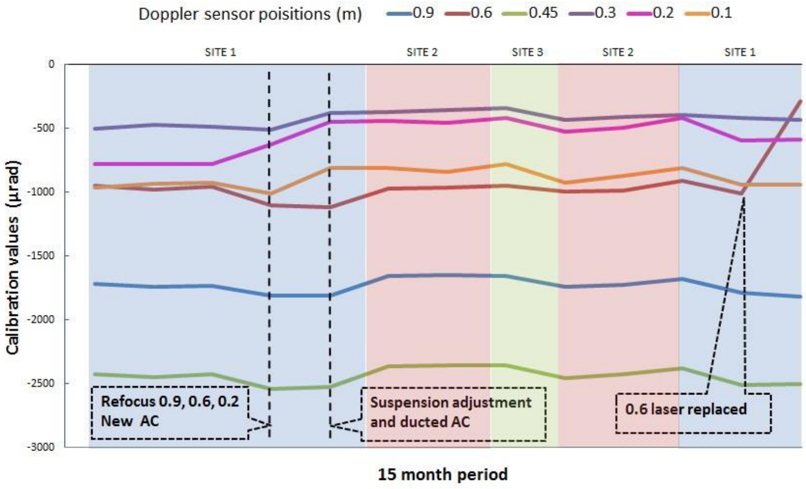

Fig. 1. Variation of calibration constants with time.

The accuracy of each calibration is critical as it not only ensures the accuracy of the measurements but it also gives the user confidence in the outputs, especially when components of the TSD are changed or modified. Fig. 1 is a plot of the calibration factors from three of the aforementioned calibration sites over a 15-month period.

It can be seen that, for the most part, the calibration constants have remained relatively stable except when there was a change to the system; e.g. trailer suspension adjustment, modification to the air conditioning system, or replacement or refocussing of a Doppler laser.

As mentioned previously, the main concern with the above calibration methods is that they rely heavily on the assumption that the pavement responds in a specific manner, rather than being a true calibration against a fixed or known reference. However, it is acknowledged that developing a viable method of calibrating the TSD to a known reference is not an easy task due to issues such as the physical size of the TSD, the manner in which the Doppler laser sensors operate, and the very high level of precision required to produce and determine an angular speed of a reference.

During the analysis of the data outputs, it was noticed that on strong roads where the deflection bowl was essentially flat, the deflection velocity of the Doppler laser sensor at the 900 mm position was consistently reading slightly higher than the 600 mm laser. This was also noticed by other TSD operators who use the offset calibration method. Research is still in progress to determine if this is a genuine pavement response, which is unlikely, or an error that is possibly introduced during the offset calibration which uses the output from the 900 mm laser as the common measurement point used to compare the readings from each of the lasers in the A and B positions.

8. Benchmarking sites

As part of its quality control procedures, ARRB has set up several benchmarking sites in Australia and New Zealand. The primary purpose of these sites is to provide confidence in the accuracy and consistency of the outputs produced by the TSD during each survey.

Locating suitable sites was not always easy and has often followed a process of trial and error. However, the selection process can be simplified by applying the following selection criteria:

- each site must be long enough to allow the collection of a sufficient amount of repeatable data and exhibit a range of different strengths. Sites are typically between 10 and 30 km long
- allow a minimum of three repeat runs pre- and post-laser calibration within the same day. Quicker testing will allow more time to perform tasks such as extra runs, additional trials, and research
- the time between each run should be kept to a minimum to reduce the possible effects of temperature changes in the pavement
- ideally of varying and moderate speed environment (up to 90 km/h), with suitable turn around locations and where the TSD can safely survey below 70 km/h if needed to minimise potential data loss
- be unaffected by traffic, i.e. peak hour traffic, parking restrictions, traffic lights, and urban areas
- within 15 minutes of existing distance/Doppler sensor calibration sites
- remain free from maintenance works for five years to build a history of the pavement performance over time.

The TSD typically makes three runs over each site pre- and post-Doppler laser calibration to monitor any changes in the measurements that may occur as a result of the calibration. Utilising the same sites throughout the duration of the five-year survey term will also allow ARRB to build-up a history that will hopefully enable researchers to assess the impact of the different seasons, climatic conditions, temperature changes, etc. on the measurements.

9. Validation sites

In many ways, the purpose and characteristics of the validation sites are similar to the benchmarking sites. However, they have a greater focus on comparing the structural measurements from the TSD with other pavement strength devices, particularly the FWD. The choice of a FWD for the comparison is understandable, as the FWD is the most common strength testing device used in Australia. However, some agencies seem intent on using the FWD as a validation tool and insisting that the derived deflection outputs from the TSD match that of the FWD. While similar results can be achieved, as is shown in Fig. 2, which shows D0 values generated by the TSD and FWD over a two-year period on the Bruxner Highway near Lismore, New South Wales, the TSD and the FWD are two fundamentally different devices and a direct agreement between the deflections derived by the two devices in all situations is unrealistic.

Apart from the initial validation work undertaken in Victoria during the commissioning of the TSD, which is documented in Muller and Wix (2014), large-scale validation exercises have been undertaken in Lismore, New South Wales in 2014 and 2015 and on the north island in New Zealand in 2015 (Wix & Whitehead 2015). Additionally, numerous comparisons between the TSD and FWD have been made on several shorter sites across the Queensland road network.

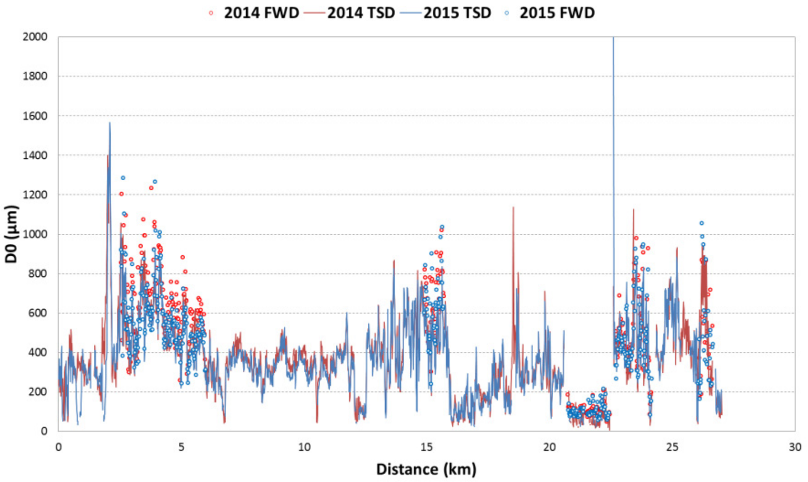

Fig. 2. Historical D0 comparisons from TSD and FWD on Bruxner Highway, Lismore, NSW.

10. Data collection issues

Several issues with the potential to affect the quality of the structural data collected by the TSD either became worse or only manifested themselves once the TSD commenced its survey work for the road agencies.

10.1. Cooling system

Since the TSD first arrived in Melbourne there has been an issue with the cooling system and the air circulation at the rear of the trailer. The lack of air circulation resulted in larger than acceptable temperature differences in the beam housing the Doppler sensors, which had the potential to cause errors in the measurements made by the TSD. In an attempt to improve the circulation, Greenwood installed a floor-mounted fan in the trailer along with some additional ducting. Whilst an improvement was noted, the system was still not able to stop the formation of warm air pockets inside the trailer when the TSD began surveying in the warmer Queensland climate. Therefore, an additional high capacity in-line ducted fan was installed in an effort to maintain a constant temperature throughout the trailer cabin.

In July 2014, the air conditioning system failed and was replaced with an entirely new air conditioning system that included metal ductwork with outlets positioned above the beam housing the Doppler lasers. The new system has two major advantages; firstly, it is a higher capacity and more efficient cooling unit, and secondly, the new ductwork distributed the cool air much more efficiently and in the right locations.

The new ducting was installed in October 2014 and it, along with the new air conditioning unit, has resulted in stable and consistent temperatures throughout the trailer, even when the outside temperature is above 40 °C.

10.2. Odometer wheel

The odometer is a critical component of the TSD as it provides the highly accurate distance and speed measurements needed to calculate the deflection velocity of the loaded pavement. However, the rougher Australian roads resulted in multiple failures of the mounting bracket and ultimately led to Greenwood redesigning the mounting bracket. The failures resulted in several days of downtime.

10.3. Differential GPS

To improve the accuracy of the GPS measurements collected by the TSD, ARRB subscribed to a real-time differential signal from a third party provider. However, the GPS receiver was not always able to access the differential signal. After much investigation, the problem was tracked to the electrical noise generated by the Doppler laser electronics. The problem was overcome by shielding the electronics rack housing the Doppler laser electronics.

10.4. Data rates

Each Doppler sensor has a nominal 1 kHz operating speed, which means it takes 1000 readings every second. The actual number of valid readings it records, known as the data rate, is usually less than this and is dependent on several factors, including:

- vehicle speed; the faster the speed, the lower the data rate
- pavement colour; the lighter the pavement surface, the higher the data rate
- height of the Doppler laser above the pavement; the main purpose of the servo system is to maintain the aperture of the laser at its optimum height so that the laser spot remains in focus.

The data rates from each of the lasers are monitored during data collection and typically vary somewhere between 800 and 900 Hz. However, after the system had been operating for some time, it was noted that the data rates from two of the Doppler lasers had decreased. This problem was rectified by refocussing the laser spot using a device developed by Greenwood which enables this task to be safely performed whilst the TSD is in operation. Additionally, another sensor eventually had to be replaced and returned to the manufacturer for internal realignment when its data rate consistently fell below 600 Hz even after refocussing.

11. Fine tuning outputs to improve data quality and alignment

From the experience gained in operating the TSD in Australia, ARRB has developed two methodologies, based on the area under the curve (AUTC) model proposed by Muller and Roberts (2013), which are aimed at increasing the amount of data reported by the TSD and improving its quality. Another methodology aligns the structural and functional data collected by the system.

11.1. Data validity

There are times when the pavement response, geometry, speed or other internal system factors (or a combination thereof) prevent the TSD from measuring a valid deflection velocity. An invalid result is defined as being a negative deflection or a null result. This usually occurs when surveying stiff pavements which do not deflect in the same way, or to the same degree, as a flexible pavement does. The stiffness of the pavement often results in negligible deflection velocities being recorded by several of the Doppler sensors. On occasion, these velocities have been observed to be negative and are probably the result of a lack of precision in the laser offset method used to calibrate the TSD.

Additionally, the pavement does not always respond as expected to the loading applied by the TSD and will report an invalid reading because of an irregularity in the pavement structure at a particular location; e.g. there may be a void, rocky infill, cut and fill, subgrade issues, a culvert, a rock outcrop, service pipe, etc. This is similar to what happens with other deflection measuring devices like the FWD when the bowl shape proves to be irregular, and non-decreasing deflections and other phenomena are observed at locations where these irregularities occur.

To reduce the amount of invalid data, the ARRB post-processing software uses a modified version of the AUTC model which will generate a deflection bowl as long as at least three of the six Doppler sensors in the 100 through to 900 mm positions measure a valid velocity reading. The use of this methodology increases the amount of data that can be reported on stiff pavements and when irregularities occur, as can be seen in Fig. 3.

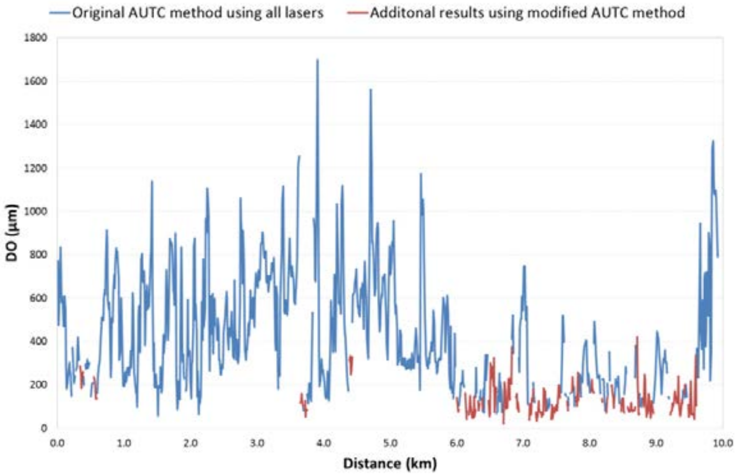

Fig. 3. Additional results reported using modified AUTC method.

11.2. Tail taming

Tail taming is a process aimed at improving the quality of the data reported by the TSD. The 'tail of the deflection bowl' is defined as being from the 900 mm laser out to where the pavement deflection velocity is assumed to be 0, which is at the 3500 mm position. There are no sensors within the tail, even though very small fluctuations in readings can naturally occur in this area for various reasons.

The AUTC algorithm fits a curve through all the deflection slope values, and if the 900 mm result is similar or close to the 600 mm value, it will result in a flatter, less tapered curve all the way out to the 3500 mm position. Due to the relatively large distance between the 900 mm and 3500 mm lasers, a small increase in the 900 mm result can cause a significant increase in the area under the graph, and a significant variance in the resultant deflection measurement.

Limiting the magnitude of the 900 mm deflection slope value to no more than two-thirds of the value at the 600 mm laser eliminates the possibility of a flat or bulged curve (from 900 to 3500 mm) and produces a more tapered typical deflection curve. If the difference is greater, the tail is cut off and excluded from the analysis. Applying this methodology has resulted in a more realistic value being reported at locations where the above occurs.

11.3. Data alignment

As described in Section 6, the Australian TSD was fitted out with a series of additional data collection systems for monitoring the functional condition of the pavement. These systems were already fully integrated into the Hawkeye acquisition platform. The challenge was to integrate the output from the TSD into the same platform. This was achieved by synchronising the GPS time and the distance measurements from the Hawkeye data sets with those from the TSD, which were collected using a common GPS receiver and odometer. This aligns the data sets and eliminates any differences in the distances reported by the TSD and the functional pavement condition data collection systems over long distances.

The process was automated using an ARRB developed utility program that takes the outputs from the Greenwood software and converts it into a format that can be processed using the Hawkeye data processing software.

12. Conclusion

The TSD is proving itself to be a system that is capable of providing Australian and New Zealand road agencies with an accurate indication of the structural condition of their road networks in a safe, economical and efficient manner. This is something the Australian road agencies had been keenly looking forward to since this technology was first identified, investigated and then trialled in 2009/10.

As an added benefit to the road agencies, the TSD has also shown that it can successfully collect synchronised structural and functional pavement condition data simultaneously via a suite of fully integrated functional pavement data collection systems which ARRB installed in the TSD.

Benchmarking and validation sites have been set up to monitor the TSD’s performance with time and against other pavement deflection measurement devices such as the FWD. The data from these sites has shown the TSD to produce repeatable results and identify the same trends as the FWD. However, some variation in the magnitude of the results has been seen over longer time periods. The method used to calculate the deflection can also affect the amount of data that is reported.

At this point in time, the Australian TSD has successfully collected over 60,000 km of survey data across road networks in New South Wales, Queensland and New Zealand. This has been done over an 18-month period, in which the TSD has travelled approximately 150,000 km.

Many lessons have also been learnt during this time. The procurement, shipping and registration of the TSD are not without their difficulties and can ultimately result in a delayed start to a survey program if sufficient time is not allowed to undertake these tasks. Additionally, the operating environment can affect the performance of the TSD which was evidenced when several components of the system had to be upgraded to meet both the rigors of the harsher Australian climate and the TSD’s high level of utilization.

References

Austroads, 2005. RoadFacts: An Overview of the Australian and New Zealand Road Systems, Austroads, Sydney, New South Wales, Australia.

Baltzer, S., Pratt, D., Weligamage, J., Adamsen, J., Hildebrand, G., 2010. Continuous bearing capacity profile of 18,000 km Australian road network in five months, 24th ARRB Conference. Melbourne, Victoria, 10 pp.

Ferne, BW., Langdale, P., Round, N., Fairclough, R., 2009. Development of a Calibration Procedure for the U.K. Highways Agency Traffic-Speed Deflectometer. Transportation Research Record 2093, 111-7.

Kelley, J., Moffatt, M., 2012. Review of the Traffic Speed Deflectometer: Final Project Report. Research Report AP-R395-12, Austroads, Sydney, New South Wales, Australia.

Martin, T., 2012. Benefits and Risks Of Investing In Network Level Deflection Data Collection. Technical Report, AP-T217-12, Austroads, Sydney, New South Wales, Australia.

Moffatt, M., Martin, T., 2013. State-of-the-art traffic speed deflectometer practice. Technical Report, APT-T246-13, Austroads, Sydney, New South Wales, Australia.

Moffatt, M., Martin, T., Muller, W., Ai, U., 2014. Traffic speed deflectometer data analysis approaches in Europe and USA compared with ARRB analysis approach. Technical Report, AP-T280-14, Austroads, Sydney, New South Wales, Australia.

Muller, WB., Roberts, J., 2013. Revised Approach To Assessing Traffic Speed Deflectometer Data And Field Validation Of Deflection Bowl Predictions. International Journal of Pavement Engineering 14, 388-402.

Muller, WB., Wix, R., 2014. Preliminary field validation of the updated traffic speed deflectometer (TSD) device, 26th ARRB Conference. Sydney, New South Wales, 12 pp.

Rasmussen, S., Hildebrand., G 2002. Development of a High Speed Deflectograph. Report 117, Road Directorate, Danish Road Institute, Roskilde, Denmark.

Rasmussen, S., Krarup, J., Hildebrand, G., 2002. Non-contact deflection measurement at high speed, In: Correria, A.G., Branco, F.E.F. (Eds.), 6th International Conference on the Bearing Capacity of Roads, Railways and Airfields. Lisbon, Portugal, pp. 53-60.

Wix, R., Whitehead, D., 2015. Innovations in pavement condition management in New Zealand using strength information from traffic speed deflectometer data, IFME World Congress & IPWEA International Public Works Conference. Rotorua, New Zealand, paper 813.