Chapter Four
Context of quadbike use

Science begins, as L.J Henderson used to say, with the scientist acquiring an intuitive familiarity with the facts. In our field this can only be achieved by the scientist's watching and talking to people at first hand, and field studies alone provide the opportunity. Science, of course, does not end there, but it certainly begins there.
(Homans, 1986: xv-xvi. Cited in Bulmer, 1988: 158)

4.1 Introduction

The aim of the study reported in this Chapter was to gain an understanding of the nature and functional requirements of the work systems within which quadbikes operate on New Zealand farms via incident-independent analysis of the tasks, the users and the machines; the 'context for ergonomics change' (Kleiner, 2006)

As indicated in the first two Chapters, very little has been published on how quadbikes are used on New Zealand farms, and this limits the ability to both interpret investigation data to sufficient depth, and subsequently to develop interventions that fit within the system as a whole. Interventions designed in ignorance of the wider system may address one problem, but in doing so, create others.

Bentley & Haslam (2006) note that the triangulation of various 'incident-centred and incident-independent' methods is important when wishing to understand the causes at the population level; "an ergonomics perspective requires analysis of factors related to the entire work system, their interaction, and underlying influences and causes." Understanding the basic mechanics of the work processes alone is therefore not enough. This is an industry where the majority of businesses are small family-owned and operated concerns. The context is not a corporate one. Farming is arguably dissimilar even to other privately owned businesses as the farm is also home, not only to those working there, but also children and others who may have little or no role in the business. Business and personal goals are interwoven and this influences the daily execution of farming processes to the extent that assumptions about consistencies in how tasks are done will result in dangerous over-simplification~.The family farm is therefore to a greater or lesser extent, less of a set of processes formed to meet stated corporate aims, and more of "a psychosocial driver of human well-being and quality of life" (Siemieniuch & Sinclair, 2005).

The data collection method drew on different sources, and ran in two phases. The first was a series of interviews, focus groups and interactive participation in training within industry. This was supplemented through data collection of the farm systems where the 156 LCE (reported in Chapter Five) took place and these data were collected at the same time as the LCE investigations.

A shortcoming of the current body of literature is that too little is known about the contexts of those LCE that are investigated in other countries, or at other times, for comparisons to be drawn with the contemporary New Zealand settings.

4.2 Methodology

4.2.1 Industry consultation

The primary data collection method was direct industry consultation at several levels reflecting the extent of the influences acting on the systems within which quadbikes are used on New Zealand farms. A combination of interviews, participant-observation and focus group methods were employed for this exploratory study. The data sources are summarised in Table 4.1, and itemised in Table 4.2.

As part of the preparation for this series of studies, the researcher completed two days of practical training on quadbike riding and theory, completing the four available New Zealand Qualifications Authority (NZQA) Standards on quadbike use which included the use of quadbikes with trailers on hill country. Following this the researcher also received practical hands-on instruction on key quadbike tasks on farms in Hawkes Bay (sheep and beef mustering) and the Waikato (electric fencing).

The researcher also enrolled as a student participant with Telford Rural Polytechnic for the ***FarmSafe Awareness*** and ***FarmSafe Plans*** training courses. These are the basic Health and Safety educational units most commonly used by the industry. Further sessions were attended as participant-observer to lead specific discussion on quadbikes and interview attendees and observer-only to review the content and record participant discussions on quadbike use.

Semi-structured interviews were conducted widely with representatives across the system levels including: farmers using quads who were not part of the LCE study, farmers choosing not to use quads, ACC and OSH staff both centrally and in the regions, private insurance providers, members of the Agricultural Health and Safety Council, training providers, Federated Farmers, quadbike dealers, mechanics and the manufacturers of quadbike implements and accessories in New Zealand.

In the case of key industry informants the subjects were interviewed in several stages from initial exploratory questioning, progressing to a more specific format as researcher knowledge of the systems and their behaviour (Sinclair, 2005) developed iteratively.

Course-content analysis of practical training sessions offered on quadbike use was conducted, and paper-based, audiovisual and electronic resources on New Zealand usage reviewed.

Table 4.1 Industry consultation – by system level

System Level	Sources
Government agencies and Regulatory bodies	• ACC • OSH • Statistics New Zealand
Non-Governmental Organisations	• AGITO • Federated Farmers • Farmers Mutual • New Zealand Council of Trade Unions (NZCTU) • SafeKids • Overseas researchers in the USA, Canada, Australia, UK.
Social environment	• ACC and OSH local staff • Family members • Farm Discussion Groups • FarmSafe training sessions • Local Trade Union organisers • Media: journalists, editors, producers
Organisation	• Farm owners / managers • Farm Discussion Groups
Physical environment	• Farm owners l managers / supervisors • Farm Discussion Groups • FarmSafe PLANS course – participation and review
Cargo	• Manufacturers of accessories and appliances • Mechanics
Machine	• Importers • Dealers • Mechanics • OSH Engineering specialists • New Zealand Qualification Authority standard training sessions with Langrip Training. Participation and review • FarmSafe Skills – ATV. Training course, Waikato. Participation and review
Rider	• Individual users • Individual farm users who have had LCE but not included in the LCE study • Individual farm staff choosing not to use quads • Farmers who use quads for work but also for recreation and/or competitive racing • Personal Protective Equipment (PPE) designers and retailers

The individual data collection exercises are itemised in Table 4.2. The method employed was a semi-structured discussion around a consistent framework with questioning centred on: the tasks, the users, the machines and the interventions tried to date. The loose format was selected as there was a need for a substantial exploratory component - the roles, interests, political positions and areas of expertise of the various parties consulted also needed to be established during the sessions. The structuring of the interviews was tightened in subsequent sessions for those who were consulted several times - such as the ACC Programme Manager for Agriculture.

Table 4.2. Industry consultation (by organisation, in alphabetical order)

Source	Interview schedules – main points
ACC Injury Prevention Office (Manager – Agriculture) (Interview 1)	• Tasks. Sources of data on quadbike usage patterns • Risk factors for key tasks – distal. Work organisation factors in LCE, performance decrement at busy times of year such as lambing/calving • Users. Macro-scale influences on those using quadbikes in the industry. Job dissatisfaction and recruitment problems getting experienced young workers in the dairy industry • Interventions tried. Influential agencies in determining regulation of use, including sources of likely support and resistance • Interventions tried. Existing research on the benefits and hazards of rollover protective structures (ROPS) on quadbikes
(Interview 2)	• Tasks and users. Critique of the methodological approach and usefulness of the findings of existing studies – including the OSH / Federated Farmers study (1998) • Interventions tried. Approaches planned and the evidence base / rationale for these • Interventions tried – design changes to the machine. Responses of the manufacturers to national level pressure and criticism of design • Interventions tried. Barriers experienced when attempting to change farmer and farm labourer behaviour,
(Interview 3)	• Tasks. Agricultural uses versus recreation, armed forces • Interventions tried. Regulation, vehicle licensing and mandatory warrants of fitness • Interventions tried. Roll inhibition devices, video resources for training and education • Risk factors and interventions. Video resources reviewed and discussed (ACC 2000; ACC 2001a; ACC2001b)
ACC Injury Prevention – Research (2)	• Interventions tried. Potential action via the Consumer Ombudsman as quadbikes arguably not fit for some purposes for which they are sold
ACC Regional Offices Taranaki, Tauranga, Timaru, Dunedin	• Users, machines and tasks. Local characteristics Interventions. • Interventions tried. Effectiveness of using Case Studies for injury prevention in the farming sector
Accessory manufacturers for quadbikes (2)	• Research and development approach • Future trends in quadbike use
Agriculture Health and Safety Council (formerly the Agriculture Industry Focus Group)	• Tasks and users. Exposure to high risk tasks • Machines. Population-specific features including: use of child sized quadbikes by smaller Asian adults in New Zealand, automatic transmissions for older riders • Machines. Matching the right vehicle to the tasks, risks from poor matching such as towing with some automatics • Interventions tried. Training opportunities for industry regulators
Agriculture Industry Training Organisation (AGITO) Head Office	• National training database analysis findings • Training, priorities and uptake • Induction training • Demographics and characteristics of new entrants to the industry
Agriculture Industry Training Organisation Coordinator (AGITO) Waikato	• Users. Knowledge gaps • Interventions tried. Training opportunities and course content for quadbike riders

Table 4.2 continued

Source	Interview schedules – main points
Industry training (AGITO) Coordinator South Auckland	• Users. Knowledge gaps • Interventions tried. Training opportunities and course content for quadbike riders
Amalgamated Workers Union (Northern, Wellington and Southern offices)	• Users. Conditions of employment, representation trends
Coroner for Southland	• Patterns of fatalities and serious harm cases in New Zealand and Britain
Employees using quadbikes (1)	• Working conditions that impact on quadbike use • Engineering considerations when attempting to modify off-the-shelf products
Emergency services. Manawatu	• Incidence of entrapment in serious injury callouts
Engineers and farmers specialising in concept vehicles for agriculture (4)	• Machines. Suitability of quadbikes for New Zealand farm conditions • Machines. Interventions such as speed governors, dual tyres, tilt warning devices
Farm Discussion groups – sessions on quadbike design and use Greytown, Wairarapa, North Island (8) Kuriwao Farm Action Group, Otago (6)	• Best ways of introducing changes in farming methods - collective and collaborative approaches • Alternatives to learning about quadbike limits by trial and error • The importance of research exercises achieving predictive power at an individual level – farmers have to be able to improve their ability to detect and manage risks with quadbikes • Ways to realistically improve machine maintenance • Influencing change amongst different age groups, trusted sources, un-trusted sources • Attitudes to over-loading, passengers, children riding • Communications difficulties from remote locations • Trends including social pressures
Farmers not using quadbikes (n=2)	• Tasks – how they may differ from farms where quadbikes used. • Machines. Experiences with quadbikes on their property, reasons for not using quadbikes now
Farming consultants (2)	• Financial implications of quadbike incidents – losses and damages
Farmers and family members who are not included in the LCE study. Includes phone interviews, email and letters (n=31)	• Tasks – how they may differ from farms where quadbike LCE are currently occurring • Users. Psychological stressors and indicators of these • Machines. Experiences with quadbikes on their property, reasons for good LCE record with quadbikes now • Machines. Comparative methods of testing stability to help purchasers get the right one • Risk factors for key tasks including discussions on historical LCE including review of television programmes: TVNZ Inside New Zealand (2004), TVNZ Assignment (2001) • Interventions tried
Farmers also riding quadbikes recreationally and competitively (n=2)	• Tasks and key risks. Differences between farm use, quadbike racing and trail riding

Table 4.2 continued

Source	Interview schedules – main points
Farmers Mutual Insurance Company Claims Manager	• Users. Characteristics • Machines. Damage types and extent following LCE
FarmSafe training Facilitators and Regional Coordinators	• User training needs and most effective approaches to developing and delivering material
Federated Farmers Health and Safety Spokesman	• Tasks • Users. Skill acquisition models • Interventions tried. Priorities for them as a lobby group, work organisation
Federated Farmers Head of Policy	• Interventions tried. Realistic time periods for behavioural change (intergenerational)
Land Transport Safety Authority (LTSA)	• On-road use of quadbikes • On-road use of quadbikes with trailers
Mechanics (2)	• Machines. Performance of different types of quadbikes and quadbike parts
Media (Journalists, radio staff, and editors) from trade press, local press and radio in farming areas, National Radio and TV farming programme producers (16)	• Local experiences, social pressures, reporting culture, • Attitudes to family use, training, PPE, • Trends in usage, advertising and sales of certain products • Communications styles and approaches that work with the farming community • Smallholder and lifestyle blocks – use of quadbikes
NZCTU	• Users. Trade Union representation and working conditions
OSH Engineering Inspectors (2)	• Tasks. Those high risk for rollover LCE, investigation methodologies by OSH, success with database project 1999 • Interventions tried. ROPS studies so far, methods and findings
OSH National Agriculture Spokesperson	• Underlying influences. Industry structure and political positions, historical perspective on injury prevention initiatives, including vehicle registration issues • Quadbike sales and usage in New Zealand • Application of New Zealand research in interventions • Interventions tried. Information resources for quadbike users
OSH National Agriculture Spokesperson	• Tasks and users. Value of OSH / Federated Farmers study (1998)
OSH. National Specialist Inspector for Agriculture (Interview 1)	• Tasks. Use of quadbikes in farm/forestry • Interventions tried. Establishment of Agriculture Safety Focus Group 1995 and the 1996 OSH Farm Taskforce; aims, functions, barriers to progress • Tasks and user characteristics. The OSH / Federated Farmers study (1998) • Interventions tried. ROPS – the history of their use in New Zealand, politics, research, and current arguments for and against • Research priorities, including the lack of awareness regarding the role of work organisation factors in LCE • Young riders - regulations, anthropometry and cognitive problems in operating adult sized machines
OSH. National Specialist Inspector for Agriculture (Interview 2)	• Task. Analysis and function allocation evidence available – is the quadbike the right tool for the job, or is it just the closest available?

Table 4.2 continued

Source	Interview schedules – main points
(Interview 3)	• Underlying influences. o Problems caused by having no National Strategy agreed, including inconsistencies in training course content o Increases in average herd size (x2) o Suspected increases in hours and speed of work • Interventions tried at national scale. Barriers experienced by OSH when attempting to work 1:1 with farmers • Interventions tried. Experiences with Best Practice initiatives in related industries.
(Interview 4)	• Users. Reporting procedures and reporting behaviours following incidents • Users. Reporting peaks during technology transition periods (eg. Oxen-tractors-quads) • Interventions tried. Attempts at national databases for investigations • Context study contacts – media • Interventions tried. New models, six-wheeler side-by side cabbed ATV – potential applications
OSH. North Harbour Agriculture Coordinator	• Users. Knowledge gaps • Interventions tried. Training opportunities and course content for quadbike riders
Overseas bodies Australia, Britain, Canada, South Africa, Sweden, USA, (n=9)	• Tasks, users and machines. Comparative data • Interventions tried. Comments on New Zealand design for front-mounted ROPS • Methods
Personal Protective Equipment (PPE) designers and retailers (n=6)	• Users. Attitudes to helmet use, specifications and standards • Interventions tried. Helmet use, insurance company reluctance to pay when PPE not used
Quadbike importers and dealers: Honda, Polaris, Suzuki, Yamaha, Kawasaki (n=6)	• Tasks. Limits of use • Users. Characteristics, preferences, buying patterns, willingness to do training • Users. Recreational sales versus occupational. Membership of ATV sports clubs • Machines. Trends, new developments, popular features • Interventions tried. Preferences for behaviour change
SafeKids	• User characteristics for younger riders
Statistics New Zealand	• Epidemiology. Agriculture survey 1999 • Farm land usage and topography
Telecommunications network and hardware providers	• Communications options for quadbike users in remote places
Trainers (private) and guides - quadbike riding and maintenance (n=6)	• Licensing of riders • Tasks. Specific risks • Users. Conceptual knowledge gaps at all ages • Users. Intuitiveness of quadbike designs – common problems for new riders • Machines. Robustness in the hands of trainee riders • Interventions tried. Training opportunities, motivators to enrol and ideal course content for quadbike riders
Quadbike tyre dealer (1)	• Ideal designs of construction and tread pattern for different situations

4.2.2 Data collection on farms where LCE have taken place

4.2.2.1 Design

The study design built on the findings from the industry consultation by formulating a context analysis of the farms systems where the LCE (reported in Chapter Five) were investigated. The context study data collection was carried out predominantly at the same visit as the LCE investigation, and consisted of semi-structured interviews and participative inspections with the LCE subject and other quadbike users at their workplace.

There were two reasons for using the same farms and same visits for both the context and LCE studies. Firstly the combined approach provided a substantially greater depth of data on the farm systems within which the LCE had taken place, which it was suspected may be needed for analysis. This proved to be the case. It was also found during the pilot stage that in some cases it took several hours on site to build the personal trust and understanding necessary to draw out the organisational level factors behind the LCE. At the same time it was realised that multiple visits were considered overly invasive by the farmers. A single visit was therefore seen as optimal to maintain goodwill.

Secondly, to secure the cooperation of the farms it was essential that the exercise as a whole made sense to them when explained in summary form during the initial telephone call. As a package, the context study and LCE study were found during piloting to have the right balance of pragmatism and thoroughness to gain support. On its own however, the context study could be seen by the respondents as either too academic, or too likely to be disguised marketing research, for busy self-employed people to give up their time.

The site work part of the context study was limited to farms where LCE had taken place. There is useful further work to be done on resilient farms where LCE are not occurring – as discussed in Chapter Six, but it was beyond the scope of this research. The task of objectively verifying the absence of LCE – rather than simply accepting

the claim of the farm owners of having had no LCE – would be a considerable, but essential first task in itself.

In four cases the subjects interviewed were contractors who had changed farms frequently and were no longer working where the LCE (through which they were contacted) took place. In all other cases the quadbike users were still at the same farm.

4.2.2.2 Sample

The sample of users was **119** identified occupational users of the quadbikes on the 53 farms studied. Recreational users including visitors getting farm tours, and children not engaged in productive farm activities were excluded. Of the **119** users, **21** were unavailable or declined personal participation in the interviews and so in these cases basic data on age, sex and employment history were obtained from colleagues.

4.2.2.3 Procedure

Initial contact was made by telephone to the individual on the farm whose LCE was being considered for investigation as described in full detail in Chapter Five. All quadbike users on the farm were invited, via the LCE subject, to take part in the context study at this point.

Timing of the site visits during the day was critical. It was found during the piloting, as described in detail in Chapter Two, that attempting prearranged group interviews on farms during working hours was largely unworkable as too few people would commit in advance, and were often scattered geographically for most of the period at work. Once the interview(s) were in progress however, others would join in if they were in the same location. Arrival of the researcher was therefore arranged to coincide with the start of breaks for lunch or morning tea when as many as possible of the users would be present or at least coming past. Initial introductions were therefore done at collection points – normally the farmhouse kitchen or the shed in the yard used for storage of personal gear and food.

The procedure on site was for an initial briefing to be held with the individual concerned, during which the Information Sheet and Consent forms (Appendix I) that had been provided in advance by fax, email or post were discussed. Additional personal copies were provided for other quadbike users that wanted to be present so that each had a copy to retain if they wished. The information was collected principally in a group setting as constructed by the people on the farm with an interest in quadbikes, unless an individual requested otherwise or the researcher suspected important subjects were being kept out of the group strategically and that their absence would seriously affect the integrity of the findings; for example, an employer not allowing an employee to relate their thoughts on the induction training provided by the farm. The context study interview schedule is included in Appendix II.

Responses were recorded using longhand notes that the subjects could read if they wished, or audio recorded using a camcorder where permission was forthcoming and then transcribed by the researcher.

Following the semi-structured interviews and focus group sessions, the machines currently used by the riders were inspected. Basic task analysis of the main tasks being undertaken with the quadbikes was then conducted using walkthrough-talkthrough and participant observations. The aim of this analysis was to gain both an appreciation of the ultimate objectives of the tasks and also enough understanding of the terminology to enable accurate, subsequent interpretation of data.

This sequence of investigation was followed as closely as possible, but had to be adjusted on some sites to fit in with subject availability, weather, tasks in hand on the day, difficulty of terrain, availability of personal transport into remote areas, and domestic politics. Sensitivity to these factors was critical to the successful collection of good quality data as none of the subjects were remunerated in any way.

In particular, the need for objective triangulation through multiple sources of corroborative data demanded careful explanation from the researcher. Riders were generally overconfident of their ability to answer certain questions accurately, such

as the total number of hours spent riding each year and most exhibited initial reluctance to cross-check against other records.

4.2.2.3 Quadbike assessment

The state of repair of the quadbikes currently in use on the farms was assessed against a set of factors judged by professional quadbike engineers to have significant effect on handling. The method was designed by the workshop staff at Rotorua Honda and validated by the Agricultural Health and Safety Council (AHSC) which includes the New Zealand Motorcycle Distributors Association (NZMDA).

The test factors were: tyre pressures (objective gauge test), tread depth (objective gauge test), wheel bearing adjustment (subjective test for any detectable play), head race adjustment (subjective test of any detectable play/knock) assessment, suspension wear (subjective test of any detectable secondary bounce), and park brake effectiveness (objective test of any movement after 35kg horizontal force applied). Twisting or cracking of the towbar and attachment structure was also visually checked for. The researcher was trained to assess these elements by the Chief Mechanic at the Rotorua Honda dealership.

4.2.3 Participatory methods

It could be argued that ergonomics is inevitably participative but the term has been loosely attached to an increasing number of case studies. Recent work by Haines, Wilson, Vink and Koningsfeld, (2002) has therefore sought to more clearly define the elements in a Participatory Ergonomics exercise, and to provide a validated Participatory Ergonomics Framework (the PEF) that enables researchers to design and describe the studies more systematically and comparably. The methods developed for the two major studies in this research exercise - the context study reported in this Chapter, and the LCE investigation study reported in Chapter Five, were therefore assessed against the PEF.

The PEF was validated predominantly against larger organisations than the 1.5 person workforces that dominate NZ agriculture, which limits its direct applicability to this quadbike LCE study but not its relevance entirely as a practical guide. There are nine elements or Dimensions of the PEF (Haines et al., 2002, p. **324)** and Table **4.3** discusses the extent to which this study engages participatory principles. As can be seen, the primary limitation is that implementation and hence the potential for full iterative development is excluded. Within this limitation however, the design of the context and LCE investigation studies can be seen to usefully incorporate Participatory principles where possible.

Table 4.3 Modified Participatory Ergonomics Framework (PEF)

	Dimension	Categories	*Quadbike context and LCE studies notes*
1	Permanence	Ongoing - temporary	*The exercise is temporary as the funding does not encompass implementation or evaluation stages*
2	Involvement	Full direct participation Direct representation Delegated participation	*Full direct participation by a sample of individual riders and industry members, Delegated representation by Agricultural Health and Safety Council members for those who belong to the 14 groups that form it*
3	Level of influence	Group of organisations Entire organisation Department Work group / team	*The study was funded by a combination of Government sources and the interventions developed apply across all levels of influence. The funding is not accompanied by any commitment to change at any level however, which is a major weakness in this type of injury prevention exercise in NZ**
4	Decision making	Group delegation Group consultation Individual consultation	*Rests with a variety of bodies, and carried out separately to this project – again a limitation of much injury prevention research.*
5	Mix of participants	Operators Line managers Senior managers Internal specialist / technical staff Union External advisor Supplier purchaser Cross industry organisation	*All included apart from unions who have a very limited membership in the South Island, and virtually none in the North Island.*
6	Requirement to participate	Compulsory - voluntary	*Voluntary in all cases.*
7	Topics addressed	Physical design / specifications Design of jobs and work organisation Formulation of policies or strategies	*All*
8	Brief	Problem identification Solution development Implementation of change Set up / structure process Monitor /oversee process	*Problem identification and solution development.*
9	Role of ergonomics specialist	Initiates and guides process Acts as expert Trains participants Available for consultation Not involved	*Initiates and guides process, acts as expert and available for consultation.*

* (Moore et al., *2005)*

Participation is also important if the design of products such as quadbikes are to match the physical capabilities and perceptual expectations of the users. A concept that emerged from Ecological Psychology in the 1970s was that of 'affordances' in design (Mikellides, 1980; Gibson, 1986). Quadbikes may have looked like "big soft

toys'' (Karnes et al., 1986), and afforded a safer and more stable option than two-wheelers, but proved to be far less benign than expected. Participatory measures are needed in conducting 'task-specific analysis of the organism-environment system' to achieve a successful affordance design (Warren, 1995), so that the intuition of new users more closely matches the actual characteristics of the machine.

4.3 Findings

Findings on the context of quadbike use on New Zealand farms are presented in the following order. Firstly the tasks for which the quadbikes are used are examined. The nature of these tasks and key characteristics that influence LCE risk are also considered. Potential mismatches between what the machines were designed for and their actual application are further explored through a discussion of changes asked for by users. The importance of these machines to the economic viability of farms is discussed using rider analysis on their alternatives to using quadbikes, and the greater costs of these options.

Key characteristics of the people using quadbikes are then discussed. The findings draw extensively on the data gathered on the 53 study farms in examining: employment status, sex, riding exposure hours, age, experience, and training. Riders' feedback on their adherence to the manufacturers' guidelines for quadbike use is reported, as is their approach to induction training for riders new to the property, and the wearing of personal protective equipment.

In the final section of the analysis a profile of the quadbikes in use is presented. It includes, the age of the quadbikes, state of repair, degree and type of modification, makes, drive train, distribution of machines by farm type, usage and ancillary implementation on the 53 study farms together with supplementary data from the industry consultation.

4.3.1 Tasks

4.3.1.1 Introduction

No previous study had established how quadbikes are used on New Zealand farms, how well suited they are for these applications, and whether there were any critical mismatches or shortcomings compromising performance and/or health and safety of the users.

4.3.1.2 Primary usage

In the vast majority of cases the machines have multiple uses at work. However, Figure 4.1 shows that the most common primary task for which riders use the quadbike is mustering (54%). The next largest task category was transporting self and dog(s) (16%), followed by bringing the herd in along the races from the grazing blocks to the milking shed. The remaining nine task areas made up the final 16%.

Recreation, including recreational hunting, represents less than 1% of quadbike use on New Zealand farms. Some non-work use is included in the personal transport category shown in Figure 4.1, but this was explained by the riders as being predominantly organised trail rides with local groups on just two or three days of the year. Less than 5% of riders took part in these. Dealerships interviewed suggested that the sports ATV clubs in New Zealand have approximately 4000 members in total, which, assuming the estimate (see 4.3.2) of the total quadbike user population is accurate, would further indicate that less than 5% of quadbike riding in New Zealand is recreational.

Farmers interviewed who had been on trail rides and also raced competitively (one was a former New Zealand title holder), noted important differences between these modes of use. Racing was considered the safest as riders are reportedly totally focussed on vehicle control, events are marshalled to keep out irresponsible riders, machines are checked (scrutineered) and the riders are generally experienced and of above average ability.

Trail riding in large groups across country is considered by participants to be more hazardous due to the competitive nature between riders that invariably emerges, combined with: a lack of discipline, no marshalling of the route, mismatched machines - some in poor condition, and the potential for distraction while riding in demanding terrain. ACC local office staff in the South Island spoke of 'rally psychology' with everyone grouped together riding 'too fast, too close'.

An eye witness to a trail ride fatality added that unfamiliarity with the route adds to the risk, as does the common practice of taking passengers on these social occasions. In ascent the passengers weight can act behind the rear axle, making a backward tip of the machine more likely, especially when the rider 'blips' the throttle, as under acceleration the passenger is forced to push back against the rear rack.

No data are available that identifies incidence or severity of quadbike injuries from these two uses specifically.

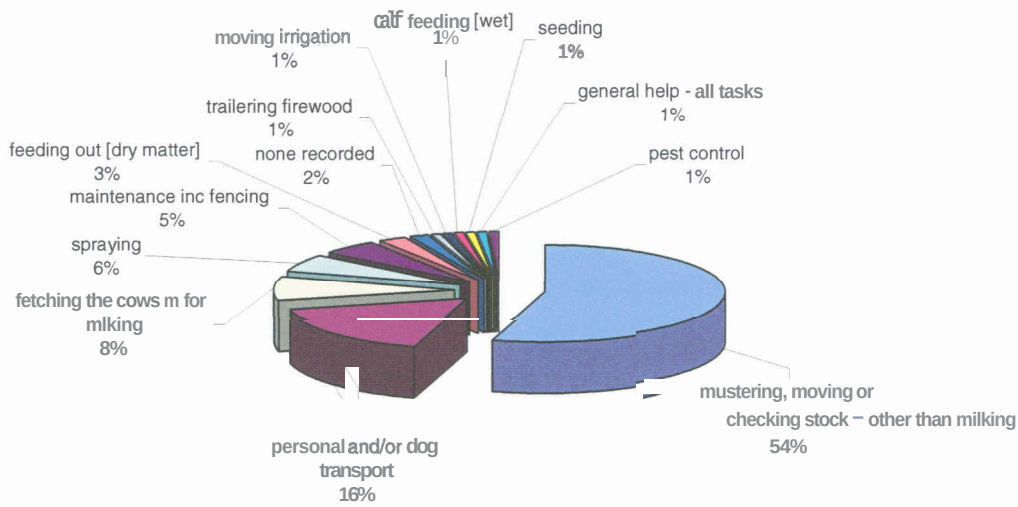

Figure 4.1 Primary task for which each quadbike is used

4.3.1.2.1 Mustering, moving or checking stock

Most commonly of all, the quadbikes are used for either moving groups of animals between grazing areas, or bringing stock to collection points for checks, treatments, or for loading onto trucks for movement to other sites. Checks and operations may also be carried out while the stock are being worked through the milking shed.

To minimise injury and distress to stock, mustering should ideally be a calm, slow speed affair, and when achieved, the slow soporific pace can in itself be hazardous. In discussing quadbike usage, riders in hill country noted having experienced micro-sleeps while moving slowly at low speed behind mobs of sheep. In the vast majority of cases however, speed is needed.

A very common scenario for LCE is where an animal breaks from the rest of the mob or herd. To keep the group together, either a dog or the rider needs to move fast for 20-30m to get into the line of the animal and 'head them off back in with the rest. A dog's acceleration and turning ability normally make them far superior at this. When the dog is young and just learning, too old, or simply not good enough, the riders attempt to do the 'heading' instead, despite knowing that they and bike combined are not really quick or agile enough. The rider is also aware that heading involves much greater risk as they can't keep an eye on both micro-terrain and animal to be headed during those few seconds' dash. Hence LCE explained as 'rider doing the dog's job' were common in the respondents' experience.

During lambing the farmer will use a quadbike and trailer to check the ewes and new-born lambs and bring in the dead ones or those that need further attention. Often in colder areas the trailer is rigged with improvised shelters, as shown in Figure 4.2 to keep the lambs alive until they get back to the farm.

The reported frequency of lambing beats reportedly varies a lot - from three times a day to once every two days depending on: whether or not the ewes are 'easy lambers' and the weather. The difficult conditions combine with fatigue to make each sortie a high risk task in comparison to general usage throughout the year. There is also some anxiety attached. The profitability of the farm for the year is influenced

heavily by the size and health of the lamb 'crop'. The individual with little or no veterinary training is also responsible for intervening where births have not gone smoothly, which is a further concern for some.

The farmer's personal approach to long term stock management can reduce inherent quadbike LCE risk through minimising hours spent riding at the busiest times of year. Where 'poor lambers' who have complications at birth have been systematically taken out of the mob and sold on, the result is a farm system that requires far less of the high risk all-hours lambing 'beats'. Instead of a quadbike and trailer being ridden through several times a day, the farmer can walk quietly through every few days as there are far less dead sheep to collect.

Figure 4.2 Trailer modified to carry lambs in exposed hill country in Southland. Live ones in need of warmth are stowed in the cut-down plastic containers for transport back to the farmhouse.

Improvisation on load carriage generally increases risk of a LCE. This is especially true when the load is a live one. When working without a trailer to place stock in, any animal found that needs bringing into the farm has to be carried across the knees of the quadbike rider so that it can be restrained.

Figure **4.3** shows further modifications. Home-made containers have been added around the dashboard console for tools and materials needed at lambing time. This ability to improvise stowage of small items is a major advantage of quadbikes over two-wheelers on expansive South Island sheep stations.

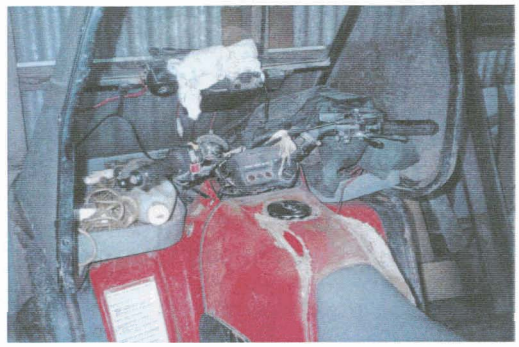

Figure 4.3 Home-made containers for tools and materials

The exposed thumb-activated throttle lever is too easily struck by the thrashing legs of the animal carried this way. Other riders report placing the animal on the running board of the quad and restraining it with their foot. There are obvious risks here to the wellbeing of the animal who is very close to the moving wheels and risks entrapment in the wheel arch, but the rider also has less control as there are generally controls (brakes, gear levers etc) to foot-operate, and the ability to weight shift and actively ride the quadbike is diminished.

Additional risk factors are reported by those respondents who have taken on run-down properties or young farms that have never been 'broken-in' - other than having the bulk of trees cleared from grazing areas. Risk factors include: financial stress from high levels of borrowing, more unpredictable surfaces to ride on (Figure 4.4) , in many cases young children to parent, and partner often in second job – adding to the isolation from immediate help if the rider is injured during the day, plus extra domestic duties at night.

Figure 4.4 Typical terrain for remote farm with previously un-ploughed grazing. East coast of Wairarapa, North Island.

4.3.1.2.2 Fencing

Fencing is specifically mentioned in just over **6%** of the LCE investigated in Chapter Five, but there are two quite different **tasks** covered by this: the building and repair of permanent (typically post and wire) fencing, and the daily moving of lightweight mobile electric fencing. The heavy work involved in permanent fencing is described later under **4.3.1.2.6** Maintenance Tasks as most new fencing runs of any significant length are constructed by specialist contractors.

Figure 4.5 The researcher demonstrating the system which allows the rider to place fencing support poles in the ground, without leaving the quadbike seat.

Movable electric fencing systems are a key tool for those seeking to run a profitable farm, as they provide control over where the stock can graze, optimising feed uptake and allowing pasture recovery. Traditionally a slow job with a lot of walking involved, these fences are now often set and retrieved without leaving the quadbike seat to speed up the process. The photograph in figure **4.5** shows a proprietary New Zealand-made quadbike-mounted system from a well-established property in the Hawkes Bay.

A cheap DIY version built on a small farm in Northland is shown in figure 4.6

Figure 4.6 Home-made quadbike-mounted fencing system

Perhaps inevitably though when dealing with fencing elements, such rigs afford significant extra opportunities for puncture injuries and pinning from point loads in the event of an LCE.

4.3.1.2.3 Collecting cows for milking

This is the third most commonly reported primary task for the quadbikes but is placed second in the list behind mustering moving and checking stock. While very different in function from gathering scattered mobs of sheep, moving a herd for milking can be argued to be a subset of the latter.

This task, using the quadbike, is normally carried out twice a day, around 5am and 4pm. The cows know where they are going, but the rider needs to open up gates ahead of them, and then move slowly at the rear of the herd along the races, re-setting the gates and the movable fences so that the stock return to the right areas of new grazing after their milking. Milking has now been reduced to once a day on some farms. The advantages of a single milking were discussed by a group of Waikato dairy farmers interviewed during the industry consultation. To offset the lower yield are: reduced costs in plant and labour, less travel time and impact from hard races and concrete surfaces for stock, less vehicle wear and tear and an improved lifestyle for the farmers.

The organisational implications of a once-a-day milking regime may be significant for quadbike LCE. Farmers experimenting with one less milking reported, during the industry consultation, reduced fatigue, and increased ability to complete afternoon maintenance tasks without rushing. The pressure of afternoon milking is also reported as an increasing stressor in those families where the second income is earned off-farm and parenting is a shared responsibility.

The task demands frequent mount/dismounts to open and close gates and set movable grazing boundary fences. A clear design advantage of a four-wheeler over a two is that the two-wheeler can easily fall over when the rider leaves it to work the gates, even if the side-stand is still functional. The ground may be too soft to take the weight or the ruts or slope may not offer the right angles. Apart from lost time in picking it up, falling over can damage the machine and spill fuel which could lead to fire as the engine is running. The four-wheeler by contrast does not rely on finding a solid piece of ground for the side-stand and can be left idling in gear, but stationary.

For a work system that contains frequent mount/dismounts on varied terrain these features of the four-wheeler clearly save time.

Very low speed riding behind the herd is far easier on a four-wheeler than a two. However, some lower limb ailments in dairy stock have been attributed to quadbike use. If the rider is too close, the animals will increase their pace to keep a comfortable distance from the noise, with resulting disorders over time. With two wheelers it was almost impossible to keep continuously moving at cow walking pace, and so the rider would have to stop and put their foot down to rest periodically – keeping them further back. A number of farmers have given out rules of thumb to young staff using quadbikes, such as keeping a full fence length (the space between two posts) back from the animals, to avoid hurrying the animals. It was suggested that the set-up of some machines resulted in them being awkward for riders to cruise comfortably at the walking pace of the slowest cow. Problems with recruitment into dairy farming in New Zealand, and apparently also Scandinavia (Lundqvist, 1996), have also resulted in a higher proportion of young workers with no farming background and therefore no acquired instinct for the psychology of herd animals which will exacerbate such problems.

Quadbike users on dairy farms are the most likely to encounter hazards related to public roads and other road users. The industry consultation revealed that Dairy operations tend to be sited on the higher quality valley land, and these more desirable districts have higher populations and hence a high density of public roads. The milking sheds and other farm buildings are generally situated close to the best land and the public road access, and so unless the farm sits all on one side of the road there can be up to four crossings of public roads per day per animal. Implications for quadbike use include: difficulties in tyre selection where sealed surfaces are to be encountered as well as deep mud, problems in maintaining an upright riding line on a cambered highway, and conflict with other drivers in fast moving road vehicles.

Figure 4.7 shows a quadbike that regularly crosses the public road with the cows. The owner has added a flashing amber light mounted high on the ROPS frame at the back to alert drivers. Note also the fastening of the home-made front storage box to the frame. Tyre inner tubes are used to lash it to the bull bars so that when the quadbike rolls there is elasticity in the joints. Rigid welded joints with bolted brackets would fracture, causing costly damage to either the frame tubing or box.

Figure 4.7 Quadbike that regularly crosses the public road

As discussed previously, it has become more difficult for farm workers to progress through the industry as share milkers, to finally becoming farm owners. The implications of this for quadbike usage are that historically, new milking staff generally had had some prior farm quadbike experience but this is no longer the case - according to the training organisation AGITO. Many young staff have also moved out from urban areas to take on dairy farm jobs, and do not adjust well to the social isolation and extreme working hours. Cumulative fatigue among young riders will increase risks of LCE, especially likely during prolonged peaks, notably the 6-8 weeks of calving.

4.3.1.2.4 Commuting and dog transport

The second most common use of the quadbike is for commuting and dog transporting, most notably travel between the staff houses and the main farm buildings at either ends of the day and at lunchtime. On large stations these can be several miles apart.

Dogs are generally provided with a mat or tray (Figure **4.8)** to sit behind the rider as they last a lot longer if not having to run everywhere – especially if they have to keep up with a vehicle. There is also less chance of these valuable animals being hit by a vehicle if they are riding on the quadbike when using public roads.

Figure **4.8** Honda with home–made dog tray

Farmers estimated that a dog needs at least two and a half, or even four years, to become fully trained, and life expectancy was reported at eight years. With the farmers running packs of up to ten dogs, being able to extend a working life by two years therefore represents a substantially greater return on investment. One farmer on a large sheep and beef farm reported that he decided to change from two-wheelers to quadbikes that his dogs could also sit on too, after loosing his best dog at the young age of *6.5* years through heart attack. It was brought on, he believed, from the mileage covered, having to run out to the mustering area as well as back.

Figure **4.9** shows a typical dog trailer on a Hawkes Bay farm. Extreme movements by these large animals can have a significant de-stabilising effect unless there are

compartments formed that keep the forces acting within acceptable parameters. For example, dogs commonly will rush from front to back if they see an animal such as a rabbit go past. Their weight and momentum acting behind the rear axle produces upward force on the rear wheels of the quadbike through the drawbar. If the vehicle has only two-wheel drive, a reduction in traction may result that is significant enough to trigger a LCE. The magnitude of this upward force is modifiable through design of the trailer and drawbar; a longer drawbar combined with trailer axle (the fulcrum) set further towards the rear minimises the effect by reducing the length of the lever arm behind the fulcrum. There is a balance to be struck with this however, as if taken to extreme, the weight being transferred onto the quadbike through the towbar can be excessive, resulting in heavy handling, fast tyre wear etc. A configuration is required that keeps positive downward force on the towbar of the quadbike at all times, without excessively loading it. A lot of trailers are home-made and this balance is achieved, if at all, by trial and error. It is an area of concern to the Land Transport Safety Authority who were interviewed on the matter during this study, and warrants further research leading to clear industry guidelines for use by commercial fabricators and DIY trailer builders alike (Moore, 2004).

Figure 4.9 Typical small un-compartmented dog trailer

4.3.1.2.5 Spraying chemicals

The use of quadbikes as light tractors has a significant impact on handling, as the machine is relatively light, has a small wheelbase and a high centre of gravity. Spray tanks can add up to 100kg, which acts as live weight when it surges in the tanks.

Spraying is primarily herbicide application, used to control unwanted growth of weeds such as gorse on pasture blocks. To be maximally effective it should be done during dry settled weather with little or no wind to drift the spray. Spraying an even application over an area is done with a wide boom arm or arms mounted across the machine. Spot spraying allows the operator with a triggered lance on the end of a long hose to apply to individual areas or weeds. This can be from the seat or when dismounted. The booms are generally mounted on the rear rack and run off the same tank as used for spot spraying.

Figure 4.10 CEDAX front mounted spray tank system with DIY spray hose extension using a domestic hose reel. The spray boom clips to the rear rack

Figure 4.11 Promotional photo of a new boom spraying system provided by CDAX Ltd, but with fluid still located above the centre of gravity of the quadbike

A recent development by the largest provider of quadbike spray equipment CDAX is the use of trailed tanks. (Figure 4.12) shows a larger capacity tank placed on a trailer.

Figure 4.12 Promotional photo of a new boom spraying system by CDAX Ltd, with fluid weight loading onto the ground through trailer wheels

These proprietary systems are widely available, but as with electric fencing equipment, many farmers elect to fabricate their own. The DIY efforts in particular can result in designs that increase the hazards markedly in the event of a rollover.

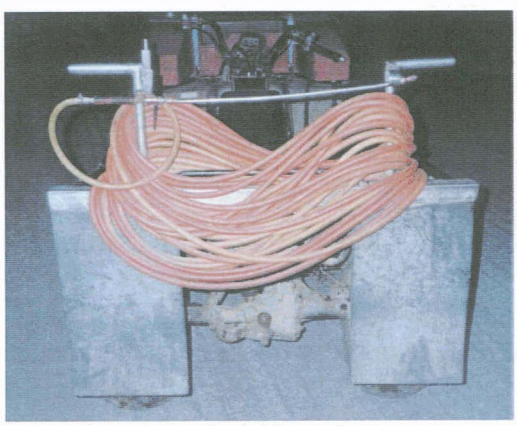

Figure 4.13 Home-made stowage frame for the spray hose with exposed spikes that could cause very serious puncture-type injuries in a rollover

Techniques vary for spot spraying. Solo operators are aware that they should park at a safe place and walk in with the hose, but they may be tempted to ride in too close if the hose is not long enough to reach far enough down the bank. They may also be tempted to spray without moving from the quadbike seat, to save both time, and the effort, of unwinding and rewinding the hose onto the drum. This puts the rider in danger as the true contours of sloping ground and its surface are often concealed by long growth in the areas being sprayed.

Some users report taking a second person when spraying to reduce risk taking and make the job faster. This person rides the machine slowly at the top of the bank or gulley while the sprayer walks with the hose and lance applying the spray.

Given that the areas to be sprayed are often the more remote sections of the property, the distance to be travelled from the farm can be considerable. There is therefore the motivation to fit tanks as large as possible onto the quadbike so that the number of return trips for refilling is reduced. For contractors especially this has significant ramifications for business profitability. Spray tanks on the viewed machines were all identified as un-baffled, i.e. fluid was free to move throughout the full tank volume without any surge control. This significantly influences centre of gravity positioning and rate of change in a roll.

It was common for spraying to be a task taken on by one individual on the farm. Often this was an older family member, such as a retired or semi-retired ex-worker. The reasoning is that it is a job that can be done at any time when the weather is reasonably settled, and so can fit in with their availability. Older riders find it attractive as there is not a lot of walking or manual handling as they see it.

In the low lying country areas there is understandably the habit of riding on the top of the stop bank (the bank formed by dredgings from the adjacent drainage ditches) to get a better view and identify areas that need spraying. These ridges are by nature soft and easily eroded. The combination of: older rider, secondary visual task, unstable angled micro terrain, fluid surge in un-baffled tanks accelerating rollovers, and water-filled ditches to be entrapped in, makes spraying often a high risk activity.

Figure 4.14 Typical low-lying country in the North Island. The dredgings are pulled out by a digger and form the stop banks, making these ridges very unstable for riding on.

4.3.1.2.6 Maintenance tasks

Maintenance is carried out predominantly at quieter times of the year outside lambing/calving or periods of intensive winter feeding. On dairy farms, the period before afternoon milking is also used for minor jobs throughout the year. The specific maintenance tasks that commonly lead to injury include work on fences, buildings and trees (Moore et al., 2005; Bentley et al., 2005).

A critical feature of doing repair jobs with quadbike is the necessary cartage of tools and heavy materials using a trailer and/or substantially loaded racks. Fence and gate repairs in particular feature in quadbike LCE event descriptions; this may be due the fact that the quadbike is the only vehicle available that can get into the remoter parts of the property with a load of materials. The main risk factor with permanent fencing appears to be transporting and handling the heavy and bulky materials (posts, wire, battens and staples) and tools. Up to 500kg in battens alone is reported as a common load. To reduce the number of trips back to the yard, riders report commonly overloading the trailers. The trailers invariably are not fitted with independent brakes, and as the loaded trailer will often weigh more than the quadbike, control in descent is very limited. If the trailer starts to jack-knife or simply pushes the quadbike faster than the rider wants to go, the rider generally attempts to keep it very straight, allow the vehicle to speed up and 'ride it out' at the bottom. For those with excessive trailed loads, steep or slippery descents are essentially therefore a controlled crash landing. Once committed to the descent the rider cannot brake or turn, and acceleration is the only remaining facet of control. The rider relies on there being a suitable 'run out' of straight level track at the bottom of the hill to enable them to slow down and regain control.

LCE in ascent when heavily loaded appear rarer and this is partly attributed to the fact that gravity may allow steep descents to be risked, but less steep routes up the hill are needed for the relatively light quadbike with heavy trailer. It couldn't pull the load up some of the hills it is asked to come down.

Farmers with experience commented that weight limits for trailer-work differed enormously between level race work and towing on hill country where the low weight of the quadbike itself and absence of trailer braking made descent, in particular, hazardous.

"It's not what you can pull in the yard - I can jump start my old tractor with the quad - it's what you can stop"
(Wellington Farmer)

The LTSA regulations covering trailers only require brakes to be fitted to the trailer once the weight of trailer and load combined exceeds 2.5 tonnes. The rationale for this presumably predates widespread quadbike use. Therefore until the regulation is revised to take more account of the newer uses by quadbikes, loads greatly in excess of the weight and stopping power of the quadbikes will be towed without trailer brakes.

4.3.1.2.7 Feeding out [dry matter]

New Zealand generally has a good grass-growing climate, and so there is far less feeding out of supplementary foodstuffs than is needed in many other countries. The most common feed types utilising the quadbikes are baled hay and haylage. Haylage is a cross between hay and silage, with the hay cut at a higher moisture content and then wrapped as a large bale in an airtight plastic bag to ferment. From an ergonomics perspective, the critical features of the feeding systems are that the older style square section bales are made to be moved by hand, whereas the big round bales can weigh from 400kg for dry matter and up to one tonne for haylage, and require mechanical handling at all stages.

Figure 4.15 One tonne bale on a car trailer

The racks that come fitted to the quadbikes most commonly used in New Zealand are designed to take the weight of one or two bales, and apart from some obscuring of vision the most common related injury scenarios appear to be from the discarded polypropylene twine getting picked up and snagging feet and wrists as it is wound under the tyres or round the axles.

Inevitably, given the culture of the industry, riders reported informal competitions on the farms to see who can carry the most bales on their quadbike and so feed out in the least number of trips. The most extravagant claim was by a farmer near Auckland.

"I can do 13 but that's sitting up high on top of the pile, and couldn't reach the (quadbike) controls so ... I rigged up some baler twine hooked round the gear shift that I could pull up to change". He was reticent when pressed to explain how he

pressed the lever to change down to a lower gear. Thirteen is highly doubtful therefore but it is clear that overloading causing obstructed vision and constrained handling is routine. It was however verified by colleagues that the idea of the baler twine had been found to work when the boss was riding the quadbike with a broken leg received in a horse riding incident. He could change down by stamping on the lever with his plaster cast 'pot' but couldn't get his toes under to change up – hence the baler twine to pull up on from the handlebars.

Of increasing concern is the manufacturing in New Zealand of purpose-built trailers to carry the heavy round bales. In some cases the trailer alone will exceed the recommended tow weight and of course has no independent brakes. With a one tonne haylage bale loaded the total could be three-to-four times the weight of the quadbike pulling it. As with fencing, the quadbike is operating well beyond its limits. Quadbikes are designed for speed and agility, and pure heavy load carriage of this kind is a conceptual mismatch.

Adding to the total risk is the practice of shunting big round bales into position by ramming them with a quadbike fitted with bull bars on the front. When hit at speed the quadbike either moves it as desired or the tyres bite and climb the bale, off-balancing the rider.

4.3.1.2.8 Movingfirewood with trailer

Old, dead, or dangerously leaning trees are cleared periodically. Most of this is done in the summer when there is time available and the ground is firm enough to get vehicles in to tow loads out. Those suitable for burning domestically are cut to rounds and hauled by trailer to a holding area near the house for splitting the following summer/autumn. The towing out of the rounds is not time critical and is reported as one of the jobs given to irregular users of quadbikes: family members, seasonal staff and students. Inexperience, peer pressure when working in a gang and the tendency to overload can be factors in LCE. The fastest growing timber Radiata Pine weighs 1 tonne per cubic metre when green. The more desirable timbers for heating are denser still and so overloading is easy to do.

4.3.1.2.9 Checking irrigation systems

In hill country properties the quadbike is often the only way other than walking or horseback of getting up the hills to check high level holding reservoirs when conditions are bad. Tractors and 4WD utes have more torque for the climb but on wet slippery surfaces with slope across the track, their weight may cause them to slide off the side. Lighter quads can bite and stay on the track, but do not provide the shelter from the weather which deteriorates as the rider climbs out of the valley. LCE on descent when the rider is cold and fatigued are reported.

4.3.1.2.10 Calf feeding [wet] using 'calfeteria'

Calfeteria is a brand name used generically for a mass feeding system operating from a trailed tank with teats. The calfeteria is pulled behind the quadbike and can hold up to 400-500 litres. Apart from the weight (1 litre of water = lkg) risk factors include lack of baffling in the tank allowing fluid surge, and the fact that the fluid sits high off the ground to allow natural gravity feed to the teats.

Experienced users have learned to operate with the right size tank for their needs and no larger. Towing a tank only half full allows greater potential for surge from side to side, destabilising the machine pulling it. Transporting the calfeteria is most safely done when either completely full or empty.

4.3.1.2.11 Spreading

Fertilisers such as nitrogen products and other granular materials are applied using quadbikes as the traction and power unit. The material is poured from sacks into hoppers, and loads can be substantial. The hopper sits relatively high in order to provide gravity feed without the need for power distribution. Most quadbikes have no Power Take Off (PTO) shaft driving from the crankshaft, as tractors do, and so have no such readily available source of mechanical power.

The height of the hopper and weight of the product (in excess of 100kg) produces a large rotational force on the towbar structure of the quadbike when it tips. Five of

the 69 machines inspected that had a towbar fitted showed signs of damage of this kind. The forces required to produce visible damage in the alignment of a towball are considerable, and would warrant further inspection of the chassis as a whole as handling may be affected.

4.3.1.2.12 Hunting and pest control

Quadbikes with shooting lights mounted are used for hunting - possums and rabbits mostly. Pest controllers also operate quadbikes for possum trapping, setting out boxes and then returning every few days to reset bait and clear carcasses. Risk factors for shooting include operation in the dark with dark adaptation of the rider's eyes comprised by periodic activation of powerful spotlights, and carrying a passenger holding a loaded gun.

Risk factors for pest control contractors are big loads, carrying poisons, heavy machines, unfamiliarity with the property and track condition, poor communications from remote sites and isolation when injured leading to long delays in getting help.

Figure 4.16 Taranaki quadbike with spotlight for shooting rabbits.

4.3.1.3 Design for the task

In the previous section the tasks for which the quadbikes are used were discussed. In this part, user opinions on existing system weaknesses were examined. The riders on the 53 study farms were asked, "what three changes relating to your quadbike, or its use, would help you the most with your tasks on this property".

The subject group as a whole had considerable quadbike experience, on average 10,000 hours each. The suggestions were generally pragmatic, detailed and in some cases based on experimental work already under development on their farm.

The findings in Table 4.4 relate to improved inherent safety through engineering design (42%), and improved handling and balance (39%), better design integration of the quadbike with ancillary equipment such as sprayers and trailers (11%) and improvements in operating costs and legislative control (8%).

Table 4.4 User opinions on how to improve quadbike functionality

Suggested improvements	n
Protection (when quadbike rolls) for rider and the clocks to be built in	24
Park brakes that are easier to apply and more effective	22
Lower centre of gravity	18
No gaps in footwell floor and / or better mudguards	16
More stable in ascent and / or point of balance further forward	13
Bigger wheelbase	13
Steering easier and safer including better damping	12
Better storage / stowage incorporated as standard	12
Cheaper parts and running costs	12
Rear axle differential	11
Reversing beeper or other device to stop inadvertent reversing	10
Practical helmets suitable for the tasks and weather	9
Suspension that is better on tussock and ascent generally	7
Integral communications system for tracking & emergency location	6
For all machines to have the option of 2 or 4wd	5
Throttle lever not proud of the handlebars	5
Kill switch or equivalent for LCE	5
Dog mats/trays purpose-made and fitted as standard	5
Lights that are more effective at night	4
Training on site and provision of training videos	4
Better worked out gearing	4
Squarer shouldered tyres	3
Dual tyre options	3
No requirement for active riding	3
Auxiliary throttle [one on the left as well for walking it off hills]	3
Baffled spray tanks	3
Lighter machine overall	3
Designed so less strength needed to ride it	2
Transmission lock	2
Swivel coupling on towbar	2
Govt control on the sale of dangerous ATV accessories	2
Cab and/or screen as standard	2
Wrap-around (270o degree) bars standard on new machines	2
Enforced WOF	2
Air bags	2
More supportive and/or comfortable seats	2
Bigger diameter wheels	1
Fully automatic	1
Optimisation of power to weight ratio	1
Tow bar arm extended to get ball more accessible	1
Quieter	1
Trailer that's designed specifically for each ATV model	1
Mirror for road use	1
Bigger spray fluid capacity on ATV-mounted tanks	1
Other (not engine related)	3
Total	261

That no one asked for bigger engines is interesting given the trend for manufacturers to bring out increasingly heavier and faster models each year. 'Who needs a farmbike that does 100km/hr -just for fetching in cows?' was a typical comment during the industry consultations. However, purchasing decisions are rarely if ever made on purely rational grounds (Jordan, 2002). More power may be a greater attraction than buyers are willing to admit.

Some people actually asked for smaller machines than are now available. Several older quadbike users volunteered complaints during the industry consultation about the reduced availability of the smaller 250-350cc machines. Reported advantages of these over the heavier replacements included: cheaper to buy and run, more nimble, more stable (presumably through lower centre of gravity), lighter and easier for older and weaker riders to control.

A commonly used technique for getting out of trouble on hills that only works with the lighter machines is to get off and drag the front around to face the vehicle straight downhill again before riding it out. This isn't an option with the heavier machines that now dominate the market. Heavier machines are also reported by farmers to be far harder to push off if they do roll onto the rider. The distributors acknowledged during the industry consultation that the newer larger-engined machines may have a greater tendency to roll if a higher centre of gravity is produced when a larger power unit is placed in the same sized chassis; the centres of gravity of both the engine and rider will be higher, but the wheelbase remains the same.

In discussing these findings with industry, a number of quadbike dealership staff remarked that changing the designs of the machines would do little to reduce LCE as it was the riders' behaviour that needed changing; "you never see two tonne of steel up in front of the judge – it's the driver that's the danger not the car". Risk Homeostasis Theory (RHT) – that is, in this case, that quadbike riders will take a certain level of risk and if you reduce inherent risk in one area for them such as improving the handling, they will simply go faster to maintain the 'risk homeostasis', emerged in the early 1980s (Wilde & Murdoch, 1982). Although the model was heavily criticised for its over-simplicity by others subsequently, for example by

Janssen (1988), this perspective clearly remains popular in some quarters, and serves as a barrier to change through constructive criticism of quadbike design.

4.3.1.4 The economic importance of quadbikes to farmers

Having described the tasks performed using the quadbikes, the subjects on the 53 study farms were asked how they would achieve the same tasks today were quadbikes not available. Responses were gained from 51 of the 53 farms. The findings demonstrate that the financial motivation to attempt to dispense with other vehicles and use the quadbike for everything is considerable.

Over a third (35%) stated that without quadbikes they would need significantly more labour, that the farm wouldn't be viable at all, or that it would encourage early sale of the farm and retirement. An average of 2.3 other vehicles per farm would be needed to replace quadbikes and achieve the same tasks, it was stated. Horses and walking are included as vehicle types. Figure 4.17 shows that in 30% of cases at least three would be needed.

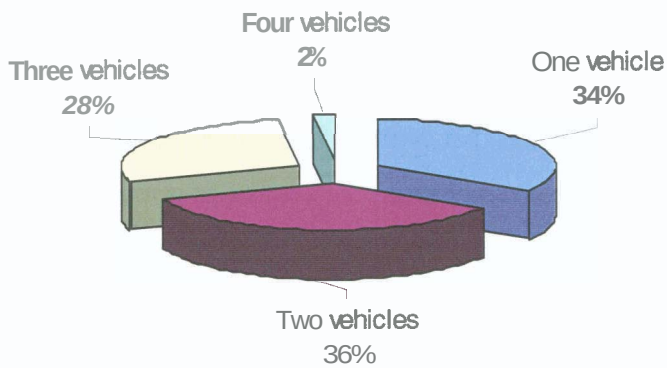

Figure 4.17 Number of other vehicles needed if quadbikes were unavailable

The most common combination of replacements anticipated was that of a 4WD Ute or Landrover, plus a two wheeler motorbike. This was stated at seven (13%) of the 53 of farms. None of the other twenty combinations were asked for at more than five (9%) farms, reflecting the very wide variety of functions the quadbikes are performing nationwide. The replacement costs were estimated at between $50,000

and $100,000 (second-hand Landrover, small tractor and a new two-wheeler). This compares to a new quadbike price of approximately $15,000.

"We bought this place on the basis of being able to do it all with one labour unit and a big quadbike..".
Young farming family on their first property. Wairarapa, North Island.

It appears to be a reasonable conclusion that some farms are now being run by people who are financially committed to using their quadbike beyond its capabilities.

"Quadbikes are a cross between a tractor and a car with the benefits of neither". Northland farmer

Analysis of the farm-types where LCE are taking place also reveals that mixed sheep and beef operations are over-represented in comparison to other types of farming. The other findings, shown in Figure 4.18, follow patterns consistent with the reports made in this context study. Sheep farmers on predominantly hill country have commented on their reluctance to use quadbikes when a large part of their work involves traversing steep sidlings (hill sides) using the narrow sheep tracks. Quadbike usage appears to be almost universal on dairy farms down in the valleys, and to a lesser extent but still the norm, on beef units. Forms of farming that focus on crops rather than animal husbandry are described by Federated Farmers as being less likely to be reliant on quadbikes as a sole vehicle, as they also need to have tractors and other heavy plant for cultivation and harvest haulage.

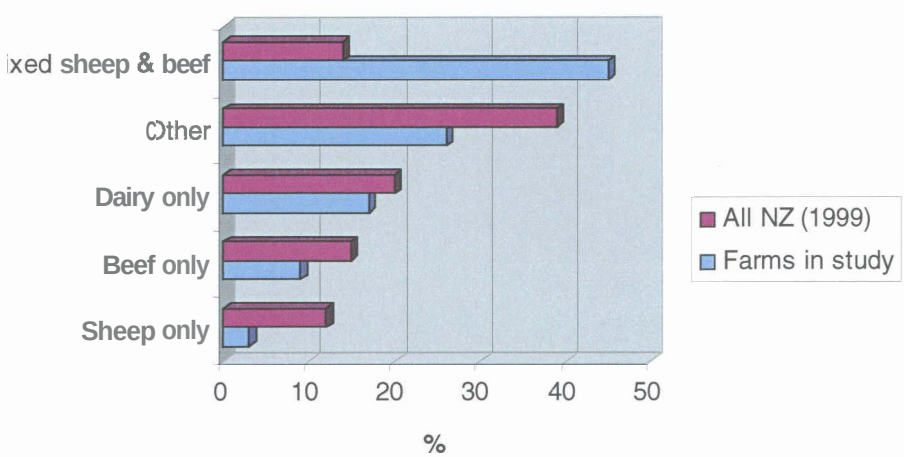

Figure 4.18 Farm activity types in this study, in comparison to the 1999 Agricultural census findings

One hypothesis that can be drawn from this is that farmers operating mixed sheep and beef units are being caught out when attempting to perform tasks with equipment not ideally suited to one, or both of these. Another possible explanation is that this type of farm is over-represented in the sort of property that new entrants to the industry buy. They are therefore financially stretched and tempted to try and make-do with less vehicles and labour. A third reason suggested is that these properties may comprise above-average proportions of low-grade land that results in difficult and unpredictable riding surfaces. Further investigation is warranted.

4.3.2 Quadbike users

> The major contribution to the complexity of driving safety is the multifaceted and adaptive nature of drivers.
>
> Lee (2006)

4.3.2.1 Introduction

This section presents the findings on the key characteristics of people using quadbikes on the farms including: employment status, sex, riding exposure hours, age, experience, and training. Riders' feedback on their adherence to the manufacturers' guidelines for quadbike use is reported, as is their approach to induction training for riders new to the property, and the wearing of personal protective equipment.

4.3.2.2 User population on the 53 farms

There were 119 identified occupational users of the quadbikes on the 53 farms in the study, indicating a mean of 2.24 riders per farm. Recreational users of the quadbikes including visitors getting farm tours, and children living on the farm but not engaged in productive farm activities were not counted.

Of the 119 riders, 21 were unavailable for personal participation in the interviews and so limited data covering just the concrete issues was obtained from colleagues.

4.3.2.3 National population and trends

There are no estimated figures available of total numbers of quadbike users in New Zealand. Taking the study findings of 1.5 occupational riders per machine as representative, would indicate a total of around 100,000 people riding quadbikes for work on farms at some point during the year.

Estimates of the workforce in New Zealand agriculture vary between 170,000 (Barnett et al., 1996) and 120,000 (personal communication Ron Ward, Agriculture Officer for OSH, 2002). Both sources indicate a composition of approximately 60% working owners, 20% family members and 20% employees. Union membership has never been as strong in agriculture as it has in the less scattered industries such as meat where plants have several hundred workers in one place. The Amalgamated

Workers Union reported in interviews for this study that membership has never been high in the North Island. It peaked at 40-50% in the South Island but has now fallen to less than 10% for agriculture and horticulture combined. The majority of these members are in the larger horticultural operations, and so the influence of the Union movement on farms anywhere in New Zealand must be considered as negligible.

The data from this study are therefore now the most comprehensive currently available to our knowledge for approximating any demographic profiles that may be needed in Public Health or the design of national level injury prevention intervention initiatives.

A relevant trend highlighted in interviews with Federated Farmers, FarmSafe and AGITO, and described in more detail by the focus groups, is the perceived increase of pressures on farmers which increases underlying risks in quadbike operation. A 1992 Lincoln University study (cited in Barnett et al., 1996) noted a decrease in paid staff on farms coupled with an increase in the amount of work being done by unpaid family members. It also reported more off-farm employment of family members, leaving the farm workers in greater isolation and with more domestic responsibilities. Two-thirds of the farms included in the Southland farming community injury prevention initiative reported by Barnett et al (1996) had pre-schoolers at home.

This supports the concerns of the focus groups members who noted spiralling competition, bigger, more valuable herds, more stringent quality standards (eg. extra scanning and disease control) enforced by the Ministry of Agriculture and Forestry (MAF), all leading to greater daily demands on their time. Land prices have climbed faster than profits further generating higher debt levels in the industry - a further underlying stressor. Debt appears to increase workload and build stress through a number of mechanisms including: reduced ability to buy in experienced help at peak times or replace old machinery that breaks down too much, extra time spent juggling bills and sourcing second-hand tools and parts, and taking on extra work for cash. These all add to the haste required to get everything done in the day, and increase the likelihood of short-cuts being taken.

4.3.2.4 Employment status and gender

70% of riders on the study farms were farmers, or family members of the farmer. Federated Farmers point out that operators of quadbikes on farms are rarely operating under direct instruction in a formalised employee-employer rule-based relationship of the kind found in other industries. A forklift truck driver in a warehouse can be given a strict set of rules to work within, and taken off driving tasks or dismissed for breaching these. On family-owned and run farms there is less practical scope for developing tightly structured operating systems that protect the user, as dismissal for contravening rules is generally not an option with family members. Supervision often has to be minimal on farms, and so unless the quadbike or rider has been visibly damaged, then breaches of the rules by the user are unlikely to be discovered. The daily working environment is also less predictable on a farm than it is in a warehouse, and so operating rules tend more towards general principles that require interpretation.

"Treat it with utmost respect. It has lots of weight and a small wheelbase, so you have to".
Mother and wife of quadbike users, Napier.

This further supports the argument for a vehicle type with a higher degree of error-tolerance.

The employment status can have a bearing on the suitability and condition of the machine being ridden. The industry consultation revealed that it has now become common on dairy farms in the South Island for younger employees to be expected to provide their own quadbike. Farm owners explained that this had emerged due to young riders racing and damaging the farm-owned vehicles. As a result, new employees without the means to get a reliable late version model state that they have no choice but to buy very cheap quadbikes in poor condition in order to get the job.

There is no mandatory vehicle inspection system for quadbikes in New Zealand, and so cheap, used quadbikes of the type being used by young people trying to get into the industry may be seriously faulty. Some were reported to have serious faults such as crash-damaged frames and missing brake parts. For individual owners, the

gradual deterioration of machines can to an extent be accommodated; they adapt to the 'local hazards' of their quadbike and ride within its diminishing capabilities: a missing parkbrake cable, a slow puncture that needs air added daily etc. The risk from these machines increases exponentially however when they are 'pooled', so that other workers at the farm may from time to time use the machine unaware of the mechanical faults.

Figure **4.19** shows slightly higher representation of family and employee riders in comparison to farm owners when compared to the national workforce estimates. This could be due to a proportion of the owners having solely a management role rather than a hands-on involvement.

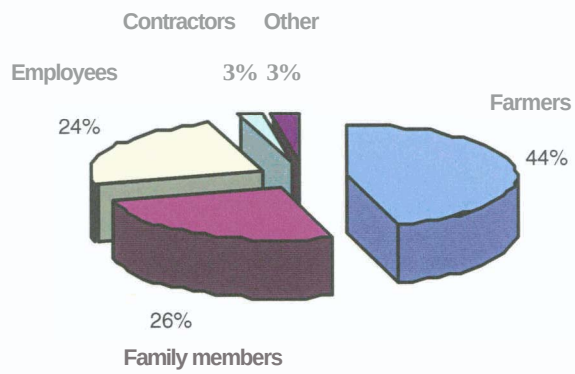

Figure **4.19** Employment status

In Table **4.5** we can see that **71%** of all users in the study are male, and that men also represent more than three-quarters of farmers and employees using quadbikes. Females, however, slightly outnumber males in the group of family members riding occupationally.

Table **4.5** all quadbike users by gender by employment status

	Male n=	Female n=	Proportion of males in each group	Total n=
Employees	26	**4**	**87%**	**30**
Farmers	**47**	6	**88%**	**53**
Family members	**15**	**17**	**47%**	**32**
Other	**2**	2	**50%**	**4**
All users	**90**	**29**	**71%**	**119**

Four users on the study farms were not farm owners, employees or family members. They were contractors and a technical consultant employed by a large fertiliser supplier. Contractors were included in the study as they represent a high-risk sub-population due to their intensive quadbike usage, unfamiliarity with customer farm terrain, lack of task variety. They are also by definition often called in to carry out work that the regular farm staff would prefer not to do – further increasing their risk exposure; for example, spraying weeds or doing fencing in remote and difficult areas. With such tasks a long way from base, big loads of materials are the norm to reduce the number of return journeys. One factor in the contractors' favour is that they are not generally reliant on unfamiliar farm equipment as they arrive for the job with quadbikes as well suited to the specialist tasks as they can afford. Spray is more often carried on customised trailers than on small quadbike-mounted tanks that destabilise the machine. Contractors' quadbikes appear to be relatively young and well-maintained by comparison to general farm quadbikes that have less intense use.

Technical consultants were not identified as high risk by any other industry factions in the consultation, but data direct from this group revealed some important risk factors. Most significantly, this population of users travel between farms in ordinary road vehicles, but then when at the farm, need to get to all parts of the property to assess pastures, or check sick animals etc in the case of a Veterinary specialist. Generally there is no practical alternative to using whatever transport is offered by the farm. This may be on the quadbike as a passenger, or where the farmer does not have time available to take them, as the sole operator of one of the farm's quadbikes.

The risk factors for technical consultants therefore include being the passenger of a rider whose capabilities are unknown, riding on unfamiliar terrain, isolation and using a vehicle that may be unsound.

4.3.2.5 Exposure

To gauge riding exposure, the subjects also estimated average and peak hours of use per week. To maximise objectivity their impressions were checked against archival sources, most commonly maintenance logbooks, work diaries from lambing/calving, and the recorded kilometres and hours of engine time run on the quadbike consoles. The annual exposure data is most reliable, especially for those quadbikes professionally maintained, as the machine-mounted devices recorded usage between services which was then recorded on the job sheets from the workshop. The annual usage history was therefore readily verifiable. Maximum hours per week data are less reliable, as users generally had to calculate mean hours per week from the annual figure and then extrapolate for the extra workload.

The findings are shown by employment status in Table 4.6. Typically we can see that the farm owners spent less time normally during the year on the quadbike, but at peak times would exceed the employees whose hours remained more consistent.

Table 4.6 (Exposure) hours of quadbike riding per week

	Mean hours per week (sd)	Max hours per week (sd)
Farmers	10 (6)	20 (13)
Employees	16 (13)	17 (12)
Family members	4	6
All riders	11	14.5 (13.3)

Total exposure hours during the year were estimated by assuming a 48/52 year for employees and a 50/52 for farmers. Peak periods of six weeks were included in this. Farmers were reportedly averaging 560 hours a year, employees 774 hours a year.

4.3.2.6 Age and experience of users

The mean age of all users was 40.7 years. Contractors and technical specialists are not shown in Table 4.7 due to the small sample size.

Table 4.7 Age and experience of **quadbike** users

	Mean age	Years of experience on quadbikes
Farmer	46 **(SD** 12 years)	14 **(SD** 5.5 years)
Employee	34 **(SD** 13 years)	**9 (SD** 6.7 years)
Family member	38 **(SD** 18.5 years)	11 **(SD** 5.4 years)
Total	40.7 **(SD** 14.8 years)	13.5 **(SD** 5.7 years)

In Figure 4.20 the data are expressed by percentage, and this highlights the preponderance of farmers in their 40s using quadbikes, and also the absence of employed **quadbike** users over the age of 60. We can also see more clearly that family members doing most of the riding are either under the age of 20, or a similar age to the farmers – partners perhaps.

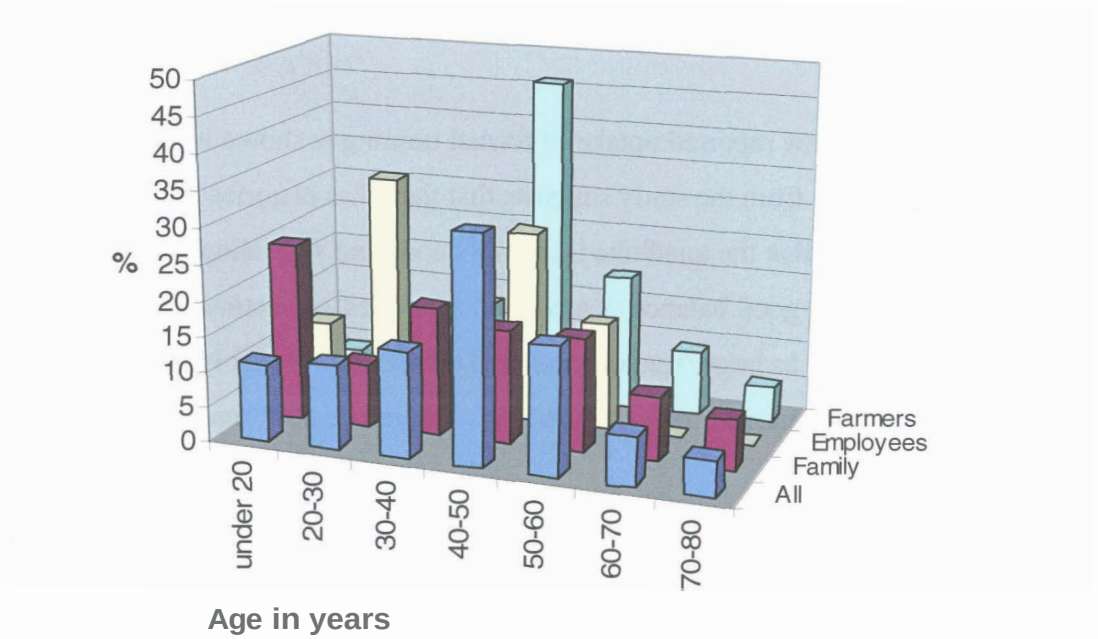

Figure 4.20 Age distribution of all users by occupation percentage

Of importance to note is that well over half (61%) of all **quadbike** users on the case study farms are over 40 years old. Comments made during the industry consultation by older subjects suggest that quadbikes have extended working life for many older farmers who might otherwise have stepped away from an active role. It does not in this sample, however, appear to have extended the life of employees.

The high proportion of family members under the age of twenty years using quadbikes highlights the importance of youths and students in the workforce.

4.3.2.7 Training

Trainers commented that new riders typically had problems with the degree of weight-shift needed, especially at low speed. Reading the route ahead and using body mass in conjunction with sensitive throttle control is needed to counter depressions when traversing slopes and Active Riding is essential for stability in these situations. An experienced farmer, now retired, commented that the quadbike appeared to 'fall between norms of expectation' for those whose intuitive base had been built on two-wheeler motorcycles and utility trucks. The quadbike was neither one nor the other, and as such required careful re-learning as it was too capable of crushing the body if treated like a motorbike, but would not slide before it tipped – unlike a utility truck.

A very low reported uptake of formal training is shown in Table **4.8.** Anecdotal evidence from the study suggests that there has historically been a perception in the industry that the quadbike is an innocuous and very simple form of transport, not requiring good balance as a two wheeler does, or accurate sense of distance to the corners – as larger tractors and **4WD** trucks do. Possibly as a result of this perception paid training courses have therefore not been seen as necessary.

Table **4.8** Quadbike training received by type

	Self taught	Informally taught by experienced rider	Formal course	n
Farmer	**50**	**4**	**0**	**54**
Employee	**22**	**4**	**3**	**29**
Family member	**22**	**10**	**0**	**32**
Total	**94**	**18**	**3**	**115**

4.3.2.8 Adherence to manufacturers' guidelines

The machines all come with manuals and stickers already fixed to the machine that advise on: maximum loads, safe angles of slope, the carrying of passengers and various other limits specific to the machine make and model. Overwhelmingly the riders saw them as irrelevant - 96% had either read and then largely disregarded them or had never found out what the recommended safe limits were in the first place. The prevailing attitude was that such guidelines did not apply to them as they had bought the vehicle for quite different purposes to those assumed by the designers and writers of the manuals.

In only two cases did riders claim to be using the machines within the recommended guidelines. Typical comments in response to the question "are you aware of the limits of operation stated by the manufacturer" were:

> *Yes but they don't apply to New Zealand conditions - what we actually use them for. I bought it for moving dogs and musterers and to pull a car trailer withfirewood - so they don't apply.*
>
> *Yes they're written all over them, but we'd be dysfunctional if we followed them.*
>
> *Yes but we exceed the loading ones. One less spray run by overloading allows one less handling of a hazardous chemical.*
>
> *Yes but (they are too simplistic),working out the maximum slope it can really handle is more complex than just taking a single figure from a manual.*
>
> *But we already knew you couldn't take them off the tracks, so we ignore the guidelines especially the passenger stuff. When we are mustering we go up the hill 3-up (rider plus two passengers),drop 2 off to walk down mustering. We couldn't do it any other way now.*
>
> *Yes, plenty of stickers and stuff in handbook as the machine was bought new. Towing and front end weight limits made sense but I don't always abide by them. Spray tank (is)60L (which)exceeds weight limit, and we have towed more.*
>
> *Yes (we know the limits), but then we exceed them. I know the actual limits for me and the machine through trial and error.*
>
> *Read the stickers when I got it but ignore them. Its just common sense when you get to know the machine.*
>
> *Am aware but don't obey them. Stickers are now unreadable anyway.*
>
> *Yes, but I use common sense instead.*
>
> *Yes but not relevant to us.*
>
> *Yes, but (the limits stated are) just to safeguard the companies. You exceed them, but within safe limits. Not possible to leave quadbikes lying around underused. Have 4 dogs to fit on it but they get off when it looks hairy - leave me to it.*

Typical comments from those who stated that they were NOT aware of all the manufacturers recommendations included:

> *There's no stickers on it now, but they wouldn't apply anyway because that's not how it's used.*
>
> *Read it all but took no notice.*
>
> *Read the relevant bits when it arrived - not much bearing on my actual later use. You HAVE TO carry passengers for example, so no point in trying to avoid it - just do it safely.*
>
> *Am aware of only what's written on racks for Kgs.*
>
> *I know the stickers are there - but not what they say.*
>
> *Only what I learned when they delivered it and did familiarisation.*
>
> *No, apart from the no passengers and not on paved surfaces.*
>
> *Not aware of speed or terrain limits -just loading.*
>
> *Plenty of stuff in the handbook but don't know any of it off hand.*
>
> *I like to work out capabilities of machines for myself. Don't pay attention to published ones.*
>
> *It was an "old machine so no manual" came with it.*
>
> *Didn't read limits material as I'm a fonner engineer and like to work it out myself.*
>
> *Dealer didn't run through these when it was delivered - but I know there are some (guidelines). Can't remember what they say from memory. Stickers are 3/4 covered in mud now – and they are only there for the manufacturers to legally cover their arse anyway.*

There would therefore appear to be strong evidence of a conceptual mismatch between the design intent and the purposes for which the machines are actually used on New Zealand farms.

4.3.2.9 New rider induction

In the industry consultation it was emphasised by the Agricultural Training Organisation (AGITO) that induction of new staff is especially important on farms as each farm environment is unique. Those running family farms may also have had little or no experience of working on other properties during their lives and the systems that have evolved in this isolation can be less predictable for newcomers as a result. Unlike workers in larger workplaces, farm staff do not typically have the luxury of colleagues to turn to for help. They are reported by Federated Farmers to generally operate in isolation from shortly after arrival.

The implications of this for the design of quadbikes is that the machines need to be suitably error-tolerant if intended to be used in an environment where a large degree of learning on the job is expected.

The quadbike users on the study farms were asked what they did for new staff regarding quadbike induction training. Systematic corroboration of their responses was not possible within the confines of the study as beyond the farm map handed out to staff no other material was recorded, and no objective measures available. Data were collected from **50** of the **53** farms. In the three outstanding cases the respondent had no supervisory element in their job and so no experience of inducting new riders.

The findings were coded under 20 headings, and each of these coded under one of three different strategy types.

Strategy Type	Approach
Primary	**Inherent risk reduction through re-design**
Secondary	**Acceptance of risks and measures taken to counter these**
Tertiary	**LCE considered inevitable, measures taken to minimise harm**

The **20** groupings are listed and explained briefly in the Table **4.9.** A mean of **1.9** distinct strategies were identified per farm.

On only 22% of farms was competence to operate the quadbike on the actual terrain reportedly assessed before being allowed to work independently. In one case out of the 50, was no guidance at all offered. The farmers simply stated "This place is worth $2.5 million. Anyone I picked would have enough brains to protect that investment - and would therefore have enough brains to know where to go on an ATV."

Table 4.9 Induction strategies reported for new riders to the farm

Strategies	Respondents (n)	Strategy type		
		1°	2°	3°
Told to stick to tracks	28% (14)		*	
Given a marked-up map showing features, hazards and no-go areas that may not be obvious	28% (14)		*	
Required to demonstrate competence on the quadbike on the terrain to be worked	22% (11)		*	
Given a familiarisation tour of the farm	20% (10)		*	
Told to walk if unsure	20% (10)		*	
Would only employ someone who already knew the place and the equipment	14% (7)		*	
Money has been spent improving tracks so new riders now don't need detailed briefing	8% (4)	*		
Told to initially stay on the flat and tracks and build up to full terrain coverage gradually	8% (4)		*	
Assumption made that anyone bright enough to run a farm will also be bright enough to safely use the quadbike without any guidance	8% (4)	n/a	n/a	n/a
Familiarisation given on the specific bike and its maintenance needs	6% (3)		*	
Told to keep speed down	6% (3)		*	
Detailed training given in the specific high risk tasks to be undertaken	6% (3)		*	
Told to stay out of the gulleys	4% (2)		*	
Told to stay off the hills	4% (2)		*	
Given a buddy until competent	2% (1)		*	
Job would be designed so that newcomer wasn't required to do high risk quadbike work	2% (1)	*		
Given a helmet and supported in wearing it	2% (1)			*

The subjects who suggested that no guidance at all should be offered on hazardous sections of the property explained that the process of drawing attention to specific hazards on a map could wrongly imply an absence of hazards in other areas. On some properties - such as bull farms where the animals could gouge out sections of track overnight, the concept of predictably safe and unsafe sections did not apply.

No respondents mentioned any standardised approach, source or publication, for example from Federated Farmers, OSH or ACC, on how to handle induction in order to protect themselves and their staff. No respondents offered or referred to any documents of their own - other than a farm map. There was nothing else in writing that might be used to inform and direct new staff about hazards, farm policies, their rights or their legal responsibilities under Health and Safety Law.

4.3.2.10 Personal Protective Equipment (PPE)

Designers of vehicles clearly have to make basic assumptions about the personal protective equipment that operators will be using.

Ankle injury from getting off quadbikes onto lumpy ground is one risk area that appears to have been acknowledged and translated into behavioural change for the riders. Around half - 52% - say that they consciously wear boots with ankle protection when riding, as shown in Figure 4.21 The 11% who claimed to wear helmets predominantly also stated that these were for use when on road surfaces – such as when travelling some distance between farm blocks on public roads.

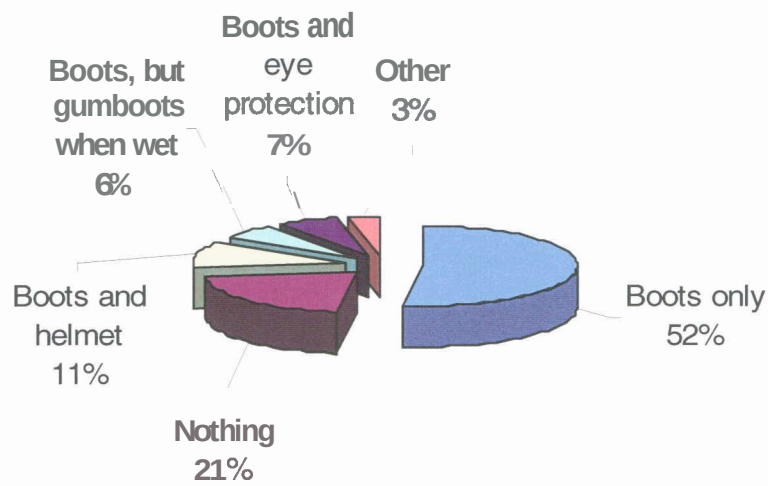

Figure 4.21 Personal Protective Equipment (PPE) worn

The epidemiological study reported in Chapter Three found that airborne debris was the injury agent in 5% of the cases. Interestingly, 7% were found in the Context study to use eye protection, presumably having learned the costs of neglecting this through experience. In addition to the findings shown in Figure 4.21, it was also reported that 10% routinely wore overalls when riding.

4.3.3 The Quadbikes

4.3.3.1 Introduction

The findings reported in this section on the quadbikes in use consider the age of the machines, state of repair, degree and type of modifications, makes, drive trains, and distribution of machines by farm type. Data on extent of use per year expressed in hours and kilometres, and the ancillary implements used with the quads, are also presented and briefly discussed.

Farmers who chose to not use quadbikes were also interviewed on their rationale for this decision. ACC staff in the South Island spoke of a discernible move back to greater use of two-wheelers on large properties.

Typical of the comments were those of a South Island sheep farmer who used a utility truck for feeding out as it offered shelter, was more stable, took a bigger load and cost little more for a basic manual model than was being charged for a large quadbike. The advantages also included inherent safety features as his young children were less motivated to try and drive it as they could not reach the pedals and see over the dashboard at the same time. He also used a two wheeler motorbike with a carrier rack on each side, to traverse the steep hillsides using the sheep tracks which would be inaccessible on a quad and carry up to 12 dead lambs. At $6000, it was about half the price of a quad. Again, he liked the innate safety feature of the machine being too big for the children to easily experiment with – their legs could not reach the ground when seated. If they tried to use it in his absence, as his neighbours' children do with their quads, the two-wheeler would fall over first.

4.3.3.2 Age of quadbikes

It is estimated by the New Zealand Motorcycle Distributors Association (NZMDA, 2001) that there are 70,000 quadbikes currently in use in New Zealand. The machines on the study farms however had a mean age of 4.5 years, (SD 3.4) - with the oldest still in regular use being a 1985 model (17 years old).

Figure 4.22 Early model 250cc Kawasaki

The manufacturers state that they 'expect quadbikes to last about seven years' (Personal communication, Grise 2002). However, Figure 4.23 shows that of the vehicles examined, 17% (11,500 machines or thereabouts) were eight years or older. Seven years of age is therefore approximately 83rd percentile for life span rather than the 95^{th} or 99^{th} as might be expected.

Time in use is significant as after the warranty period of three years few are serviced professionally, and quadbikes have no mandatory check on fitness for purpose at any age – unlike registered vehicles.

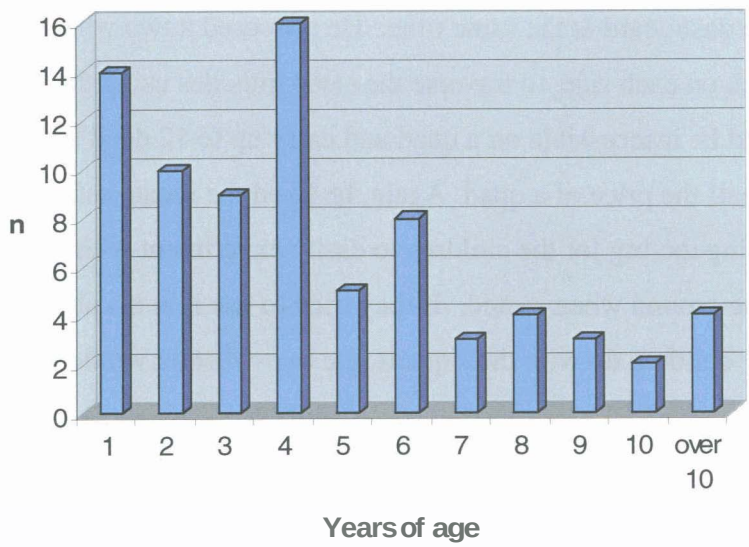

Figure 4.23 Age of working quadbikes

4.3.3.3 State of repair

The fitness of purpose of machines in service is clearly a prerequisite for safe and efficient performance. In the absence of a mandatory annual or six-monthly condition check as exists for cars and other registered vehicles, quadbikes need to be of a design that maintains minimum standards of safety without professional intervention. The aim of this section of the context study was to establish whether critical standards relating directly to handling, and therefore LCE avoidance, were being met.

The Otago focus group findings suggested that they would consider it unusual for farmers to conduct daily maintenance checks on quadbikes in that region; they are treated more like cars (''who checks their Toyota before they jump in to go to work?'') than tractors (grease points and oil do need to be monitored every few hours of work to avoid damage). Cars, however, have their mandatory tests to pass and a reminder is sent to the owner, resulting in checks and repairs being done to ensure minimum fitness for purpose.

In the absence of a mandatory system, or equivalent motivators, many quadbikes are simply ridden until enough faults emerge to justify taking it into town to be repaired. In the interim, it will be not fully functional, and its faults may not be apparent to the infrequent user – especially if they do not take the time to check it over before riding. In particular, quadbike brakes quickly loose effectiveness without regular attention; unbalanced braking performance when slowing for corners, and handbrakes can become so slack as to be incapable of holding the machine on a slope.

Women on the farms were reported (by the focus group men) to be more sensible about quadbike use generally, including maintenance.

Some **69** (mean age **4.6** yrs) of the 70 machines used on the 53 study farms were given a basic check against a set of factors that were seen by professional quadbike engineers to have significant effect on safe riding. These factors were: tyre pressures, tread depth, wheel bearing adjustment, head race adjustment, suspension wear, and park brake effectiveness.

Figure 4.24 Inspection of front wheel bearings for wear

Twisting or cracking of the towbar and attachment structure was also checked for. Such signs commonly indicate that extreme loads have been towed and rolled – the torsion from which may well damage the chassis of the quadbike.

Hand/park brake testing method was for the machine to be stationary on a flat hard surface, with brake full on and the equivalent of a 25kg force (250 newtons) applied horizontally to the rear rack.

Some 60% (41) of all machines failed on one or more of the six tests as described, and 12 of these machines (mean age 6.75 years) failed on three or more tests. Twenty eight machines passed the full set of tests. The most common failures were due to excessive play - in the head race of the steering and in the wheel bearings.

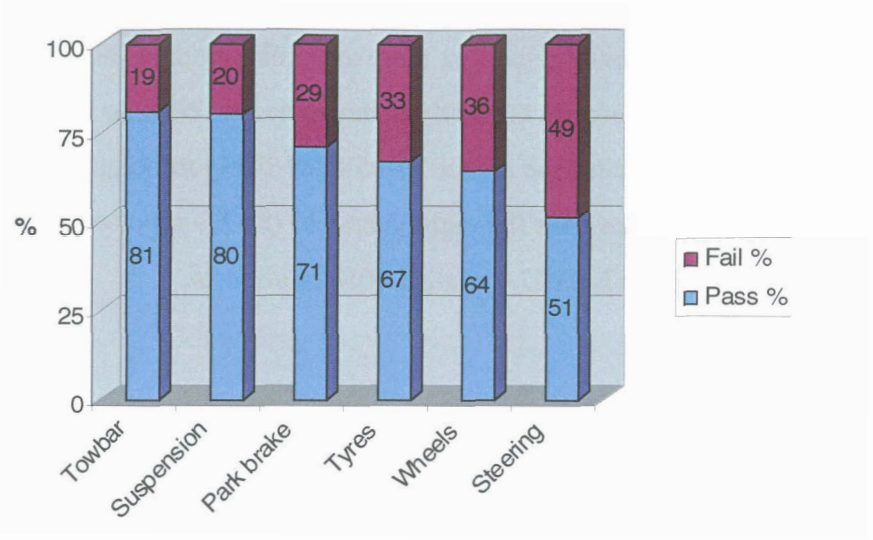

Figure 4.25 State of repair - all machines

Of the machines over three years old – and hence out of the warranty period, **73%** failed at least one test. Figure 4.26 shows that the pattern of failure remains reasonably consistent with excessive play in the steering head as the most common problem. The older machines are generally lighter and more obviously unsuitable for heavy loads and towing, which may explain the lower figure for towbar damage and heavily worn suspension.

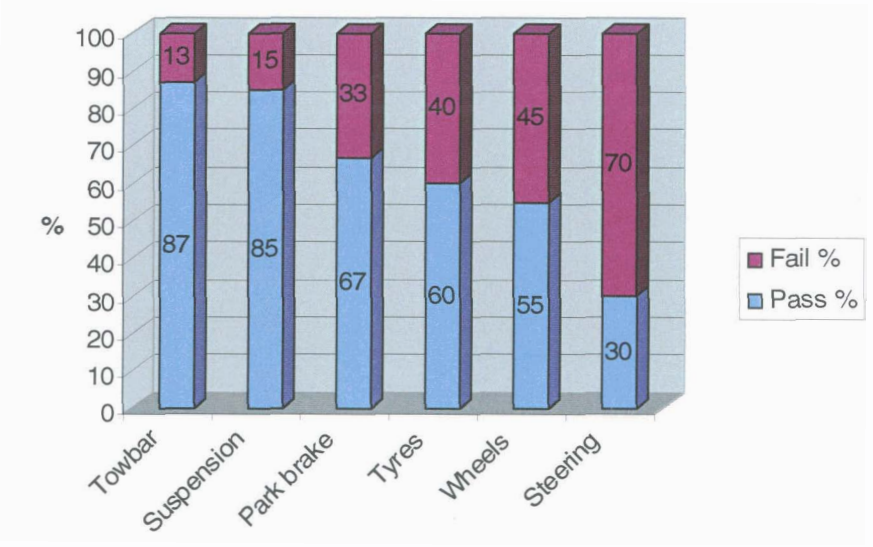

Figure 4.26 State of repair - machines over three years old

As reported in the previous section, there are probably more old quadbikes in use in New Zealand than there are currently believed to be. With no mandatory checks on condition of the vehicles, the oldest **10-15%** are likely to be in poor state of repair. In this study, machines over the eight years old (n=9) - reported as the average retirement age by the NZMDA - failed **46%** of all tests.

4.3.3.4 Modifications

Machines used for the purpose for which they were specifically designed should not need modification by the purchasers. A clear advantage of designs that do not need changing, post-sale, is that features can be integrated and the design can be tested as whole to ensure safety concepts are not corrupted. The aim of this section of the context study was to examine: the extent to which quadbikes as sold in New Zealand matched the needs of the farming community, what changes were made where the designs fell short, and what if any specific risk factors these changes may introduce.

Almost all (96%) of the machines were modified from the form in which they were sold. Some were temporary, such as a mechanism using baler twine to change gear rigged by a rider with a leg in a plaster cast. Most however were permanent and changed the performance characteristics of the machine in a rollover substantially.

Figure 4.27 Combination of modifications. Sheep and beef farm Otago

Figure 4.28 Home-made ply sheet dog tray

Figure **4.29** shows the most common modifications to be bullbars and the addition of a small platform fitted onto an existing rack (dog tray) for the dog to stand on.

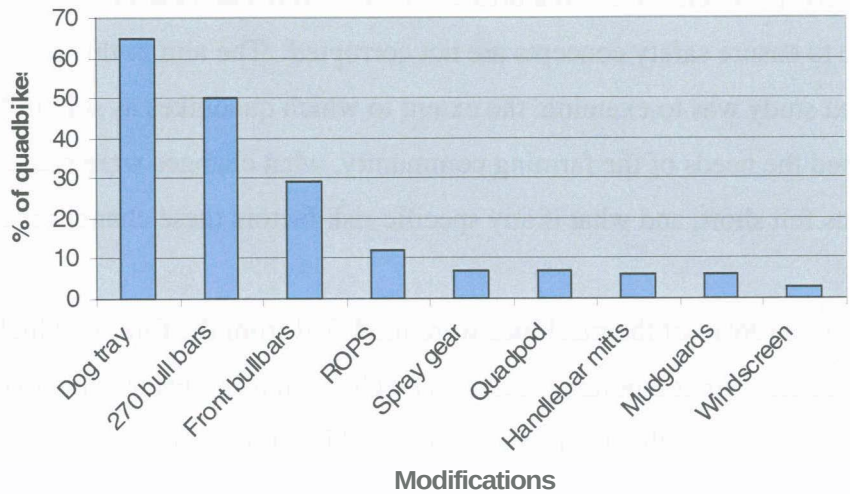

Figure **4.29** Modifications to the quadbikes

The 270° bullbars protect the quadbike on the front and sides, predominantly from damage caused by contact with gates and animals. In a rollover however this accessory increases the chances of crushing injury through the application of a point load to the body through the tubing as the vehicle tips through **90** degrees. The design concept of the quadbike is that it has large diameter rounded curved surfaces so that in a roll the rider gets hit by blunt surfaces that will cause general bruising through a dissipated force – rather than puncturing/fracturing/trapping through greater point loads (personal communication, Cooper-Smith **2002).** The addition of bullbars and racks – often fitted by the dealers on new machines as desirable accessories - clearly works against this concept.

Figure 4.30 Honda fitted with extended mudflaps, 270° bullbars and a custom-made weather cover using heavier gauge tubing than the retailed versions

Having to heavily modify accessories or make their own to fit can lead to some poorly performing and also dangerous solutions. Hazardous sharp elements were discussed in earlier sections, and another example are QuadPods. These are three-sided weather screens fitted onto most machines in Southland, Otago and other Southern regions which experience a lot of harsh weather. Dust inhalation problems are reported as a negative pressure zone forms behind the screen, with eddying air and debris swirling around the face of the rider. Dust also collects thickly on surfaces obscuring displays. This would have been evident in wind tunnel tests had QuadPods been developed as an integral part of the quadbike design.

4.3.3.5 Trailers and other implements used with quadbikes

Very few of the cases analysed in Chapter Three reported the involvement of a trailer. Industry consultation with Federated Framers representatives involved in sheep operations suggested however that the (problematic) use of trailers was far more widespread than these low numbers implied. This section of the study therefore sought to establish the extent to which trailers were used in conjunction with quadbikes, and whether there were any generic task-specific risk factors linked to these.

It was found that **46** (87%)of the farms used at least one lightweight trailer as one of the three main implements, and the designs varied greatly. The majority of farmers had either made their own light trailers or had heavily modified the ones they had

bought. In six cases farmers reported using the heavier car trailers behind their quads, mostly for moving building materials. The industry consultation with farmers and suppliers in the South Island revealed that in intensive sheep farming operations the trailer is rarely detached from the quad.

As shown on figure **4.3**1 the most common uses of the light trailers were for moving small animals including dogs, and shifting maintenance gear, such as fencing tools and supplies.

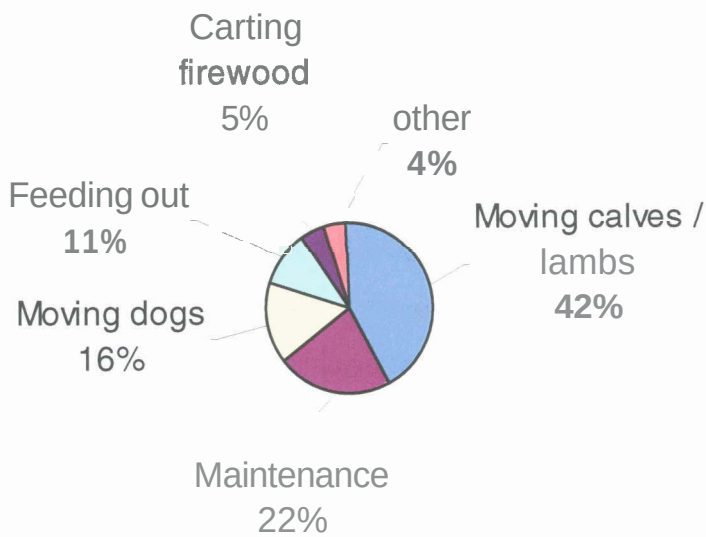

Figure **4.3**1 The purposes of light trailers used with quadbikes

Inherent risk factors involved with towing were reported to be: altered dynamics resulting in critical loss of traction, failure to allow for the extra width when towing, jacknifing while turning too hard when chasing stock and extreme musculoskeletal loading when attaching or detaching the trailer.

Other trailed implements commonly used were rush cutters, fertiliser spreaders and calf feeding tanks.

4.3.3.6 Roll-Over Protective Structures (ROPS)

There is a continuing debate on the use Roll Over Protective Structures [ROPS], and whether they act as protective devices or injury agencies. OSH are undecided, and have taken the unusual position of publishing guidelines on good practice in their design and fixing (OSH, 1998a), without actually endorsing their use.

The study did not set out to produce conclusive data on the effectiveness or otherwise of this intervention in preventing injury, but useful data were obtained on why some farmers so adamantly support ROPS, while others oppose them, to further inform the debate.

It was positively identified that the machines on the study farms had ROPS fitted in 20% (31) of cases. The types are shown in table 4.10, there may have been more actually in use on machines not seen.

Table 4.10 Roll Over Protective Structures - types used

ROPS type	n
Rear mounted – T Bar	13
Rear mounted – unspecified type	8
Rear mounted – 'staple' or 'soccer goal' shape	5
Front mounted (just high enough to protect handlebar mounted instruments]	1
Other or unspecified	14
Total	31

The T Bar is lighter than the staple or soccer goal shape and allows the rider to bale out in 'backwards and at a 45 degree angle', which is a significant advantage as it is (anecdotally) the direction intuitively taken by riders. There is no published research to support this however.

Figure 4.32 Home-made T-Bar **ROPS**

The following Table, 4.9, shows a summary of the 'for and against' comments regarding **ROPS** by all taking part in the context study, both current riders on farms and other interested industry parties. Further research is needed in this area, but the study questions posed need to extend beyond the debate on rider protection in a rollover, to include the **ROPS** as part of a wider system of daily use. The **ROPS** serve **as** a mounting frame for lights, tools and weather protection; they also provide a useful means of levering up-turned vehicles back onto their wheels. Absence of a systems approach in any such study would severely limit its practicality.

Table 4.9 Summary of comments in favour of, and against, the use of **ROPS**

In favour of **ROPS** being available:	Against **ROPS** being available:
Where the tip is very slow and to the side, riders report being able to stay with it confidently knowing that the roll will be arrested. There appears to be a group of users who are convinced through personal experience of the value of ROPS for them in this particular situation - and with their particular machines. In a side roll, the ROPS is reported to generally dig in and arrest further movement in any direction. In hill country this may well save a long walk to retrieve the machine from a gully. Damage to machine may be reduced. If in an exposed location on a big station the loss of transport in poor weather with no communications to base could compound hazards further. In a rearward flip, the ROPS is reported to offer more time to bale out, as the quad sits up on the ROPS before rolling back. The T Bar ROPS especially is reported as an excellent lever for putting the quad back on its wheels after a rollover. Lighter riders may have trouble righting the newer heavier machines without some leverage to help, and may have to make it back some miles on foot with injuries if machine cannot be used. Some riders operating a lot in marginal hill country with ROPS reported rollovers without injury or damage to be a regular enough occurrence that they no longer viewed them as Loss of Control Events worthy of mention or avoidance.	Rear-mounted staple ROPS can obstruct the 'bale out' route stopping the rider from rolling clear so easily, or allowing them to get crushed between the tube and ground.. The raised centre of gravity of the machine produced by adding the ROPS increases instability and the possibility of rolling. When it does finally roll in a rearward flip the front end of the quad is driven into the ground from a greater height when a ROPS is fitted, resulting in extra damage to the front of the machine. Where the roll is in the forward direction and abrupt enough that the rider is thrown clear of the protected zone defined by the rear-mounted ROPS, riders are concerned that the ROPS tubing is capable of inflicting point load damage on the body. Fitting ROPS satisfactorily onto machines may be getting more difficult due to the tubing of the chassis frames now being less substantial toward the rear of the machine. There are reports of ROPS being bolted onto racks instead of the frame as a result. Should a roll occur, racks are very likely to be damaged to a point of needing repair or replacement. There were reports of head strikes on the tubing when using front mounted ROPS or cage ROPS with front-mounted members. There are reports of the ROPS snagging on overhead obstructions such as branches when operating in wooded and grazing areas being cleared of trees. These were with rear fitted ROPS where the rider misjudges the clearance needed or simply forgets the structure is there.

4.4 Discussion

The aim of the context study reported in this Chapter was to gain an understanding of the nature and functional requirements of the work systems within which quadbikes operate on New Zealand farms via incident-independent analysis of the systems including: the tasks, the users and the machines.

Semi-structured interviews and focus groups were principally used to explore the characteristics and dynamics of quadbike use at several different levels of the system from individual rider to Government agencies and regulatory bodies. The Context study data were built iteratively with a number of stages to the interviewing – increasing from highly exploratory to specific on-farm analysis as system understanding was compiled.

A particularly important level of data to collect related to risk factors in the Social Environment. Suicide rates are high amongst farmers in New Zealand (Langley & Stevenson, 2001), and stress generally has been identified as a factor in vehicle incidents (Lagarde et al., 2004) and farming–specific studies (e.g. Simpson et al., 2004). The pervasive influence of sustained low income on health outcomes through various mechanisms is an established (Susser & Susser 1996; Krieger, 2001) though sometimes overlooked (Pearce, 1996), tenet of traditional epidemiology. The context study methodology therefore provided, in combination with the investigations, insights into these mechanisms as they relate to quadbike LCE. It was clear from the findings of Chapter Two that the knowledge gap was substantial in this area. These factors had not been covered either by the macro level epidemiological studies nor the more detailed incident-specific investigations conducted by the Department of Labour. Further studies also need to include enquiry into the existing mechanisms of positive change in the farming communities. The limited work done in this area proved encouraging (Barnett et al., 1996), illustrating that effective leadership may naturally emerge from any level in farming, as in industry (Blewett, 2002).

The findings discussed in this Chapter suggest that there are significant enough differences in the tasks and the rider population for serious attention to be paid to the design mis-matches arising.

Primary usage on New Zealand farms was found to be dominated by mustering and other tasks that required substantial modification of the quadbike design, and /or use quite dissimilar from recreational riding. Spraying, building maintenance, fencing, hauling firewood, feeding out require the carriage of heavy, shifting, awkward and angular loads inconsistent with a recreational vehicle that is designed to be actively ridden (using human weight shift) and assumed to periodically roll without serious damage to machine or rider. The modifications made tend to reduce stability and handling performance, and increase the likelihood of serious puncture or fracture wounds. In most cases the potential for entrapment is also raised by the additions made.

Further investigation is needed to establish in detail the legal obligations of designers, manufacturers and suppliers of ancillary equipment used in conjunction with quadbikes in New Zealand farming. The system of ensuring the overall fitness for purpose of ensembles was clearly not working well enough at the time of this study to match the expectations of users.

Interesting but dangerous conflicts also arise when traditional systems, developed before the quadbike era, are merged with this later form of delivery. For example, in the use of loops of polypropylene-type twine for holding bales together which are then delivered on a quadbike - a vehicle with exposed moving parts. This form of mismatch requires attention in any further study as reports of near misses and actual harm to hands and feet are numerous.

Inexperience and lack of confidence adds to the risks for tasks such as firewood hauling, and the light feeding-out of small traditional bales, which are reported to be often allocated to family members or visitors.

The findings of the context studies indicated that the New Zealand farmers interviewed identified so little with the design intentions of the manufacturers that that they almost universally disregarded the user guidelines. "Yes but they don't apply to New Zealand usage - need to carry passengers etc - it's what we buy them for" (Northland Farmer). There is also suspicion that the conservative limits in the manuals and on the stickers are set by corporate lawyers protecting their company in the highly litigious US market, rather than by engineers who tested the vehicle. "They aren't real what they say – I've gone beyond and they haven't bitten me. Put extra loads on etc and you [just] have to make practical adjustments". This farmer has typical views, but his use of the quadbike was extreme. He showed the researcher a car trailer that he said he used for moving regularly for loads of up to 2 tonne of bagged cement. This 2 tonne load would be 7-8 times the weight of the quadbike, but still within the legal limit of 2.5 tonnes for an un-braked trailer – highlighting the dangerous extent of under-regulation that persists.

A number of the findings support the idea that quadbikes to be used on farms need a greater degree of designed-in error-tolerance than they currently have. Seventy percent of the riders on the study farms were farmers or family members, rather than employees with rules to follow, and none of them had had any formal quadbike training. Strategies for safely introducing new riders were consistent with this approach, with less than 10% of the study farms seeking to address hazards at source through primary prevention methods. Safe and effective methods of use would ideally therefore conform to prior learning stereotypes and be highly intuitive – which is not the case. Maintenance standards were found to also be low, adding to further the extent to which the onus is placed upon the individual rider to adapt to hazards as they present.

As a result of not believing that the manual relates to their usage patterns, and moreover considering the guidelines laughably conservative, the capabilities of many quadbikes in New Zealand appear to be determined mostly, if not entirely, by trial and error. While it may be true that "it is only by making errors that you learn skills" (Rasmussen, 1985) and that indeed, failure is a necessary ingredient in a healthy system, (Hollnagel, 2005), these have to be survivable for the skills to be acquired

and applied. The objective of the exercise may therefore not be to entirely eradicate all future occurrences, but rather to bring the cost of these failures within an acceptable limit whereby they no longer outweigh the long term gains from the lessons learned (Perrow, 1984).

Greater error-tolerance is also needed when steering at speed on unpredictable and probably lumpy grazed terrain. The rider needs to be able to divide attention to monitor stock movement as well as monitor the route ahead. This presents a function allocation conflict. A prerequisite for the Active Riding of motorbikes is the almost continuous perception and processing of information about the route ahead – allowing anticipatory shifts of body weight to counter forces from the terrain. At key moments of peak acceleration and turning when circumstances for a rollover event are most favourable, attention will tend to be on the animal being headed – not the micro terrain in front of the machine. This is a critical mismatch. With recreational North American trail riding as described by Delisle (1988), there is no innate visual distraction involving animals for riders.

Despite the view of manufacturers that the way quadbikes are used in New Zealand is unique (Cooper-Smith, 2004), there may be an argument for more consideration of farming needs in future designs internationally. Rodgers (1999), in his telephone survey of 500 riders across the USA for the US Consumer Product Safety Commission, found that half reported using their machines at least some of the time for farming and ranching tasks as well. These, and other non-recreational uses, had increased in total from the 52.5% recorded during their 1989 survey to 73.7% ten years later. If more machines are being bought for significant amounts of occupational use on farms, then the designs emerging should reflect that.

Further studies are needed overseas to establish whether the key task of mustering and moving stock identified in New Zealand is similarly critical for other occupational users such as the farmers and ranchers mentioned by Rodgers.

The findings of this study indicate clear differences in the age of the two populations. North American rider populations are a lot younger. Rodgers (1999) found four fifths of US riders in his telephone survey of 500 users to be under 45 years of age. Legare (2002) in his study of off-road injury events, reports three quarters of the quadbike and snowmobile-using population (in personal communication he advises that they use the same trails through the year with one or other machine depending on snow conditions) to be aged between 20-39. By comparison, 61% of New Zealand riders in this study were over 40.

The ability of older riders to master the quadbike may be hindered not only by the general age-related decline in cognition, but for those who have had a lifetime on two wheelers or light 4wd utes/landrovers there is also the need to un-learn entrenched patterns and affordance assumptions. As one ex-farmer put it, the quadbike "falls between norms of expectation".

As also noted by Rodgers (1999), engine sizes have increased steadily since the 1980s. Rodgers reports machines over 300cc representing 9% of the market in 1989 and 40% ten years later.

The findings of this context study suggest that the designers of the increasingly powerful, heavier machines are not addressing the design mismatches as perceived by occupational users. None of the riders on the study farms identified more power as a need. Better stability, handling and protection in a rollover were requested instead. The subjects reported that the increased power and weight was actually aggravating these problems in many cases, with heavier handling, greater instability and more risk of entrapment. The advantages of extra power and weight may of course be entirely in keeping with identified wishes in the recreational market.

New Zealand representatives of the manufacturers stated that Honda at least were responding and restricting the importation of larger machines (personal communication, Cooper-Smith). On further questioning it was revealed that the reason for this was not user safety, but the cost effectiveness to Honda of honouring the quadbike three year warranty. "People blow them (clutches) out by trying to tow

too much – thinking that at 650cc it should be able to pull anything''. The marketing of these larger machines with 'all the grunt you'll ever need' to quote from a recent advertising campaign, clearly encourages such mismatches to occur where the user believes they have a light tractor as well as a nippy form of personal transport. The name All Terrain Vehicle, is clearly an unhelpful misnomer in English speaking countries. The French version, Vehicule Tout Terrain, similarly.

The findings in this study on the replacement vehicle implications and what it would cost to replace quadbikes on the farms studied clearly demonstrate the value of this type of machine in modern New Zealand farming. After twenty years of assimilation there may now be as many as one third of farming enterprises in the dairy and sheep & beef sectors who believe their commercial viability to be reliant on having a powerful quadbike. For these farms one relatively cheap vehicle can, 'at a pinch' carry out a wide array of tasks that would otherwise require an extra capital (400% - 700%)to buy extra vehicles. **A** clear danger is that the sole vehicle will be operated to the limits of its capabilities and beyond on a regular basis.

ROPS are the one significant safety intervention that farmers have attempted to implement since the introduction of the quadbike. In Chapter Two the reasoning behind the very substantial legal resistance of the manufacturers to **ROPS** was discussed, but the findings of the simulation studies have failed to convince all of those using quads on New Zealand farms that they should be abandoned. The analysis presented in this Chapter shows that for those users who (due to their personal riding style or tasks) experience only slow speed rolls to the side, there may indeed be only benefits from having **ROPS** fitted.

OSH have acknowledged this by resisting pressure from the manufacturers to ban **ROPS** outright, and given farmers not only the legal option of fitting them if they wish, but also formal Guidelines to assist them do it to a good standard of engineering. It is surprising, in light of this, that alternative design concepts that afford the protection required, without the high-speed impact drawbacks, have not emerged.

4.5 Conclusions

In this Chapter the context of quadbike use on New Zealand farms, including the functional requirements of the tasks relating to the quadbike were discussed. The research also generated findings demonstrating fundamental, and potentially hazardous, mismatches between the designed intent of the machines and the functional characteristics required of the machines on New Zealand farms.

Significant gaps in knowledge have been addressed. This study established the range of tasks for which quadbikes were being commonly used and the intrinsic risk factors associated. Conceptual-level design mismatches were identified. Prior to this study there were no researched estimates available of the numbers or characteristics of quadbike users on farms in New Zealand, nor the uptake levels of quadbikes per farm. These gaps were addressed.

This study also provides a sufficiently clear description of the context of farm use in New Zealand within which investigated LCE are taking place, for future researchers and those in other countries to be able to draw comparisons more confidently between this research and their own.

This study provided insights that informed the next stage of the research reported in Chapter Five - investigations of LCE; both through assisting interpretation and in the iterative refining of interventions to ensure that they fitted within the system as a whole.