How many of the fines below have you had in the past year:

Fine Type
Speeding fines
Red light fines
Seatbelt fines
Distraction fines (using mobile phone, eating, ..etc)
Driving on the wrong side of the road
Parking fines
Others (please specify)________________

Section 5: Demographic Information

152.	Age
153.	Gender ❑ Male ❑ Female
154.	Marital status ❑ Single ❑ Married ❑ Widow ❑ Divorce
155.	Education Level
156.	Years of driving experience
157.	How many kilometres do you drive per day? Km
158.	Would you like to add anything?

Investigation of Quad bike handling characteristics and their implications for on road use

David Hicks[1], Raphael Grzebieta[1], Keith Simmons[1,2], George Rechnitzer[1,3] and Mario Mongiardini[1]

[1]*Transport and Road Safety (TARS) Research Centre, UNSW Australia*

[2]*KND Consulting Pty Ltd*

[3]*George Rechnitzer & Associates Pty Ltd*

Corresponding Author: David Hicks, Level 1, Old Main Building, UNSW Sydney, 2052, NSW, Australia, david.hicks@unsw.edu.au, 61 2 9385 5242.

This peer-reviewed paper was first presented at the 2016 Australasian Road Safety Conference (ARSC2016) held in Canberra, ACT, Australia and first published in the ARSC2016 Proceedings as a 'Full Paper'. It underwent the full peer-review process by independent experts in the field. It is being reproduced here with the kind permission of the authors and is now only available in this edition of the JACRS.

Key Findings

- Quad bikes have a critical speed between 26 km/h and 35 km/h.
- Roadside structures such as traffic islands and kerbs can displace a seated rider from the quad bike and in one instance, resulted in the quad bike rolling over.

Abstract

Quad bikes or All-Terrain Vehicles (ATVs) continue to be a significant cause of serious injuries and fatalities in many countries. Of particular concern are injury incidents related to quad bike use on-roads. Results from the University of New South Wales (UNSW) Quad Bike Performance Project identified that most commercial quad bikes tested, demonstrated an oversteer steady-state handling characteristic. A mathematical relationship exists between a vehicle's oversteer characteristic and a 'critical speed' at which the quad bike is at risk of suddenly losing control. Theoretical analyses indicated that the critical speed for the tested quad bikes ranges between 26 km/h and 35 km/h. Computer simulations were also performed to determine whether quad bikes can safely interact with speed humps and roadside structures such as kerbs and traffic islands. The simulations indicated that quad bikes could traverse on-road speed humps without displacing the rider off the seat. However, traversing roadside structures such as a kerb or a pedestrian island, resulted in the displacement of the rider off the seat and in one instance a rollover. The results suggest that quad bikes are unsafe for on-road use where speed limits have been set to 50 km/h or more and where there are road features such as kerbs and traffic islands that need to be negotiated by the rider. In summary, quad bikes are vulnerable to the speeds and roadside structures found in the on-road environment.

Keywords

Quad bike, road, handling, oversteer, understeer, kerb, traffic island

Introduction

Quad bikes, referred to in other countries as All-Terrain Vehicles (ATVs), are claimed to be high-mobility off-road vehicles characterised by a straddle-type seat and a handlebar for throttle and steering control. They also have large low pressure tyres and a locked rear axle (no rear differential) for increased traction in rocky and soft terrains.

Quad bikes have several handling characteristics that are different to other four-wheeled vehicles including cars, four-wheeled drives and even other off-road vehicles (SVIA, 2013; Weir, Zellner, 1986). In particular, quad bikes have a low stability threshold equivalent to a fully loaded semi-trailer heavy truck, which means they are particularly prone to rollover whilst negotiating turns and riding on slopes (Grzebieta et al, 2015a; Milosavljevic et al., 2011; Grzebieta, Rechnitzer, Simmons and McIntosh, 2015b). Consequently, it is recommended that quad bike riders actively change their position on the vehicle to increase the vehicle's rollover threshold when turning as well as when going over irregular terrain, bumps and other obstacles (Lenkeit and Broen, 2014; Honda Australia Rider Training, 2012). Such movement of the rider on the quad bike is commonly referred to as 'Active Riding'. This can involve a wide range of body movements including; leaning from a sitting position, sliding the pelvis across the saddle and adopting a crouched or standing position.

Aspects of a quad bike's design for use on low-traction off-road surfaces, such as low pressure tyres and locked rear axle, means their use on sealed road surfaces can be dangerous and is warned against by quad bike manufacturers (SVIA, 2013). In addition, similar to motorcycles, quad bikes do not offer any crash protection (i.e., rider restraint and roll cage), making the rider vulnerable in a public road environment where they can crash into other vehicles or other vehicles can crash into them.

Quad bike deaths and serious injuries related to quad bike use on public roads have been observed all over the world including in the USA, Sweden and Australia. Moreover, a statistically significant increase in the odds of injury associated with sealed roads has been identified (Shulruf and Balemi, 2010; Grzebieta et al., 2017). In the USA and Sweden, public road quad bike fatalities (65%) accounted for a higher percentage of the overall fatalities than off-road fatalities (58%) (Persson, 2013; Williams, Oesch, McCartt, Teoh, & Sims, 2014). In the USA, single-vehicle crashes accounted for up to three-quarters of on-road quad bike fatalities and injuries, with rollover also often occurring (NHTSA, 2015; Williams, Oesch, McCartt, Teoh, & Sims, 2014; Denning, Jennisson, Harland, Ellis, Buresh, 2012; Denning, Harland, Ellis, Jennissen, 2013). Similarly, the quad bike was the only vehicle involved in approximately 90 percent of quad bike crashes in Sweden, with rollover being the most prevalent injury mechanism associated with fatalities (70%) (Persson, 2013). Collisions with other road vehicles are also common amongst quad bike crashes (Persson, 2013; Denning, Harland, Ellis, Jennissen, 2013 & Grzebieta et al., 2014a). In a recent study of 141 Australian quad bike related fatalities, 11 percent were noted as occurring on public roads. These fatal events often involved collisions with other vehicles or objects (Grzebieta et al., 2014a; McIntosh, Patton, Rechnitzer and Grzebieta, 2016).

There is unanimous agreement between quad bike manufacturers and safety stakeholders that quad bikes should not be used on-roads (Weintraub and Best, 2014). Despite this, many countries continue to allow quad bike access to roadways with increasing pressure placed on regulatory authorities to permit their use in such environments (Grzebieta et al., 2014b). In the USA, quad bike use on-roads is permitted in 36 out of 50 states, with varying levels of access ranging from travelling only on certain road surfaces or at certain times of day, to complete access to all public roads including sealed roads (Maciag, 2016). In many US states, quad bike jurisdiction is implemented by local ordinances (Maciag, 2016). In West Virginia, where the quad bike fatality rate is eight times the national average, quad bikes are banned from public roads except for the purpose of crossing a roadway (Hall, Bixler, Helmkamp, Kraner, Kaplan, 2009). Despite this, on-road fatality rates have continued to rise to the extent that on-roads deaths are now higher than off road deaths in the USA, suggesting that the state laws and/or their enforcement have not been effective in curbing this issue.

In the European Union (EU), agricultural quad bikes that are designed for off-road surfaces are not permitted for public road use under Regulation (EU) 168/2013, as of January 2013. Furthermore, from January 2016, quad bikes that are designed to travel on roads are required to have a 'safe cornering device', such as a rear differential (European Union, 2013). In Australia, quad bike access to roads is tightly restricted with some states allowing conditional registration (Roads & Maritime Services, 2015; Vicroads, 2014). In NSW, conditional registration is only available in situations where the quad bike will be used mostly off-road or in off-road areas, but needs limited access to the road network, where there will be limited mixing with general traffic on sealed roads and when it will be floated from site to site (Roads & Maritime Services, 2015).

Dynamic Handling Attributes of Quad Bikes

Steady-state cornering characteristics

One method of assessing a vehicle's handling characteristics is by measuring it's 'understeer' or 'oversteer' characteristic. This is measured by determining the relative amount of lateral slip experienced by the front and rear wheels during a turn and can be measured experimentally through the test procedures outlined in SAE J266 (SAE, 2002) and ISO 4138:2012 (ISO, 2012). When slip at the front tyres exceeds that at the rear, a vehicle is said to be in 'understeer' and the driver or rider must increase the steering input to remain on the desired path. A vehicle with more slip at the rear than the front is said to be in 'oversteer' and the driver or rider must decrease the steering input to remain on the desired path. Furthermore, a vehicle that has the same amount of slip at the front and the rear is said to have a 'neutral steer' characteristic. Grzebieta et al. (2015b) identified that several commercially available quad bikes tested demonstrated an oversteer handling characteristic. This characteristic has also been identified by several other studies that investigated quad bike handling (Forouhar, 1997; Grzebieta R., Rechnitzer G., Simmons K., 2015a; Allen et al., 1989; Chen, Tsal, Chen, and Holloway, 1989).

At the vehicle's limit of handling (when the traction limit of the tyres has been reached), an understeering vehicle will plow out of a turn and an oversteering vehicle will spin out at the rear, as illustrated in Figure 1. For a vehicle with an oversteer characteristic, at speeds greater than its 'critical speed' the vehicle can become dynamically unstable if perturbed and reach the limit of its handling and spin out or rollover. The critical speed of an oversteering vehicle is found using the following mathematical relation expressed in equation (1) (Gillespie,1992):

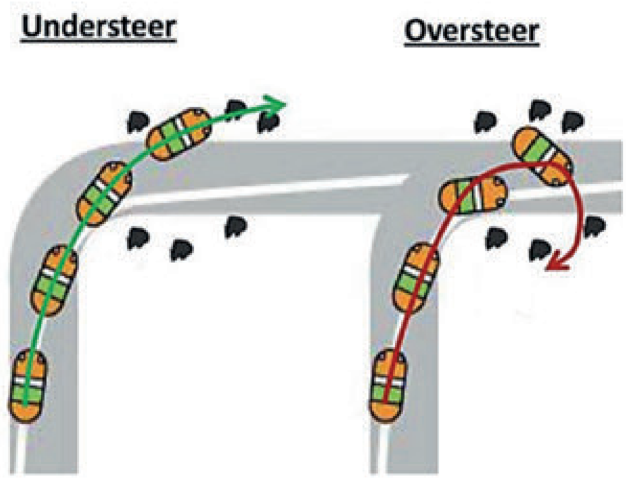


Figure 1. Understeer and oversteer path (Pollitzer and Little, 2014)

$$V_{crit} = 3.6\sqrt{-Lg/k}\ (km/h) \qquad (1)$$

where, L = wheelbase (m), g = 9.81 m/s^2, k = understeer gradient (rad/g).

Previously noted above, quad bikes are predominantly manufactured with an oversteer characteristic. On the other hand, Recreational Off-highway Vehicles (ROVs) are an example of a vehicle with predominantly understeer characteristics (ROVs are also referred to as Side-by-Side Vehicles (SSV's)). However, one particular vehicle, namely the Yamaha Rhino, possessed an oversteer characteristic which was highlighted by the US Consumer Product Safety Commission (CPSC) as a concern. They stated that *"oversteer in ROVs is an unstable condition that can lead to a rollover incident, especially given the low rollover resistance of ROVs"* (Pollitzer and Little, 2014; CPSC, 2014). In addition, Gillespie (2015) advised the US Recreational Off-Highway Vehicle Association (ROHVA) that an *"oversteer vehicle can be driven safely as long as they are below the critical speed"*.

Obstacle Traversing Characteristics

Mattei et al. (2011) demonstrated that traversing a bump-like obstacle placed perpendicular to the direction of travel of a quad bike and in-line with both wheel tracks, displaces a seated rider vertically off the seat. Similarly, the authors have shown that a bump-like obstacle placed perpendicular to the direction of travel and in-line with one wheel track of a quad bike, can cause a seated rider to be displaced vertically and laterally across the seat (Grzebieta et al., 2015b & 2015c; Hicks, Mongiardini, Grzebieta, Rechnitzer, Simmons, 2015). It was hypothesised that this lateral displacement and unintentional steering of the quad bike could lead to quad bike roll-overs.

As previously mentioned, it is recommended that when traversing bump-like obstacles, the quad bike rider should assume an 'active riding' standing position (Honda Australia Rider Training, 2012). In an on-road environment, the Authors believe that quad bike riders are less likely to use 'active riding' techniques because of the number of factors, e.g. avoiding colliding with other traffic, that require the rider's attention. In addition, the psychological perception of a sealed road being an easier riding environment than off-road could relax the rider into a non-active posture. Obstacles are commonly found in the form of speed humps, kerbs and traffic islands on public roads. Figure 2 shows two traffic islands which could be ridden over in an errant driving scenario.

Objective

This paper aims to investigate whether the dynamic handling characteristics of a quad bike affect their performance on sealed road surfaces. Using the oversteer gradient obtained for the series of quad bikes tested during the dynamic handling phase of the Quad Bike Performance Project (QBPP) the 'critical speed' for these vehicles was determined and considered in light of current road speed limits (Grzebieta et al, 2015b). In addition, computer simulations were performed to observe whether a quad bike can safely manoeuvre over speed humps and roadside features including kerbs and traffic islands. The Author are not aware of any similar analysis having been carried out and published in the open literature.

Barrier Kerb Profile

Semi-mountable Kerb Profile

Figure 2. Examples of traffic islands

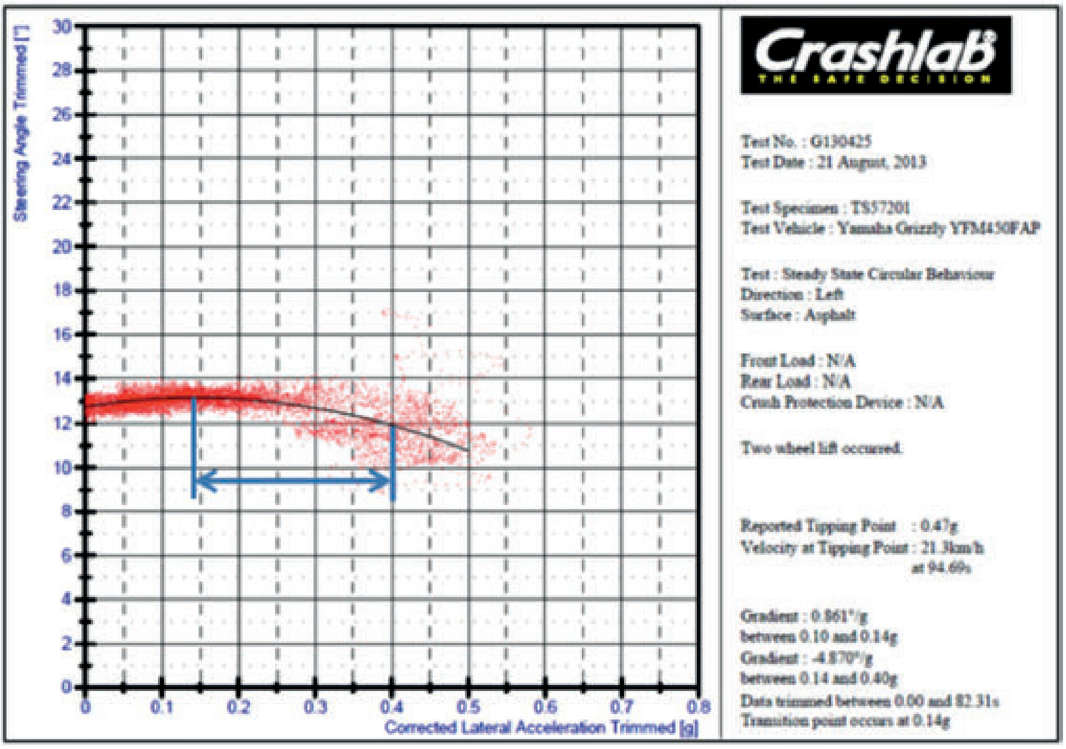


Figure 3. Lateral acceleration versus steering angle measured for a Honda TRX250 during the QBPP, transition point at 0.14 g (Grzebieta et al, 2015b).

Method

Cornering Hazard

The critical speed of the eight commercially available adult-sized quad bikes was calculated. It was calculated using the critical speed equation (1) and inputting the oversteer gradient published by Grzebieta et al. (2015b). The oversteer gradient (i.e. steering angle/lateral acceleration) between the transition point (0.14 g) from understeer to oversteer and 0.4 g lateral acceleration was used for these calculations (indicated by arrows in Figure 3). However, if the transition point occurred at less than or equal to 0.1 g, then the oversteer gradient between 0.1 g and 0.4 g was used (indicated by arrows in Figure 4). This method provides a conservative estimation of the quad bike's oversteer gradient. Further detailed description of the experimental test setup used to determine the oversteer/understeer gradient is presented elsewhere (Grzebieta et al, 2015b).

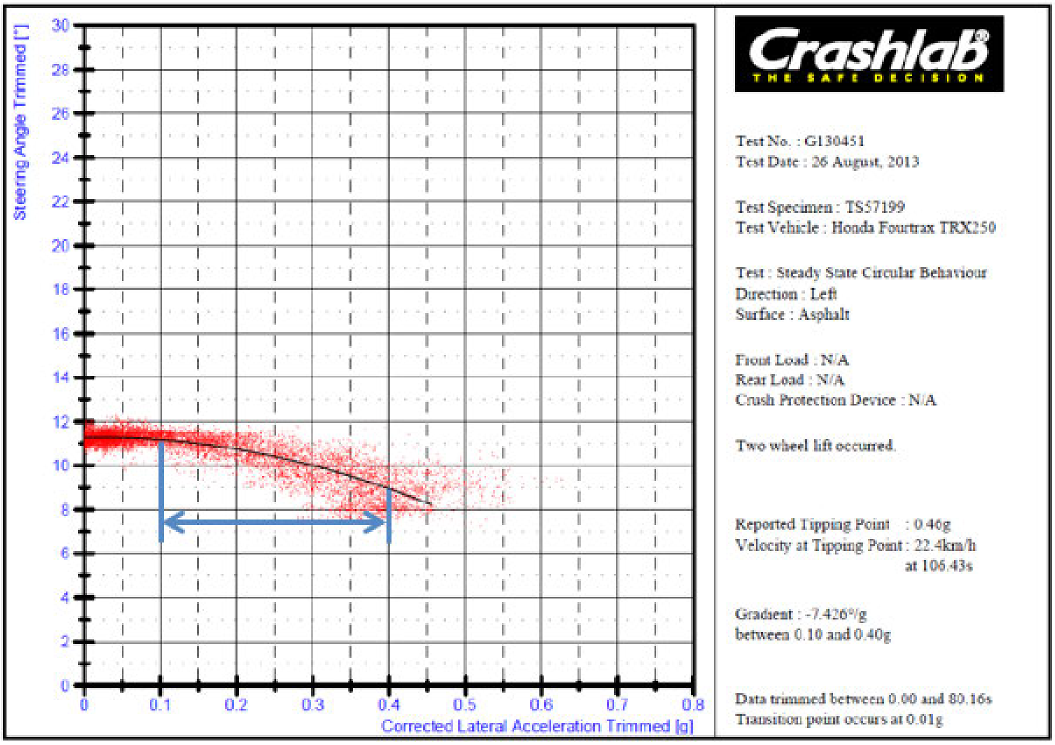


Figure 4. Lateral acceleration versus steering angle measured for a Honda TRX250 during the QBPP, transition point at 0.1 g (Grzebieta et al, 2015b).

Infrastructure Hazards

Simulations were performed to determine whether on-road obstacles such as speed humps, kerbs and traffic islands present a hazard to quad bike riders and can potentially cause them to lose control of the vehicle. The simulations were performed using a Finite Element (FE) model of a quad bike and seated rider to observe the kinematics of riding over speed humps and roadside kerb structures. The FE quad bike model was previously verified and validated to represent a seated rider traversing a semi-cylindrical obstacle (Hicks et al., 2015; Mongiardini, Hicks, Grzebieta, Rechnitzer, 2014). A seated 95th percentile HIII Anthropometric Test Device (ATD), commonly referred to as a crash test dummy, was used for this analysis. The hands of the ATD were attached to the handle bar while traversing the speed humps and road side kerb structures.

Scenarios were simulated with the rider seated on the quad bike while traversing two different speed hump profiles that are used for local area traffic management on suburban roads across Australia (Austroads, 2015). These speed humps included a 'Watt's Profile' speed hump simulated at two different heights equal to 75 and 100 mm as well as a 'Flat-top' type speed hump (Figure 5). The Flat-top speed hump was simulated with the minimum recommended longitudinal dimensions (i.e.,1.2 m and 2.0 m) and the maximum height of 100 mm to provide the most severe perturbation.

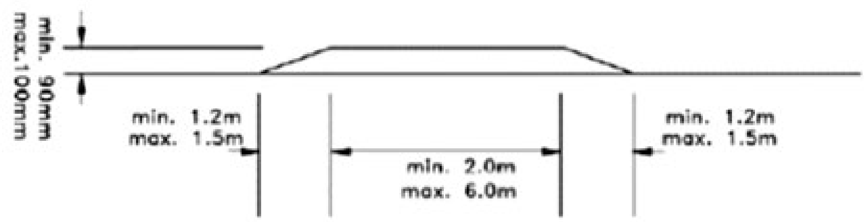
These simulations were performed at the range of speeds that each type of speed hump was designed to be traversed (Austroads, 2015). The speed hump simulations performed is shown in Table 1. Each speed bump was positioned perpendicular to the direction of travel and in-line with both wheel tracks of the quad bike. In addition to this, the 100 mm tall 'Watts Profile' speed hump was simulated placed in-line with only one wheel track, to represent a speed hump that can be avoided with one wheel track.

A series of simulations were also performed to investigate the effect of traversing a traffic island. Two different types of Austroads standard kerb profiles were simulated including the 'Barrier Kerb' type and the 'Semi-mountable' kerb profiles (Figure 6) (Austroads, 2015; Standards Australia, 2000). The kerb profiles were simulated placed perpendicular to the direction of travel and in-line with one wheel track as well as in-line with both wheel tracks.

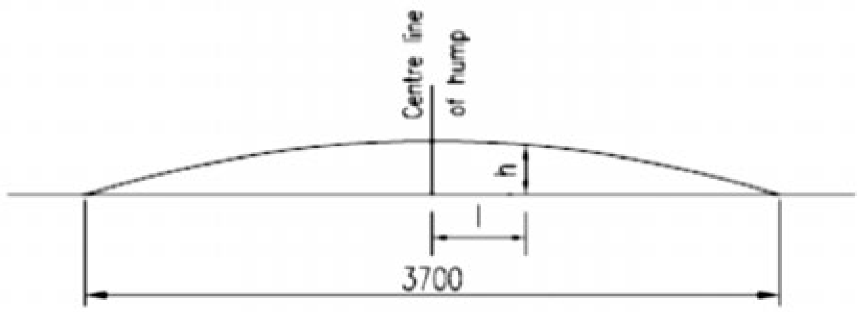
Table 1. Speed Hump Simulations

Speed Hump Type	Wheel Track(s)	Speed (km/h)			
		20	25	30	35
Flat Top (100 mm)	Both	Yes	Yes	Yes	No
Watts 1 (100 mm)	Both	No	Yes	Yes	No
Watts 2 (75 mm)	Both	No	No	Yes	Yes
Watts 1 (100 mm)	Single	No	Yes	Yes	No

No = not simulated
Yes = Simulated



Flat Top Profile (Austroads, 2015)



Watts Profile (Moreland City Council)

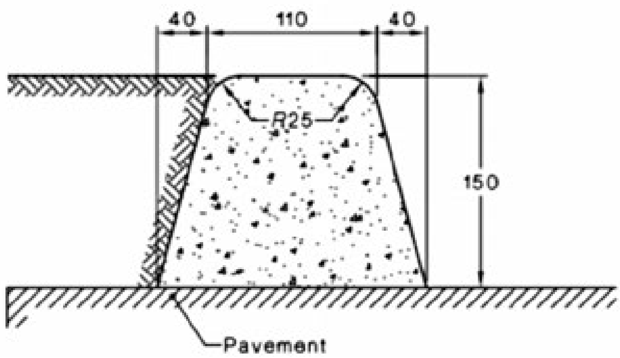
Figure 5. Speed Hump Types

Table 2. Kerb Simulations

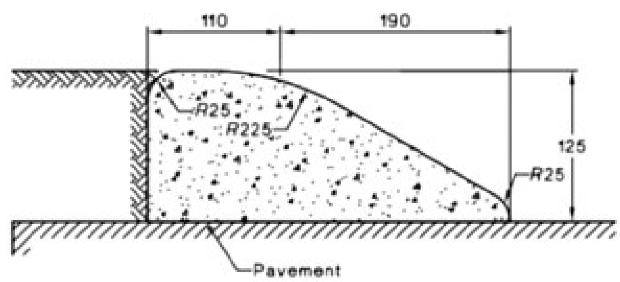
Kerb Type	Wheel Track(s)	Speed (km/h)	
		30	40
Barrier	Both	Yes	Yes
	Single	Yes	Yes
Semi-mountable	Both	Yes	Yes
	Single	Yes	Yes
Infinite Barrier	Both	Yes	Yes

Yes = Simulated

The simulations were performed at 30 km/h and 40 km/h to represent scenarios where a rider had only time to slow down before impacting the kerb without swerving (Table 2). The kerb profiles were simulated with a longitudinal length of 400 mm to represent a traffic island (Figure 2). In addition, the barrier kerb was simulated with an infinite longitudinal length to represent the scenario of hitting a kerb placed along the road edge.



Barrier Curb



Semi-mountable Kerb

Figure 6. AS 2876 Kerb Profiles (Standards Australia, 2000)

Results

Cornering Hazard

The critical speeds calculated for the quad bikes tested during the QBPP are shown in Table 3. The critical speed results ranged from 26 km/h to 34 km/h with an average speed of around 30 km/h.

Table 3. Calculated Critical Speeds

Quad Bike Model	Critical Speed (km/h)
Honda TRX500	34
Yamaha YFM450	32
CF Moto CF500	32
Polaris Sportsman 450	32
Suzuki Kingquad 400ASI	29
Kawasaki KVF300	28
Kymco MXU300	27
Honda TRX250	26

Infrastructure Hazards

The 'Flat-top' speed hump and both 'Watts profile' speeds humps, when traversed with both wheel tracks by a seated rider did not displace the rider off the seat of the quad bike. Similarly, the taller (100 mm high) 'Watts profile' speed hump traversed with one-wheel track did not displace the rider off the seat of the quad bike (Table 4). In contrast, in all simulations of the seated quad bike rider traversing a kerb or traffic island, the rider was displaced vertically off the seat and in the single wheel track scenarios laterally as well (Table 5). The rider was displaced higher off the quad bike during the simulations of the quad bike traversing the traffic island as opposed to the roadside kerb. This was attributed to the increased pitching motion of the vehicle when it moved over the traffic island and resulted in the ATD being separated from the quad bike for a longer period of time. At 40 km/h, impacting the barrier kerb profile traffic island with a single wheel track resulted in the quad bike rolling over.

Discussion

A vehicle that has an oversteer characteristic can become uncontrollable and spinout if perturbed during use at or above it's critical speed (Pollitzer and Little, 2014; Grzebieta et al., 2015b). For quad bikes with low lateral stability and higher friction tyres on sealed roads, the vehicle may instead rollover suddenly (Gillespie, 1992). The critical speed results presented in this study provide an understanding of when an oversteering quad bike could become directionally unstable (Gillespie, 1992). These speeds of commonly used quad bikes are lower than the speed limits and traffic flow speeds of local and main roads across Australia (i.e. below 50 km/h). Thus, if regulators permitted the use of quad bikes on-roads, these vehicles would likely operate at speeds higher than their critical speed, which, as vehicle handling theory indicates, may become directionally unstable and result in loss of control and rollover crashes. Testing should also be conducted to confirm the potential and circumstances for loss of control due to exceeding the calculated critical speeds.

Rider testing suggests that if the rider remains vigilant and uses appropriate 'active riding' techniques, the quad bike can be safely ridden at speeds higher than the critical

Table 4. Rider separation for speed humps

Speed Hump Type	Wheel Track/s	Speed (km/h)			
		20	25	30	35
Flat Top (100 mm)	Both	No	No	No	-
Watts 1 (100 mm)	Both	-	No	No	-
Watts 2 (75 mm)	Both	-	-	No	No
Watts 1 (100 mm)	Single	-	No	No	-

No = No separation

Table 5. Rider Separation for Kerbs

Kerb Type	Wheel Track/s	Speed (km/h)	
		30	40
Barrier	Both	Yes	Yes
	Single	Yes	Yes (Rollover)
Semi-mountable	Both	Yes	Yes
	Single	Yes	Yes
Infinite Barrier	Both	Yes	Yes

Yes = Separation

speed (Forouhar, 1997). This is the same as a racing car driver being able to control a race car that has an oversteer characteristic. Close attention to vehicle parameters and early intervention (using steering and throttle) at the slightest variation in detected yaw rates or lateral acceleration allows the driver to keep the vehicle under control. However, the public road environment presents a number of factors that would require the rider's full attention, such as avoiding collisions with other road users. These factors would considerably limit the rider's ability to assess and adopt appropriate 'active riding' techniques and to monitor feedback from the vehicle. In addition, the on-road environment being characterised by flat, smooth surfaces may influence riders to believe that active riding techniques are not required and may also encourage higher travel speeds. Without appropriate warning and training, quad bike riders would be unaware of the risks associated with operating at speeds higher than the vehicle's critical speed.

It is recommended by industry trainers that when traversing obstacles, e.g. on private and farm roads, riders should use active riding from a standing position (Honda Australia Rider Training, 2012). However, as previously discussed, this may not always be realistic in the on-road environment. The simulations suggest that well designed speed humps on public roads may not necessarily present a risk to quad bike riders if traversed at a safe speed, i.e. at or below the speed humps design velocity. However, the simulations indicate that roadside structures such as traffic islands and kerbs can displace a seated rider from the quad bike. Of particular concern is clipping a roadside feature with one wheel as this can induce a rollover. Even travelling at speeds close to the 50 km/h default urban speed limit of suburban roads and some main roads would still be a particularly high risk activity.

The evidence and discussion provided in this paper are also applicable to the use of quad bikes in the off-road environment and on farms. Many quad bike serious injuries and fatalities occur whilst riding on hard off-road surfaces including unsealed roadways, clay soils and grass covered paddocks where the co-efficient of friction is similar to that of a sealed road surface (Grzebieta et al., 2017; Grzebieta et al., 2014b; Renfroe, 1996; Wright, Carpenter, Johnson, Nelson, 1991).

Although not discussed in detail in this paper, the lack of rider restraint and rollover protection means that quad bike users are vulnerable road users similar to motorcycle and bicycle riders. The high number of quad bike collisions with other road users seen in the USA, Sweden and Australia highlights the vulnerability of quad bike users in a public road environment (Denning, Jennisson, Harland, Ellis, Buresh, 2012; Denning, Harland, Ellis, Jennissen, 2013; Grzebieta et al., 2014b).

Unfortunately, there is not enough detail known about the crash mechanisms of on-road quad bike crashes to determine whether operation at speeds higher than the critical speeds indicated, have contributed to crash scenarios. Nevertheless, the authors are aware of a fatality where a rider travelling on a bitumen road at a speed above the critical speed of the quad bike, suddenly underwent violent steering oscillations as described by a witness, resulting in the vehicle crashing. Hence, it is possible that loss of control due to 'critical speed', may have contributed to some of the single vehicle crashes that have occurred. This is especially likely in the case of the 42 percent of single vehicle fatalities in the USA that involved speeds that were too fast for the conditions or exceed the speed limit (Williams et al., 2014). Similarly, there is insufficient detail known about on-road quad bike crash mechanisms, to determine whether roadside structures including traffic islands and kerbs were causal to on-road quad bike crashes.

Conclusions

Quad bike manufacturers warn against riding on sealed surfaces such as on public roads. Despite this, there is increasing pressure on governments and regulatory authorities worldwide to permit their use on such roads, though mainly in the USA and more recently in Europe. If the number of on-road quad bikes continue to increase, pressure could come to bear on Australian regulators to relax current laws. This study highlights and discusses the dynamic handling characteristics of quad bikes, indicating that these vehicles have an increased crash risk when used on sealed surfaces and are therefore unsuitable for use on-roads, particularly when considering their lack of crashworthiness.

In Australia, a quad bike's critical speed would be likely exceeded if operated in a public road environment. This feature when combined with its underlying oversteer characteristic and low stability, indicate a significantly elevated risk potential for quad bikes to lose control and rollover as a result of interaction with roadways. Moreover, simulation analyses of a quad bike interacting with roadside kerbs and traffic islands, further indicate that a rider traveling over such road features could be displaced off their seat and lose control of their vehicle and in some situations rollover.

Acknowledgements

The Authors would like to gratefully acknowledge: WorkCover Authority of NSW (now Safework NSW) and the Australian Competition and Consumer Commission (ACCC) who funded the QBBP; Ross Dal Nevo, Drew Sherry and staff from Crashlab, Roads and Maritime Services, who carried the testing referenced; and Dr. Andrew McIntosh and Dr. Patton who collected and analysed the Australian Coroner's Case Files. The authors would like to also thank the Victorian Institute of Forensic Medicine (VIFM) as the source organisation of the National Coroners Information System from which fatality quad bike data relevant to public roads referenced in this paper.

References

Allen, W., Szostak, H., Rosenthal, T., Klyde, D. (1989). Steady State and Dynamic Properties of All terrain Vehicles Related to Lateral directional Handling and Stability. *SAE Technical Paper*, 891105.

Austroads. (2015). *Local Area Management, in Guide to Traffic Managment Part 8*.

Chen, S., Tsal, L., Chen, J., Holloway, D. (1989). Steady-State Handling of Four-Wheeled All Terrain Vehicles (ATVs). *SAE Technical Paper*, 891117.

Denning, G., Harland, K., Ellis, D., Jennissen, C. (2013). More Fatal All-Terrain Vehicle Crashes Occur on the Roadway Than Off: Increased Risk-Taking Characterises Roadway Fatalities. *Injury Prevention*, 19, 250-256.

Denning, G., Jennisson, C., Harland, K., Ellis, D., Buresh, C., 2012. All-Terrain Vehicles (ATVs) on the Road: A Serious Traffic Safety and Public Health Concern. *Traffic Injury Prevention*, 14, 78-85.

European Union. (2013). *Regulation (EU) No 168/2013*. Journal of the European Union.

Forouhar, F. (1997). *All-Terrain Vehicles Frequency Domain Response Analysis and Rider Behavior*. Paper presented at the IEEE International Conference on Control Applications, Hartford, CT.

Gillespie, T. (1992). *Fundamentals of Vehicle Dynamics*. Society of Automotive Engineers.

Gillespie, T. (2015). *Comments on CPSC NPR for ROVs*.

Grzebieta, R., Rechnitzer, G, McIntosh, A., Mitchell, R., Patton, D., and Simmons, K. (2014a). *Investigation and Analysis of Quad Bike and Side by Side Vehicle (SSV) Fatalities and Injuries*, Quad Bike Performance Project (QBPP) Report 3-2014: Supplemental Report, Transport and Road Safety (TARS) Research Report, The University of New South Wales, Sydney, Australia.

Grzebieta, R., Rechnitzer G., Simmons K., Hicks D., Patton D., Mongiardini M., McIntosh A., Sherry D. and Dal Nevo R.

(2015a, June). *The Australian Terrain Vehicle Assessment Program (ATVAP)*, Proc. 24th Int. Technical Conf. on the Enhanced Safety of Vehicles (ESV) Gothenburg, Sweden.

Grzebieta, R., Rechnitzer, G., Simmons, K. (2015b). *Dynamic Handling Test Results,* Quad Bike Performance Project (QBPP), TARS Research Report No. 2, University of New South Wales, Sydney, Australia.

Grzebieta, R., Rechnitzer, G., Simmons, K. and McIntosh, A. (2015c). Final Summary Project Report: Test Results, Conclusions, and Recommendations, Quad Bike Performance Project (QBPP), TARS Research Report No 4, University of New South Wales, Sydney, Australia.

Grzebieta, R., Rechnitzer, G., McIntosh, A., Simmons, K., Mitchell, R., and Patton, D. (2014b, November). *Road-Related Quad Bike and Side by Side Vehicle Casualties*, Proceedings of 2014 Australasian Road Safety Research, Policing and Education Conference, Melbourne, Australia.

Grzebieta, R., Soufiane, B., Simmons, K., Hicks, D., Williamson, A., Rechnitzer, G. (2017). *Quad bike and OPD Workplace Safety Survey Report: Results and Conclusions*, Transport and Road Safety (TARS), University of New South Wales, Sydney, Australia.

Hall, A., Bixler, D., Helmkamp, J., Kraner, J., Kaplan, J. (2009). Fatal All-Terrain Vehicle Crashes: Injury Types and Alcohol Use. *American Journal of Preventative Medicine*, 36, 311-316.

Hicks, D., Mongiardini, M., Grzebieta, R., Rechnitzer, G., Simmons, K. (2015). *Analysis Of Quad-Bike Loss-Of-Control Using Experimental and Simulated Dynamic Bump Tests*, presented at the Enhanced Safety of vehicle (ESV), Gothenburg, Sweeden.

Honda Australia Rider Training (HART). (2012). *ATV Course Rider Handbook, Honda Training Pty Ltd*, Version 4.

International Organisation for Standardisation (ISO). (2012). *ISO 4138:2012 Passenger cars--Steady-state circular driving behaviour--Open-loop test methods*, Geneva, Switzerland.

Lenkeit, J., Broen, P. (2014). *Measurment of "Rider Active" Effects on ATV Performance*. Dynamic Reasearch Inc.

Mattei, T., Bond, B., Hafner, J., Morris, M., Travis, J., Hannah, G., Webster, J., Lin, J. (2011). Definition and Measurement of Rider-Intrinsic Physical Attributes Influencing All-Terrain Vehicle Safety. *Neurosurgical Focus*, 31(5).

Maciag, M. (2016). *ATVs and Public Roadways: A Deadly Combination*. Public Safety & Justice. Governing. (http://www.governing.com/topics/public-justice-safety/gov-roads-atvs-fatalities.html)

McIntosh, A. , Patton, D., Rechnitzer, G. and Grzebieta, R. (2016). Injury mechanisms in fatal Australian quad bike incidents, *Traffic Injury Prevention*, 17(4), 386-390.

Milosavljevic, S., McBride, D., Bagheri, N., Vasiljev, R., Carman, A., Rehn, B., Moore, D. (2011). Factors Associated with Quad Bike Loss of Control Events in Agriculture. *International Journal of Industrial Ergonomics*, 21, 317-321.

Mongiardini, M., Hicks, D., Grzebieta, R., Rechnitzer, G. (2014). Modeling a Quad Bike (All-Terrain Vehicle) for Simulating Rollover Events, *Journal of the Transportation Research Board*, 1, 50-60.

Moreland City Council. (Accessed: 2016). *Road Hump - Watts Profile A180.01*.

National Highway Traffic Safety Administration (NHTSA). (2015). *Fatalities in Traffic Crashes Involving All-Terrain Vehicles*. U.S. Department of Transport. Available at: (https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812193)

Persson, J. (2013). *Better safety on Quad Bikes*. The Swedish Transportation Administration.

Pollitzer, P., Little, B. (2014). *Proposed Rule: Recreational Off-Highway Vehicles (ROV)*. Consumer Product Safety Comission.

Renfroe, D. (1996). Effects of Surface Anomalies and Tire Mechanics on ATV Tire Friction Coefficients. *SAE Technical Paper*, 961000.

Roads & Maritime Services (Accessed: 2015). (2015). *All terrain vehicle/quad bike*. Available: (http://www.rms.nsw.gov.au/roads/registration/get-nsw-registration/vehicle-sheets/all-terrain-vehicle.html)

Shulruf, B., Malemi, A. (2010). Risk and Preventive Factors for Fatalities in All-Terrain Vehicle Accidents in New Zealand. *Accident Analysis and Prevention*, 42(2), 612-618.

Society of Automotive Engineers (SAE) Internaltional. (2002). *SAE J 266, Steady-State Directional Control Test Procedures for Passenger Cars and Light Trucks*, Vehicle Dynamics Standards Committee, Warrendale, PA, USA.

Standards Australia. (2000). *Concrete kerbs and channels (gutters) - Manually or machine placed*, AS 2876.

SVIA (Accessed: 12/05/2014). (2013). *Position in Oposition to on-road operation of ATVs*. (http://www.svia.org/Downloads/PositionPaperOpposingOn-RoadUse.pdf)

US Consumer Product Safety Commission (CPSC). (2014). *Safety Standard for Recreational Off-Highway Vehicles (ROVs)*, Notice of Proposed Rulemaking, 16 CFR Part 1422, RIN 3041-AC78, Docket No. CPSC-2009-0087.

Vicroads (Accessed: 2014). (2014). *Special work vehicles (quad bikes)*. Available: (https://www.vicroads.vic.gov.au/registration/new-registration/register-non-compliant-vehicles/special-work-vehicles)

Weir, D., Zellner, D. (1986). *An Introduction to the Operational Characteristics of All-Terrain Vehicles*. SAE International, 860225

Weintraub, R., Best, M. (2014). *ATVs on Roadways: A safety Crisis*. The Consumer Federation of America.

Williams, A., Oesch, S., McCartt, A., Teoh, E., Sims, L. (2014). On-road all-terrain vehicle (ATV) fatalities in the United States. *Journal of Safety Research*, 50, 117-123.

Wright, R., Carpenter, T.Johnson, F., Nelson, R. (1991). Stability and Maneuverability Problems of ATVs. *SAE Technical Paper*, 911944.