REDUCING ALL TERRAIN VEHICLE INJURIES (ATVs) AND DEATHS - A WAY AHEAD

George Rechnitzer
Raphael H. Grzebieta
Andrew S. McIntosh
Keith Simmons
Transport and Road Safety (TARS) Research, University of NSW
Australia
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ABSTRACT

The use of ATVs both recreationally and in the workplace (particularly on farms in Australia), continue to be major contributors to fatal and serious injuries both in the USA and Australia.

This paper firstly presents the findings from the authors' 2003 study into ATV safety and potential countermeasures [1], and secondly, some 10 years later, leads into the current major test program being undertaken for the WorkCover Authority of NSW on ATV (Quad Bikes and Side-by-Side Vehicles) stability, handling and crashworthiness at UNSW.

The 2003 study was carried out at the request of the Victorian WorkCover Authority and the State Coroner to provide a review of previous research relating to ATV fatalities and serious injuries and to examine the feasibility of fitting effective occupant protection systems, particularly regarding rollover.

While current prevention strategies continue to focus on lower order risk controls such as rider training, personal protective equipment (PPE), and administrative controls, the authors consider that the very successful passenger vehicle New Car Assessment Program (NCAP) type test and rating program could also be applied to improve ATV safety.

INTRODUCTION

Advances in vehicle safety have had a much checkered history, with periods of significant resistance to safety development, followed by major and profound advances. This is well illustrated by advances in automobile safety on many fronts: moving from largely a 'blame the driver' approach to a holistic 'safe system approach' bringing together 'safe drivers on safe roads in safe vehicles' [2].

Moving on from the days of Ralph Nader's revolutionary critique of auto safety in 1965 'Unsafe at any Speed' [3] onto the USA FMVSS auto standards in the early 1970's and then onto NHTSA's creation of NCAP in 1979. As quoted in the history of NCAP [4] "*In 1979, NHTSA created the New Car Assessment Program (NCAP) to improve occupant safety by developing and implementing meaningful and timely comparative safety information that encourages manufacturers to voluntarily improve the safety of their vehicles*".

The NCAP program has been successfully adopted in many regions including Europe, Australia, Japan and Asia, for example.

No one involved in transport safety can be in any doubt of the dramatic improvements in vehicle safety and crashworthiness, from the high road toll decades of the 1960's and 1970's to the much lower tolls in the developed world in the 1990's through to the current decade. Many vehicles now have multiple airbags, greatly improved crashworthy structures, and handling assistance (ESC, pre-brake, etc.). However, during this time the auto industry, in many cases (with well-known notable exceptions, of course) seemingly and often actively resisted development and implementation of many safety technologies which are now not only standard but ubiquitous (e.g. airbags). Yet, today the auto industry can proudly boast of its great technological and safety advances, and the great benefits in terms of reduced community trauma.

Thus advances in safety were not inhibited by lack of engineering know how, but rather by lack of 'will' or incentive. Incentives for the auto industry have come in many forms, e.g. regulations (mandatory national vehicle safety standards), comparative consumer testing (NCAP), market competition, and perhaps even product liability litigation.

Of particular significance was the requirement for vehicles to meet minimum crashworthiness 'performance' standards based on set injury criteria, such as in FMVSS 208 frontal impact standards, offset frontal impact and side impacts.

Handling improvements such as ABS and ESC (and all types of other driver assist systems) complement the improved vehicle crashworthiness through crash prevention measures. Of course, measures relating to improved driver action (drink driving, speed enforcement, etc.) and road design all contributed significantly, and form part of the safe system approach to road safety [2].

This leads to consideration of the current status of ATV safety, the decades long apparent 'impasse', and in the authors' opinion, a possible way ahead.

Before presenting material on ATV safety, some discussion is necessary concerning the use of the terminology 'All-Terrain Vehicles'. In Australia, the term for vehicles commonly used on farms over rougher terrains is Quad Bikes (Figure 5) or Side-by-Side Vehicles (Figure 8) depending on their size and farming task. Both an Australian Coroner and the US Consumer Product Safety Commission have indicated that the term 'All-Terrain Vehicles' is misleading and may result in false assumptions as to the terrain that Quad Bikes can safely traverse [5,6]. Nevertheless, while the authors sympathise with this perspective, throughout this paper the term ATV will be used to represent Quad Bikes unless otherwise indicated in the text that the ATV vehicle is a Side-by-Side.

ATV SAFETY - AN OVERVIEW FROM THE 2003 MUARC STUDY

The follwing summary is taken from the MUARC study [1].

This study was carried out at the request of the Victorian WorkCover Authority and the State Coroner with the aim of presenting a review of previous research relating to ATV fatalities and serious injuries and to examine the feasibility of fitting effective occupant protection systems, particularly regarding rollover.

The study involved three main activities:

1. A review of the epidemiology of ATV related fatalities and serious injuries in Australia, USA, UK and New Zealand;
2. A detailed literature review examining previous research on ATV safety and proposed improvements to handling and fitment of Rollover Protective Systems (ROPS);
3. The design and evaluation of a proposed ROPS comprising a protective structure and occupant restraint system (seat and four-point seatbelts), considering both moderate and severe lateral rollovers.

The main findings from the study were:

- ATV rollovers are a major cause of fatalities in Australia, with crushing of the rider by the ATV, or ejection with impact with the ground or objects being the primary injury causal mechanism. Most serious incidents occur in agricultural settings.

- Although ATVs are based on motorcycle structures with two extra wheels added, they have significant differences in handling, usage and collision modes. Despite these major differences, ATV safety philosophy retains and promotes, *quite inappropriately*, a motorcycle based and rider-centred perspective on safety, rather than a vehicle one. That is, ATV safety is considered to depend on rider separation from the vehicle and the addition of protective clothing and helmet. Simply put, such safety philosophies are ill conceived and dangerous for ATV riders. They do not offer any protection in the most common modes of injury with ATVs – rollovers, nor collisions.

- The design of ATVs in terms of their short wheel base, relatively narrow track and high centre of gravity positions, and lack of a differential, result in adverse handling characteristics, which are intended to be compensated by active-riding techniques. Such techniques require shift in position of the rider's body to increase stability during manoeuvring. Stability analyses of the benefits of active riding show these to have quite limited benefit (about 20% or less), and overall would appear to be overrated as a means of enhancing the control of ATVs.

- Virtually all of the previous international research on fitting ROPS on ATVs to date has been predicated on having an unrestrained (or ineffectively restrained) rider so as to maintain active riding. This has led to protective structure designs with very poor effectiveness and in many cases designs that could well increase severe injury risk. Similarly, the ROPS designs suggested through the New Zealand

(NZ) ROPS guide and those of United Kingdom Health and Safety Executive (UK HSE) are ill conceived, totally inadequate, and indeed dangerous, as they provide inadequate survival space and do not require proper restraint systems.

- To ascertain the benefits and feasibility of fitting effective ROPS, three crash scenarios were modelled, with and without the protective system. The first scenario was an ATV travelling at 7km/h across a 30-degree slope in which the ATV rolls due to hitting a rock. The second scenario involved the ATV travelling at 30km/h across a 30-degree slope and rolling due to hitting a rock. The third scenario was the same as the second, but with the ATV travelling at 20km/h. In the case of the ATV without ROPS, in the first scenario, the ATV rolled onto the rider, and in the second and third scenarios the rider was ejected striking the ground resulting in severe injury levels (fatal in the 2nd scenario). In the three scenarios where the ATV was fitted with the ROPS, the occupant received low injury levels.

- It is possible to design a practical rollover protection system for an ATV that will protect a rider against serious injury in a rollover, and other collision modes. Such a system requires a lightweight but high strength structure that protects the occupant survival space, together with a high backed seat with side bolsters, and seatbelt system to effectively restrain the occupant within the protected zone.

- The provision of ROPS on currently designed ATVs will result in reduced stability. To regain the original stability ratings, such ATVs would require either increased track width or lowering of centre of gravity height.

Comments on MUARC study and ATV ROPS

The MUARC report proposed a ROPS system for ATVs as shown in Figure 1. This was based on fundamental crashworthiness principles on what would be required *ideally* for effective rider protection both in a rollover and in collisions. From this perspective, the deficiencies of other ROPS systems such as the rear single post or similar (as in NZ) were considered by the authors at the time as quite deficient, and even potentially dangerous.

While such a perspective may have appeared justified at the time, in hindsight, a more incremental approach based on 'harm minimisation' now appears to be pragmatically more appropriate. The 'all or nothing' approach does not reduce injuries in the interim. For example, two-post ROPS were encouraged to be retrofitted to older tractors in Victoria without seatbelts being mandated also - despite the knowledge that a risk of ejection from the tractor without seatbelts was still possible. Overall, this would be regarded as an effective pragmatic safety outcome for older tractors [7].

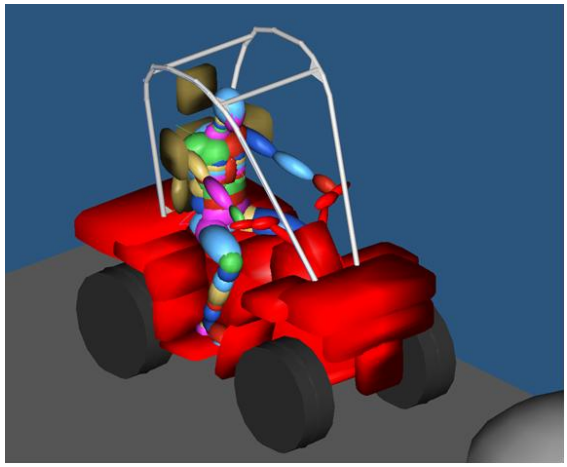

Figure 1. Proposed MUARC ROPS for ATV, with four-point seatbelt;winged seats. MADYMO model analysis.

On the other hand, the MUARC ROPS (and indeed any ROPS) was also strongly opposed by the ATV industry, and regarded by them as being more injurious than not having such a system. Such a claim was based on computer simulations by Zellner et al, and strongly questioned by the authors and others [8-10]. The industry still opposed ROPS and Crush Protection Devices (CPDs) of all types claiming these do more harm than good [11, 12].

ATV INJURY

Lower et al. [13] presented data on the 127 quad bike deaths in Australia between 2001 and 2010: "*It examines differences between causes of death occurring through use of the machine in farm/non-farm settings and during work/non-work operation. Data were extracted from the National Coroners' Information System (NCIS). In total, 65% of fatalities occurred on-farm, with 45% of incidents being work-related and 46% involving rollovers of the quad bike.*"

The report notes that "*A study of trends in farm deaths in Australia found that while deaths from tractor rollovers had decreased by 74% between 1982–84 and 2001–04, deaths associated with*

quad bikes had increased nearly 13-fold. … Massive increases in occupationally related incidents have also been reported in the United States of America (USA)".

Lower quotes USA data "*Between 2000 and 2007 in the USA there was an average of 723 deaths per annum attributed to quad bike use*."

In regard to injury mechanisms, rollovers predominate [13]: "*Analysis of the nature of the crash event highlights the leading mechanisms of injury as: collision with stationary object (34), rollover with no load or attachments (33), collision with other vehicle (10) and rollover with spray tank (9). Rollover of the quad bike attributed to 46% of all deaths where the mechanism of injury was known. Additionally, where the work status and mechanism were known, rollovers accounted for 58% of deaths*."

The report identifies the incidence of thorax injuries and asphyxia in rollover cases, and the potential benefits of Crush Protection Devices [CPDs] for prevention: *The significant variation in the primary cause of death between rollover and non-rollover events is a crucial finding. With 53% of rollover deaths involving the thorax, asphyxiation and drowning alone, the potential benefits of any crush protection device to prevent entrapment are clearly apparent. In addition, it can be reasonably contended that a sizeable number of head (24%), neck (14%), abdomen (4%) and multiple injuries (4%) incurred in rollovers could be averted by such a device".*

ATVs and CRUSH PROTECTION DEVICES

In response to the incidence of fatal and serious injury rollovers involving ATVs, and lack of any industry response to provision of rollover protection systems on ATVs (who maintain that such systems are hazardous), CPD systems have been developed by Trax LifeGuard (Figure 2 and 3) [14], and Quadbar (Figue 4) [15].

While in principle it is clear that such systems will have a protective benefit, it is also clear that they cannot be effective in all rollover situations, as ejection still occurs and crush by stiff areas on the ATV may still result. The research on the level of effectiveness has yet to be done.

Industry criticism of CPDs

Most ATV manufacturers have strongly opposed the introduction of CPDs or other ROPS systems: "*Australia's peak body for the automotive industry, the Federal Chamber of Automotive Industries (FCAI) together with the Australian All Terrain Vehicle (ATV) industry, comprising the leading distributors, have today called for proposals for the use of rollover devices on ATVs to be rejected*." [11]

The Federal Chamber of Automotive Industries (FCAI) statement notes that "*Reports released*

*Figure 2***.** TRAX LifeGuard CPD system [14].

*Figure 3***.** TRAX LifeGuard CPD system, showing deformable characterstics [14].

Figure 4. Quadbar CPD system [15].

last week by Dynamic Research Inc. (DRI), an internationally recognised firm specialising in applied research in the areas of vehicle dynamics and controls, simulator technology and accident investigation, confirmed that Rollover Protection Systems (ROPS) and Crush Protective Devices (CPDs) on ATVs can cause unacceptably high levels of harm in comparison to their benefits.

Updated research into one type of locally-produced CPD found that it caused more harm than it prevented in the sample of overturns examined, regardless of whether a helmet was worn"

The referenced report by Zellner et al [8] involved "*Approximately 3,080 computer simulations were run, with the baseline ATV and the Quadbar ATV, using 110 "low energy" overturn types, and six additional variations of each overturn type in order to reduce the sensitivity of the results to the details of any single overturn type, for the helmeted condition and for the unhelmeted condition*."

The report concludes that: "*The overall updated results were that in the helmeted condition the Quadbar had an injury risk/benefit percentage of 108% [69%, 168%]; and a fatality risk/benefit percentage of 134% [79%, 219%]. ….. In extending this sample estimate to the population of overturns, these confidence intervals indicate that the injury risks and fatality risks of the device are not statistically significantly different from the injury benefits and fatality benefits of the device, respectively, i.e., for the population of overturns, the Quadbar would cause approximately as many injuries and fatalities as it would prevent.*"

Of course there have been significant criticism and disagreements with the methodology used in such analysis by Zellner et al. and others, and indeed vice-versa [9, 10, 12, 16-18].

Thus, it appears there is little agreement on the way forward in improving ATV safety, particularly in regard to rollover [11]. The industry position remains focused on rider training, administrative controls and personal protection equipment (PPE): "*Unfortunately, while the focus remains on rollover devices, real solutions will continue to be ignored. Attention should instead be maintained on helmet use, training and keeping children off full-size ATVs.*"

In contrast, users of ATVs, farm industry groups, safety regulators, and safety researchers, see from the history of safety advances in transport that design countermeasures are possible but that the ATV industry continues to negate promotion of or indeed adequately research any solutions.

Hence, the decades-long impasse on advancing ATV safety and the need for a new approach, is set out in this paper as a way ahead to reduce ATV trauma.

THE CURRENT QUAD BIKE AND SIDE-BY-SIDE VEHICLE PERFORMANCE TEST AND RATING PROJECT

To help overcome this 'impasse' in progressing ATV (i.e. Quad Bike) safety, WorkCover Authority of New South Wales (Australia) has funded the *Quad Bike Performance Project*. This major project is also strongly supported by the State Government of New South Wales (NSW), and is based at the Transport and Road Safety (TARS) Research unit at the University of NSW, with the project led by the authors of this paper. The project commenced in September 2012, with completion expected for December 2013.

The project aims are:

1. Establishment of stability, handling and crashworthiness ratings for the selected Quad Bike models;

2. Development of an NCAP type testing and rating system New Quad Assessment Program (NQDAP) for rollover stability and rollover crashworthiness.

The main project stages are:

1. Selection and purchase of 16 new representative Quad Bikes and Side-by-Side vehicles as shown in Figures 5 to 9;
2. Biomechanics analysis: further detailed identification of injury mechanisms related to rollover, especially crush and asphyxiation; and development of related crashworthiness test methods;
3. Series of static stability tests for lateral rollover and forward and rearward pitch, based on tilt table tests with and without rider (Hybrid III Anthropomorphic Crash Test Dummy (ATD)); and with typical fitment and combinations of accessory loads on the front and rear. Effect of a selected sample of crush protection type devices (CPDs) on stability will also be tested [see Figure 10];

4. Series of crashworthiness tests related to lateral rollover and front and rear pitch, to determine serious injury risk with and without CPDs;
5. Establishment of stability ratings and crashworthiness ratings for the selected Quad Bike and SSV models;
6. Development of an NCAP type testing and rating system New Quad Assessment Program (NQDAP) for rollover stability and rollover crashworthiness.

In addition, the project has now received funding to include dynamic handling tests. This will complement the stability evaluation and will be included as part of the NQDAP rating. Improvements in Quad Bike and SSV handling has been highlighted by authors such as Roberts and others [19] as being practical means to reduce crash and rollover risk.

The testing program is being undertaken at the Crashlab test facility in Sydney, Australia.

The vehicles selected for testing include eight Quad Bikes typically used in the work place, particularly on farms [see Figures 5 & 7], three sports/ recreational type Quads [see Figure 6], and five Side-by-Side utility style off-road vehicles used in the workplace/farms [see Figures 8 & 9]. The three sports/recreational Quads were added to the project and funded by the Australian Competition and Consumer Commission (ACCC).

In addition to the multi-disciplinary research team undertaking the project, the project is also supported by a highly experienced Project Reference Group, which includes a worldwide range of experts in Quad Bike vehicle safety issues. The Reference Group includes ATV industry representatives, farming groups, safety regulators, university researchers, and safety consultants.

The outcome of the project is to provide a clear 'way ahead' to improve the safety of Quad Bikes and SSV type vehicles used in the workplace /farm (and recreationally) by providing consumers with a NCAP style performance based safety rating system to help identify appropriate vehicles for their use.

Such a rating system is intended to help provide incentives to manufacturers and consumers to drive competition for improved safety for such vehicles, in a similar way to what has been achieved for automobile safety.

By focusing on a performance based system, rather than by prescription (e.g. prescribed fitment of CPDs), leaves open a wider range of vehicle design enhancements in relation to crash prevention (handling improvements, electronic

Figure 5. One of the "workplace' Quad Bikes at Crashlab.

Figure 6. A sports/ recreational Quad Bikes at Crashlab.

Figure 7 One of the "workplace' Quad Bikes at Crashlab, with a Hybrid III ATD 'rider', and other Quad Bikes and SSVs at Crashlab.

Figure 8. One of the SSVs at Crashlab, awaiting testing.

Figure 9. Another SSV style vehicle at Crashlab.

*Figure 10***.** ATV tilt table static stability test being carried out at Crashlab, UNSW-TARS project, Feb 2013. Quad Bike loaded with rider (95th % Hybrid III ATD, with front load and rear Quadbar CPD fitted.

controls, etc.) and crashworthiness (rider/ occupant protection) in a crash.
An additional further intended outcome of the Project is the development standards for improved handling and reduced risk of rollover through performance requirements for lateral stability, and lateral, front and rear pitch crashworthiness.

CONCLUSIONS

ATV rollover crashes represent a major mechanism in fatal and serious injuries for ATV users, particularly in the farming sector.

Currently, little progress has been made in reducing such rollover incidents or severity with a strong community and regulatory push for CPD type devices, which is being opposed by the ATV manufacturers as unsafe. To help overcome this impasse on improving Quad Bike safety, the authors consider that ATV safety can be improved by drawing on the successful methods developed in the NCAP programs which use crash and other performance based tests to provide consumers with vehicle safety ratings, rather than prescriptive approaches.

This paper has outlined a major testing and safety rating project being undertaken at the University of New South Wales and Crashlab to develop the New Quad Assessment Program (NQDAP), and performance standards aimed at reducing the incidence and serious/fatal injury risk resulting from ATV rollovers.

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