Motorcycle Route Audits Using an Instrumented Motorcycle

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Abstract

The Queensland Motorcycle Safety Strategy 2009 - 2012 outlines the government's direction to address motorcycle safety over the next four years. An important element of this strategy is a $20M funding commitment for targeted safety enhancements on routes on which motorcyclists are over-represented in crashes, particularly those involving single-vehicle, loss-of-control crashes and crashes where roadside objects have contributed to the severity of injuries sustained.

To assist with this work and to enable better understanding of the risks encountered by motorcycle riders, an instrumented motorcycle has been developed. The data collected from the bike will be used to improve knowledge of the dynamic behaviour of motorcycles, rider's behaviour, as well as to assist with the development of countermeasures. In the longer term, it may also have potential to assist with development of design standards that are more cognisant of motorcycle performance characteristics.

This paper outlines experience with the acquisition and development of the instrumented motorcycle, and experiences to date using the bike to undertake road safety audits. This paper does not report on any in-depth findings from the data collected by the instrumented motorcycle, although this will be documented as more routes are audited.

Keywords

Instrumented Motorcycle, Road Safety Audits

Introduction

The Queensland Department of Transport and Main Roads (TMR) is strongly committed to reducing road trauma. The Queensland Road Safety Strategy 2004 – 2011 and biennial Action Plans provide a coordinated approach to road safety that deliver new initiatives encompassing the three E's of road safety – Engineering , Education and Enforcement, underpinned by Safe System Principles.

TMR is responsible for the safe and efficient operation of the state controlled road network (approx 35,000 km). Motorcycles are a legitimate part of the traffic mix on this road network, providing riders with both mobility and a low cost transport option, however, motorcycles are also one of the most vulnerable modes of transport. Queensland has seen a year on year rise in motorcycle casualties and this project is aimed at reducing this road trauma and the social consequences that result.

In 2009, 331 people died on Queensland Roads and 60 of these were motorcyclists, representing 18% of the state's road toll.

Year	Fatalities (All)	Motorcycle riders and pillions fatalities	Motorcycle registrations
2009	331	60	155,220
2008	328	72	145,513
2007	360	73	130,786

Table 1: Motorcycle fatalities compared to all fatalities [1]

The safety of all Queenslanders is one of TMR's main priorities. The department is focussed on reducing fatalities and road traffic injuries for all road users (irrespective of modal choice), through a number of interrelated programs and initiatives. This particular 'Safer Roads Sooner' program is aimed specifically at reducing the risk of death or injury to motorcyclists using a motorcycle specific safety auditing and remedial treatment process.

[1] Department of Transport and Main Roads Crash Database

Background

The Motorcycle Mass Action Program (MMAP) aims to provide motorcyclists with an easy to read road environment with forgiving roadsides on those routes with a high number of motorcycle crashes. This is being achieved through motorcycle specific safety audits, of high risk routes, carried out by experienced road safety engineers and experienced motorcyclists. Whilst it has always been good practice for safety auditors to consider all modes of transport and road users during the audit process, and although not completely disregarded, motorcyclists have been difficult to cater for. Motorcyclists are vulnerable road users but are often treated as a light vehicle, with sometimes little understanding that the very different dynamics of a motorcycle require specific consideration in terms of the level of risks encountered. Most road safety auditors have at some stage been pedestrians, cyclists and drivers, providing the auditor with a greater understanding of the potential hazards experienced by those modes. It can often be the case that a low risk hazard for a four wheeled vehicle can be a high risk hazard to a motorcyclist It is for this reason that motorcycle specific audits are being carried out at locations with a motorcycle crash history.

The instrumented motorcycle forms an important part of the route auditing process, through the collection of motorcycle specific data that will help identify motorcycle risks on the network. This will improve our knowledge of the dynamic behaviour of the motorcycle on specific sections or routes of the road network and further identify parameters that could be used to improve riding conditions specifically for motorcyclists and provide a more in-depth and quantitative risk assessment of the routes audited. This project is aimed at developing an instrumented motorcycle to identify motorcycle specific safety risks and thus mitigating or eliminating potential road environment contributing circumstances. Use of an instrumented motorcycle on the major motorcycle routes will enable a better understanding of the road problems encountered by this road user group and might even promote greater empathy with the motorcycle community.

Motorcycle Acquisition and Development

The initial feasibility stage of this project has involved a research, review and in-depth discussion with those in the motorcycle industry to gain more of an understanding of what was currently available in terms of instrumentation for collecting motorcycle specific data. This was successful in proving initial guidance into what technology already existed in the market place. These initial discussions focussed on the feasibility of purchasing a motorcycle equipped with cameras, recording devices and GPS for the purpose of a motorcycle auditing tool. The resulting data from such a bike would be beneficial in terms of viewing parts of the road network from a motorcyclist's perspective and also driver/rider behaviour studies. It is essential that we develop a more in-depth understanding of the possible causes of motorcycle crashes at specific sites. Whilst the cause is often blatantly obvious, in many cases, it is not. This led to the concept idea of an instrument motorcycle, capable of collecting information on the interaction of the road and two wheeled vehicles. A variety of different collection sensors were fitted in a 'plug and play' format which provided flexibility for future development.

Whilst this project is still in its infancy, we are confident that we will be able to collect useful data, that when analysed will provide a more detailed understanding of the dynamics of a motorcycle and the potential risks in terms of road surface condition, geometric layout and other attributes that will help determine additional specific motorcycle safety treatments on the road network.

Whilst the primary focus was to obtain a specialised audit tool, other uses for the instrumented motorbike have been identified as feasible options, for example; motorcycle crash investigation, motorcycle behavioural studies and to raise the profile of motorcycle safety in general.

Motorcycle Selection

As the project involved the procurement of a motorcycle that was to be fitted with suitable instrumentation to provide useful road safety data specific to a motorcycle, selecting the right motorcycle for the task was extremely important. With such a wide range of potential motorcycles, the selection was based on the perceived features required and feedback from both the instrumentation suppliers and

Queensland Police Service (QPS). QPS use motorcycles suitably fitted with appropriate wiring, harnesses, lights and panniers as part of their established motorcycle fleet and utilise a vigorous procurement process.

The following features were identified as being necessary for the motorcycle during evaluation:

- Ability to cater for rapid start/stop situations (for instance, sufficient engine capacity to rapidly accelerate to highway speeds while carrying rider and equipment),
- Fairing protection for the rider at high speeds,
- Suitable road biased tyres capable of limited off-road use (such as gravel shoulders),
- Front or rear luggage rack(s) with enough carrying capacity for inspection equipment and safety equipment,
- Centre and side stand,
- Capability to be ridden over stormwater gutters, low embankments and similar obstacles,
- Low maintenance requirements,
- Capacity to mount additional equipment such as GPS or other devices. Many sports bikes have very little space.
- Shaft driven (reducing requirement for rider maintenance checks)
- ABS braking (providing rider with a higher level of safe braking)

In summary, the type of vehicle required had to be capable of carrying the weight of both rider and additional equipment on a variety of surfaces as well as providing safety benefits and a good level of comfort for the rider.

The motorcycle chosen for this project is the Yamaha FJR1300 touring motorcycle (Figure 1), following considerations of a number of safety and usability criteria.

Figure 1: Yamaha FJR 1300

Personal Protective Equipment

As a standard safety precaution, individuals authorised to use the instrumented motorcycle are required to have high level training and experience, possess the appropriate licences and be provided with the necessary personal protective equipment. Australian Standard (AS/NZS1698) helmet, full length vertebrae boot, full gauntlet gloves, and full body suit with spinal protection are worn by the rider.

Instrumentation

Each of the sensors and the associated instrumentation fitted to the Yamaha FJR1300 have been individually selected from a range of products currently available, with the aim to improve our knowledge of the dynamic behaviour of the motorcycle on specific sections of the road network and furthermore to identify some parameters that could be used to improve the riding conditions specifically for motorcyclists.

Data Acquisition System and Software

The data acquisition system measures and records important vehicle parameters via sensors. This data can be analysed to gain an insight into the audited route from a rider's perspective, behaviour of the rider and/or motorcycle dynamics, which can ultimately result in increased motorcycle safety, through amplified understanding of motorcycling behaviour. The basic hardware requirements include a logging device, sensors and wiring, plus a PC/laptop for data download and analysis.

The data logging system comprises an ADL3 Advanced Dash Logger with

- 250MB of internal flash memory
- Up to 1khz sample rate (per channel)
- Up to 300 channels of data
- CAN, RS-232 and Ethernet communications to external devices (laptop, GPS module, external sensors, Audio/Visual system, etc.)
- 52 Input/Output connections
- LCD display screen

Video Capture System (VCS)

The VCS is an integrated on-vehicle system designed and built for the motor racing environment and other harsh environments. The VCS records video and audio using the MPEG-2 video compression format at a broadcast quality (Figure 2). It includes a built in real-time graphics processor that allows sensor data to be overlaid onto the video without the need for additional hardware. Multiple video streams, from on-bike cameras for example, can be linked with logged data for synchronised playback of footage alongside other analysis components. Multiple camera angles can be viewed concurrently and, when overlay data is selected, these views update to show a side by side comparison with a forward and reverse capability, variable play speeds, and video linked to graph and map cursor positions to location of motorcycle on route.

Figure 2: Video Display

The video capture and recording system has the capability of using two cameras (currently fitted front and rear) with data recorded to an SD Card that has been proven suitable for motorsport applications. The video camera units are configured using a laptop. There is no display for the rider to view and therefore no distraction for the rider. The inter-linked micro phone for overlaying rider comments on video is proving beneficial for later assessment.

Global Positioning System (GPS)

The GPS unit (Figure 3) is a self contained antenna and receiver unit, fitted to the rear top box of the motorcycle. It is fitted with a universal connector and is preconfigured to be compatible with the other data acquisition devices. The installed unit is suitable for the high dynamics of motorcycle applications and provides a 5Hz update rate.

Figure 3: GPS Unit

The (GPS) unit provides speed and position information, as well as altitude, heading, date, time and GPS statistics. The GPS position information is being used in the data analysis software to show and compare the riding lines and to create maps. The ridden lines can also be plotted over aerial photographs, providing the path travelled in a real life context.

The GPS provides the spatial ability of the motorcycle data, allowing for overlays of any other spatial data to be included in later analysis, such as crash data and posted speed limits etc.

Motorcycle Dynamic Sensors – Force and Motion Sensors
A number of other sensors have been installed to measure vital parameters of the motorcycle and road relationship, for example:

- Wheel speed – Hall effect sensor reading the tone wheel mounted on the front and rear wheel hub,
- Suspension position - linear potentiometer measuring damper deflection, front and rear,
- Engine RPM – engine pulse count,
- Throttle position – rotary potentiometer to measure throttle butterfly percentage,
- Gyroscope – 3 axis and a 1 axis microelectronics gyroscope,
- Magnetometer – 3 axis digital compass,
- GPS - providing position, speed and heading updates five times per second,
- Steering angle – linear potentiometer, steering head angle,
- Accelerometers – 2 and 3 axis accelerometers

The sensor data is manipulated via a number of mathematical functions to provide additional data for analysis.

Individual Math Functions:
- Inverse Corner Radius = allows the curve radius to be displayed graphically (rendering this as the inverse of corner radius permits easier graphing).
- Gradient = longitudinal gradient.
- Lean Angle = the lean angle of the motorcycle relative to horizontal.
- Pitch Angle = the angle of the motorcycle due to the effects of acceleration and braking
- Road Surface = a dimensionless value that indicates the variation of the local road surface from flat and level. This provides an overview of the entire audit route allowing for areas of potential concern to be quickly identified. Amplitude and frequency of road surface imperfections.

Data Analysis

The real strength of data acquisition lies in the analysis of the logged information. Specialised software is used to perform calculations and chart the data in order to identify trends, problems and potential improvements. Due to the distance and time involved in the audits it is desirable to provide tools to assist in the analysis of such a large amount of data. Individual maths functions have been and are still being developed to assist in identifying specific attributes and road/rider relationships. Specialised software tools have been developed to configure the logging device for analysis of logged data. The suite of sensors installed have been wired up to transmit measurements to the data acquisition device, which logs this information for further analysis.

As an articulated two-wheeled vehicle, motorcycles have dynamic stability characteristics that are unique when compared to other types of vehicles. Motorcycle stability is more sensitive to changes in shape, texture and skid resistance of the road surface, and the camber of the road. The ability to correctly target specific motorcycle safety treatments will enable scarce funding to be maximised and it could reasonably be expected to contribute to a reduction in motorcycle fatalities and serious injury crashes. In some cases there is a clear distinction between actual location of motorcycle and other vehicles crashes.

The dynamics of each are very different, as are the factors that contribute to a crash occurring. As an example (Figure 4), the data plotted onto the audit route shows that motorcycle crashes (green) and other vehicle crashes (yellow) are occurring along very different parts of the audit route. This data assists the audit team in ensuring it considers motorcycle safety treatments at the locations where motorcycle crashes occur and the potential contribution of these treatments to other vehicle crashes.

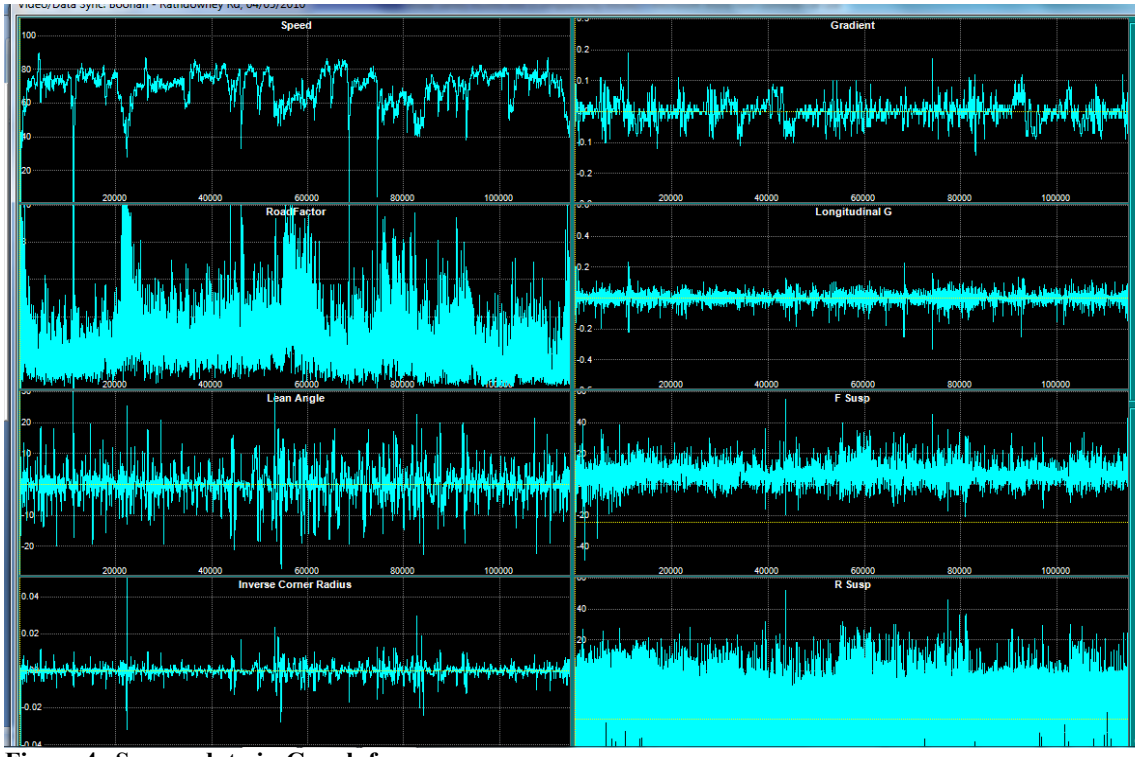

Figure 4: Sensor data in Graph form

A number of data combinations can also be utilised for analysis, such as crash data and rider comments. When overlaid on the audited route (Figure 5) they are proving very beneficial to the audit team in identifying potential crash contributing factors.

Figure 5: Display of crash data along audit route

A number of other datasets are being utilised to assist the audit team in assessing risks along the route, such as a visual of signed speed limits (Figure 6).

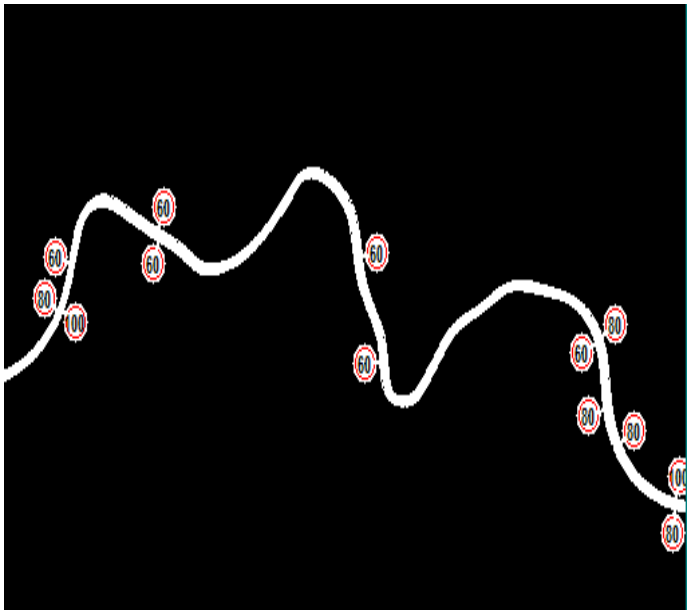

Figure 6: Overlay of signed speed limits

The motorcycle specific audit involves an experienced (and appropriately trained) rider reporting on the road conditions and identifying hazards and environmental factors (Figure 7) that could contribute to an increased risk of a rider losing control.

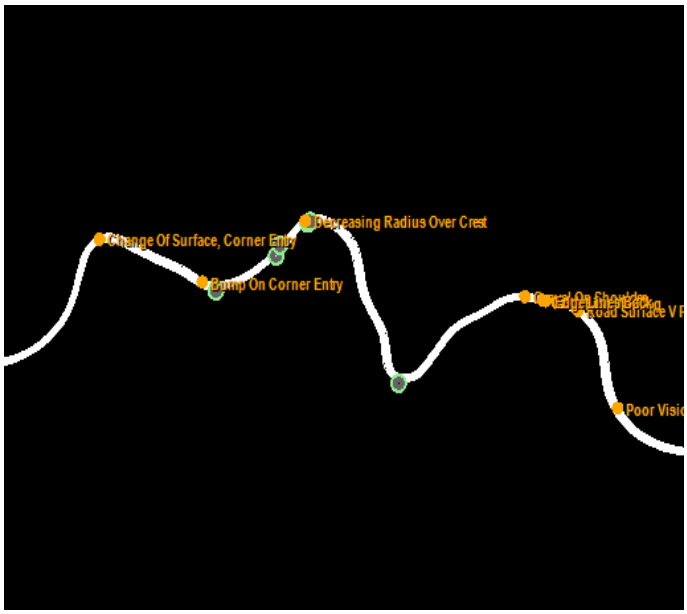

Figure 7: Combination plot of rider comments and crash locations

Investigation into the relationship between 'loss-of-control' type crashes, curve radius and road gradient, is being assisted by the ability to colour theme any or all of the above parameters to identify where they occur along the audited route. Theme mapping of the collected data allows for a visual identification of any dataset (Figure 8). This combined with crash data also provides a useful tool for the audit team.

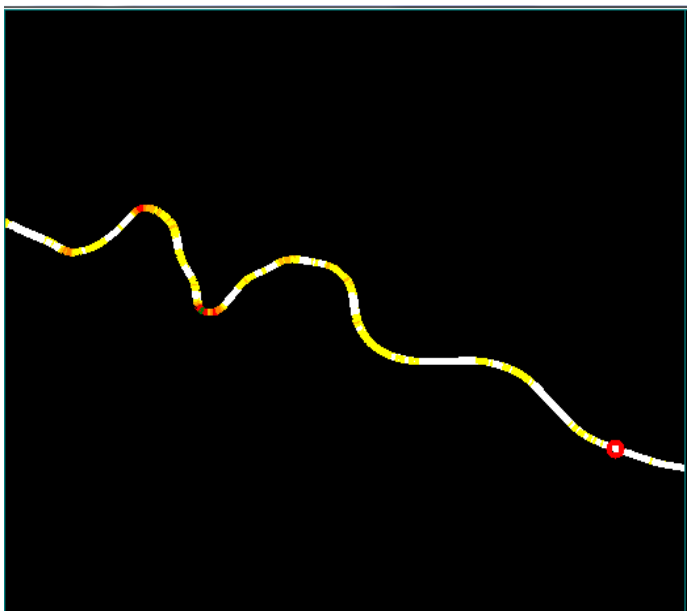

Figure 8: Theme map of corner radius

An aerial photography overlay provides a bird's eye view of the audit route, and the software tools currently allow us to display speed, posted speed signs, geographical coordinates, points of interest (user defined), historical crash data with detailed pop-up screens, road surface, altitude, gradient and the inverse corner radius (Figure 9).

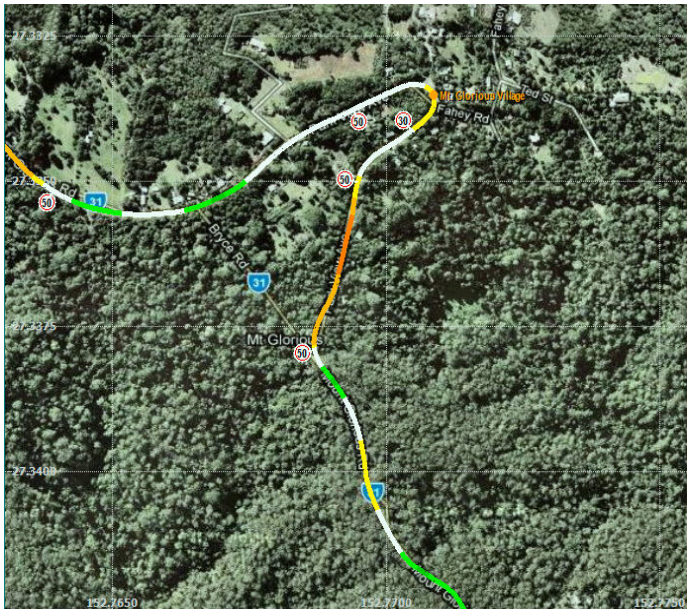

Figure 9: Aerial photograph with data overlay

The instrumented motorcycle has, to date, only been used on three of the MMAP audit routes, with much of the instrumentation still being assessed. The audit team comprises, as a minimum:

- A senior road safety auditor (TMR)
- A senior road safety auditor (Contracted)
- A road safety auditor (TMR)
- Experienced motorcyclist

The motorcyclist is required to ride through each site and identify possible environmental factors (including, but not limited to: wet/dry, day/night road conditions, sight distance, rutting, resurfacing or road repair and the condition of line markings) that could contribute to motorcyclists losing control. Where appropriate, the rider can provide comments and suggest treatments/measures to improve safety.

The remainder of the audit team follow in a support vehicle, taking note of all motorcycle safety issues identified on route. Where safe to do so, regular stops are made for members of the audit team to discuss each section of the route being audited. In addition to the data being collected by the motorcycle from the on board instrumentation the audit team are also collating their own visual observations of the route.

On completion of each audit, data is downloaded from the motorcycle for analysis. Rider commentary and video play back provide an instant tool for the team to review and make additional comments once back in the office.

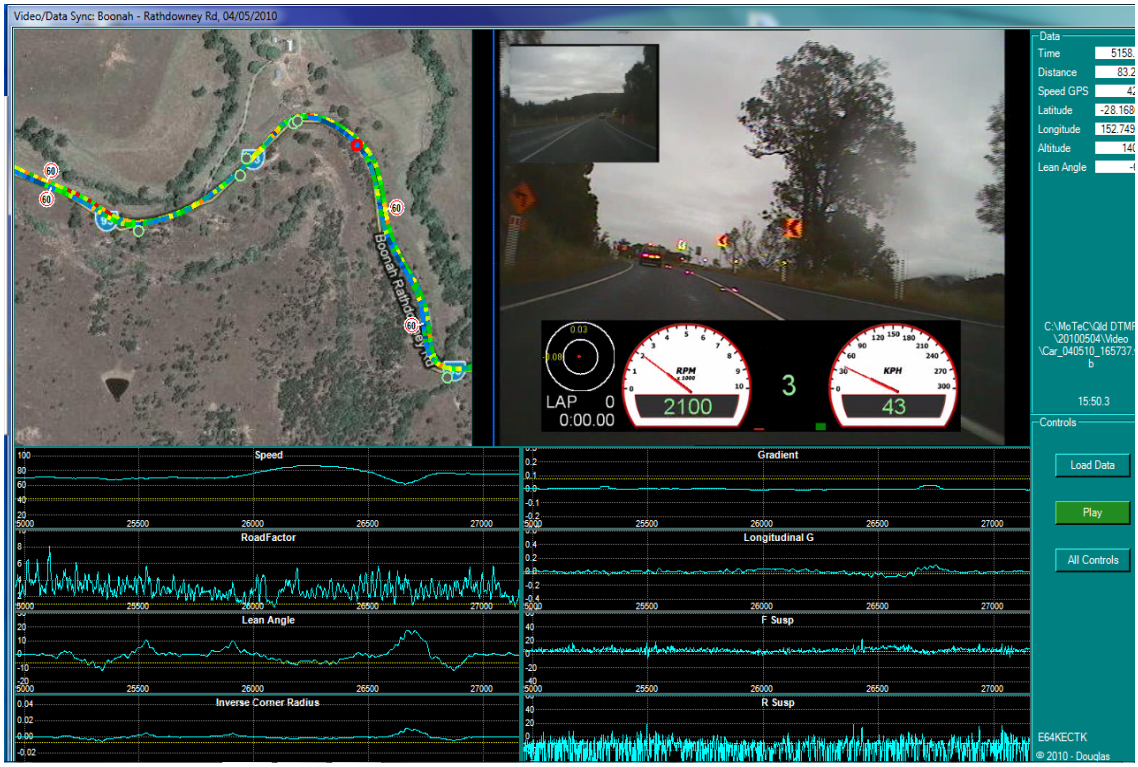

Figure 10: Combined functional display

Combining a number of the display functions (Figure 10) allows for specific sections of the audit route to be replayed (in slow motion if required) as many times as required, allowing the audit team more time and information to assess any of the risks identified.

Continuing Development

The instrumented motorcycle is still under development, with continuous improvements and expansion of its functionality being an ongoing process.

Work is currently underway on the following:

- Corner radius less than 100m, using this as basic criteria for recommending motorcycle under-run rail on all existing barrier, allows for an instant plot of locations and lengths of rail required.
- Damper deflection, front and rear, combined with longitudinal force data provides a good indicator of locations with an inconsistent road surface within the braking and acceleration zones of the motorcycle (potential correlation with loss of control crashes).

The project team is also in the early stages of developing a risk model for curves, using parameters such as:

- Crash type
- Corner radius
- Gradient
- Lateral acceleration
- Load transfer rate

Specific hazards for motorcyclists may not be as hazardous for other road users; e.g. potholes, loose gravel, slippery or sunken pits and a number of roadside hazards. The profile of the road surface and environment can influence both the possibility of avoiding a crash and the severity of injury to a motorcyclist in the event of a crash. As a two-wheeled vehicle, motorcycles have dynamic stability characteristics that are unique when compared with other types of vehicle. Motorcycle stability is more sensitive to changes in shape and texture of skid resistance of the road surface. The ability to correctly target specific motorcycle safety treatments will enable optimal allocation of limited funds and is expected to contribute to a reduction in motorcycle fatal and injury crashes.

Conclusion

There are a number of readily discernible benefits that will accrue from the operation of the instrumented motorcycle, which include:

- Quantification of motorcycle specific road surface deficiencies
- Quantification of combined geometric safety deficiencies such as rutting in a braking area on approach to a substandard curve or roughness on off-camber curves
- The ability to apply objectivity to motorcycle specific road safety audits
- The ability to do motorcycle specific crash investigations
- Marketing opportunities to inform both motorcyclists and the general public of TMR's commitment to road safety and a progressive approach
- Communication, education and research opportunities.

Acknowledgements

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Ms. Tania Meredith – Department of Transport and Main Roads

References

1. Department of Transport and Main Roads crash database.